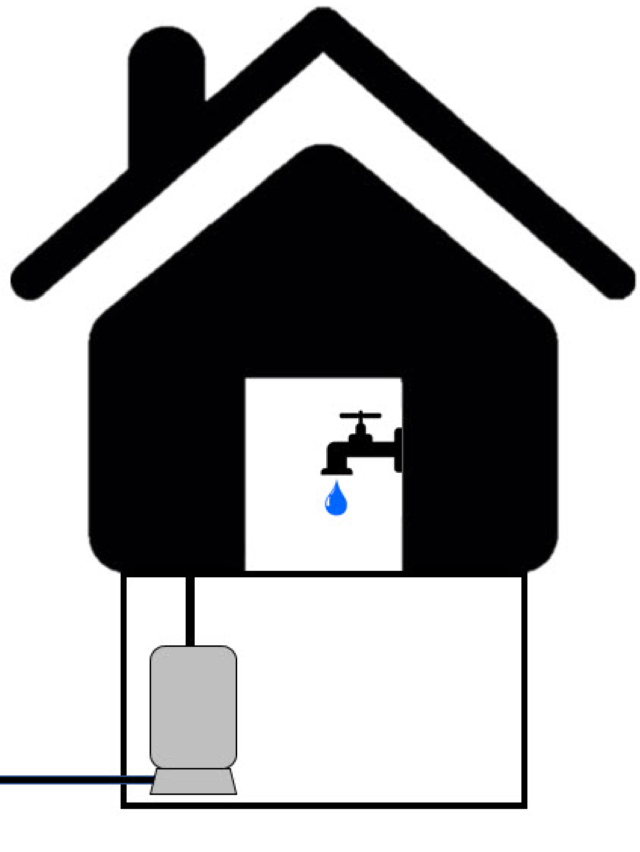
STATE OF MICHIGAN
WATER WELL MANUAL



MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY
DRINKING WATER AND ENVIRONMENTAL HEALTH DIVISION
ENVIRONMENTAL HEALTH SECTION
SOURCE WATER UNIT
WELL CONSTRUCTION PROGRAM

August 2023

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Chapter 1: INTRODUCTION

The purpose of this manual is to provide an individual with an understanding of water well construction practices and the regulation of water supplies in Michigan. Among the topics covered in the manual are water supply regulations, hydrology, well construction methods, pump and pressure tank fundamentals, sampling and testing, and plugging abandoned wells. Most chapters contain an introduction, supporting text from various sources, and the corresponding rules in the Well Construction Code.

This manual also serves as a study guide for those individuals who are seeking registration as a water well drilling contractor or pump installation contractor in the state of Michigan.

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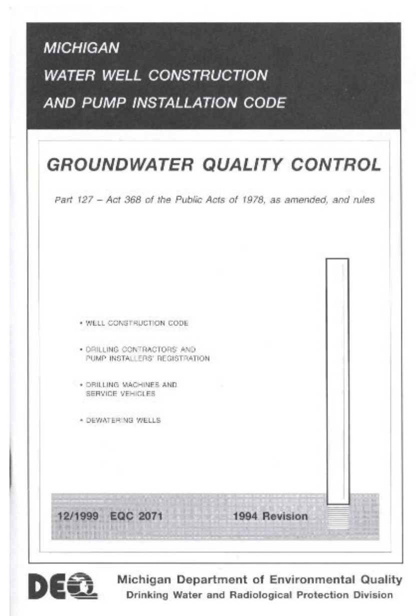
This manual can be found at: Michigan.gov/WaterWellConstruction.

MICHIGAN WATER WELL CONSTRUCTION AND PUMP INSTALLATION CODE

The first well code became effective on February 14, 1967, when the Michigan Department of Public Health (now the Michigan Department of Environment, Great Lakes, and Energy [EGLE]) promulgated the Administrative Rules authorized by passage of the Ground Water Quality Control Act (GWQCA), 1965 PA 294. The most recent revisions to the Michigan Water Well Construction and Pump Installation Code (Well Construction Code) went into effect on April 21, 1994. The Statute authorizing the Well Construction Code is now Part 127 of the Michigan Public Health Code, 1978 PA 368, as amended.

The Well Construction Code contains minimum specifications for the location and construction of water wells and associated pumping equipment. The Well Construction Code establishes standards for the materials and methods used to complete water wells, and install pumps, pressure tanks, piping, valves, and controls. Standards for the plugging of abandoned water wells, dewatering well construction and abandonment standards, reporting requirements, minimum qualifications for the registration of water well drilling contractors, drilling machine registration requirements, and code enforcement provisions are also covered.

The Well Construction Code Booklet can be ordered from:



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The Well Construction Code and Statute can also be downloaded from the EGLE website at: Michigan.gov/WaterWellConstruction.

The Statute and Administrative Rules are found under the "Laws and Rules" section.

REGULATION OF WATER SUPPLIES

The following Acts and Rules contain the regulation of water supplies.

Ground Water Quality Control Act

- Passed March 31, 1966
- Contractor Registration
- Well Drilling Advisory Board
- Rules: Well Construction Code

Ground Water Quality Control Rules

Administrative Rules promulgated by EGLE

- Adopted: November 23, 1966
- Effective: February 14, 1967 to April 20, 1994

Act 399 PA 1976, Safe Drinking Water Act

- Regulates public water supplies
- Based on federal Safe Drinking Water Act
- Act effective: January 4, 1977
- Rules effective: January 11, 1978

Act 294, PA 1965 Ground Water Quality Control Act

- Became Part 127, 1978 PA 368 (Michigan Public Health Code)
- Amended in 1972 to include Dewatering Well Standards

Part 127, Act 368

- Revision project 1990 to 1993
- Minimum Program Requirements (MPR) were established for each core program
- Sections include:
    - Definitions
    - Applicability/exemptions
    - Well owner rights
    - Contractor registration fees and certificates
    - Water Well and Pump Records
    - Local health department authority
    - Contractor enforcement

SAFE DRINKING WATER ACT

Public water supplies (Type I, Type II, and Type III) are regulated under the Safe Drinking Water Act, 1976 PA 399. Examples of public water supplies include community water supplies, apartment complexes, schools, restaurants, campgrounds and parks, retail stores, and two private homes sharing one well. The construction regulations of public water supplies are in conjunction with Part 127 of the Safe Drinking Water Act, 1978 PA 368. Local health departments (LHD) regulate Type II and Type III supplies. EGLE regulates Type I supplies. It is important that water well contractors are aware of all permit requirements when installing a public water well. Isolation distances and grouting requirements are two examples of public well permit requirements that may be stricter.

<table>
<tr><th colspan="3">Classification</th><th>Description</th><th>Examples</th></tr>
<tr><td rowspan="4">Public Water System</td><td colspan="2">Type I
Community</td><td>Provides year-round service
to ≥15 living units
OR to ≥25 residents</td><td>Municipalities, subdivisions, apartments, condominiums, nursing homes, manufactured housing communities</td></tr>
<tr><td rowspan="2">Type II *
Noncommunity</td><td>Nontransient</td><td>Serves ≥25 of the SAME individuals on an average daily basis
for ≥6 months per year
(and is not a Type I)</td><td>Places of employment, schools, day care centers, bottled water sources</td></tr>
<tr><td>Transient</td><td>Serves ≥25 individuals or ≥15 service connections on an average daily basis for ≥60 days per year
(and is not a Type I)</td><td>Hotels, restaurants, campgrounds, churches, highway rest stops</td></tr>
<tr><td colspan="2">Type III</td><td>Public water system that is not a Type I or Type II</td><td>Subdivisions, apartments, condominiums, or duplexes with 2-14 living units,
facilities serving <25 individuals
or
open <60 days per year</td></tr>
<tr><td colspan="3">Private Water System</td><td>Serves a single living unit</td><td>Single family home</td></tr>
</table>

***** Type II public water systems are also classified according to their average water production during the month of maximum water use. A Type IIa system produces 20,000 or more gallons per day and a Type IIb system produces less than 20,000 gallons per day.

LOCAL HEALTH DEPARTMENT'S ROLE

Introduction
Michigan incorporates a preventive public health strategy to ensure that newly installed water well systems are safe and reliable. The Drinking Water Program is administered as a joint effort between Michigan's LHDs and EGLE. The Well Construction Code allows the state of Michigan to delegate well permitting duties to the LHDs. LHDs have review jurisdiction for Type II and Type III public water wells, private water wells, and other types of water wells.

Funding
LHDs receive state funding from an annual appropriation by the state legislature to the Department of Health and Human Services. There is a contract between the state and LHDs for delivery of services such as: well and onsite wastewater system permitting and food service inspections. LHDs also charge local fees for permitting activities.

Minimum Program Requirements
The LHD's must comply with the established Minimum Program Requirements (MPR) to receive state funding. MPRs require LHDs to do the following:

- Issue well permits
- Inspect water supplies
- Investigate groundwater complaints
- Investigate contamination sites
- Approve water supply systems

EGLE evaluates the LHDs on an annual basis to ensure that they are complying with the MPRs.

Local Sanitary Codes
LHDs each have their own legally adopted local sanitary code that covers water supplies. Water wells constructed in Michigan must also comply with any local code requirements. Failure to comply with a local code requirement is a violation of Rule 112, Part 127 Act 368 PA 1978.

Local code requirements may be more stringent than the state code for matters such as isolation distances and water sampling. Permits in areas of groundwater contamination or certain geological characteristics may also have more stringent permit conditions. Many LHDs have "well first" areas that require an acceptable water supply be obtained prior to obtaining a sewage disposal permit or building permit.

CHAPTER 2: HYDROGEOLOGY

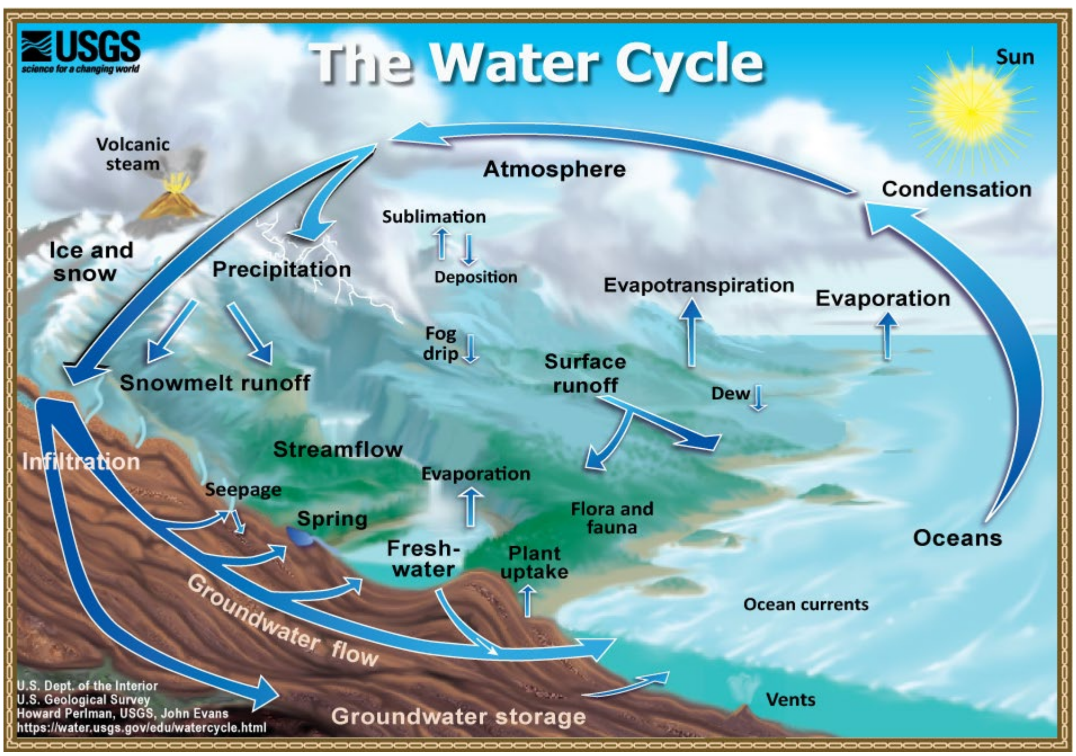
Hydrology, by definition, is the science dealing with the properties, distribution, and circulation of water on and below the earth's surface and in the atmosphere.

Hydrogeology is the branch of geology concerned with the occurrence, use, and functions of groundwater and surface water.

Resources
Most of the information in this section are excerpts from "Agriculture's Role in Protecting Ground Water," Conservation GEM Program Manual – December 1991.

Another very good hydrology document is *Basic Ground-Water Hydrology, Water Supply Paper 2220, United States Geological Survey*. It can be found at https://Pubs.USGS.gov/WSP/2220/Report.pdf.

Introduction
Hydrology is the study of the movement and interaction of water on the earth surface, below the surface and in the surrounding atmosphere. Surface water includes streams, rivers, ponds, lakes, and the oceans. Water below the ground surface that occupies the tiny open spaces within the soil and subsurface materials is called subsurface water. Subsurface water has two components, one is soil moisture which is found in unsaturated areas and the second is groundwater which is found in the saturated areas. The water in the atmosphere is held as water vapor which may condense as droplets to fall as precipitation. These three areas of water storage are dynamically linked to each other by the continuous movement of water from place to place. This is the concept of the hydrologic (or water) cycle (see figure below).



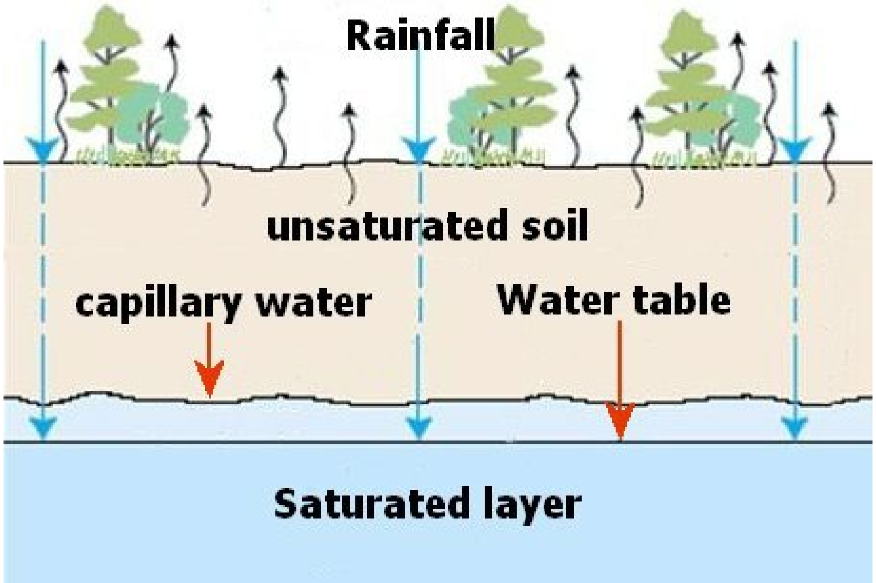
The Hydrologic Cycle
Within the hydrologic cycle, water moves in and out of the three storage areas (surface water, subsurface water, and atmospheric water). The input of water to one area must be accompanied by an output from another. The pathways of water movement within the hydrologic cycle are outlined in the below table.

Mechanisms of Water Movement in the Hydrologic Cycle	
Atmosphere to Surface	Precipitation – condensed water vapor; rain, snow, hail, dew, frost
Surface to Atmosphere	Evaporation from land or water surfaces Plant transpiration
Surface to Surface	Down slope stream flow Down slope overland flow
Surface to Groundwater	Ground surface infiltration and downward movement Infiltration and downward water movement from losing streams or ponds
Groundwater to Surface	Upward groundwater movement into gaining streams or ponds Root uptake Artesian water movement producing a flow at the surface from a confined aquifer release point
Groundwater to Groundwater	Down slope groundwater flow within and between aquifers

Energy
The driving force behind all the water moving pathways are the energy differences from point to point throughout the hydrologic cycle. Solar energy is the primary driving force for the water movement pathway between the surface and the atmosphere. Water will always move from a point of higher energy toward the point of lower energy along the path of least resistance. Water will move, for instance, from a zone of higher pressure to one of lower pressure, from higher temperature to lower temperature, and from higher elevation to lower elevation.

THE SUBSURFACE

Introduction
The subsurface is divided into two principle regions, the unsaturated zone and the saturated zone outlined in the table below. The subsurface materials in these areas can be characterized by their degree of compaction and cementation. From this viewpoint, geologic materials can be classified as 1. unconsolidated, 2. unconsolidated but totally compacted, or 3. consolidated, if compaction and cementation has occurred.



Unsaturated Zone
The unsaturated zone is the area of the subsurface that has a combination of air and water within its pore spaces. It contains the root zone which is the soil area that plant roots occupy in order to obtain water and nutrients. The unsaturated zone extends from the ground surface down to the water table which divides the unsaturated zone from the saturated zone. In other words, the upper surface of the saturated zone is the water table.

The amount of water held in the unsaturated zone is based on the amount of water that soaks into the surface, the amount absorbed by plant roots and the amount that moves downward across the water table into the saturated zone. The unsaturated zone holds water much like a sponge. It can vary from being nearly saturated, with all the spoil pores filled, to being wrung out of excess water but still moist. Gravity is responsible for draining the excess water from the unsaturated zone. When the unsaturated zone reaches the point at which no more water can be pulled from it by gravity it is at its field capacity. Before water can infiltrate out of the unsaturated zone into the saturated zone, the water storage capacity (field capacity) of the soil must be exceeded. This fact provides the irrigation manager with a useful tool to keep expensive water and nutrients in the root zone rather than flushing them through the water table.

Saturated Zone
The saturated zone is the subsurface region where all available voids and pore spaces are completely saturated (i.e., filled) with groundwater. This subterranean region can consist of multiple layers composed of soil materials (e.g., clay, sand, or gravel) or various types of consolidated rock. The layers within this zone that can supply groundwater of an acceptable quantity and quality are called aquifers. Some layers can transmit a great deal of water and some very little, depending on the type of material it is composed of. Sandstone, for instance, can transmit more water than shale and a gravel aquifer can supply water more readily than one of clay material.

Water in the saturated zone, like all other areas of the hydrologic cycle, is moving. It moves much more slowly than water in the other parts of the cycle, but the reason for its movement is the same: an energy difference from higher to lower elevation. Stream flow velocities range from a few feet (ft.) per minute to many feet per second. In comparison, groundwater moves very slowly. In a coarse sand aquifer, groundwater flow velocities may be as fast as one foot per day. A clay layer, on the other hand, may allow groundwater flow at a rate of only 0.3 inches (in.) per year!

Unconfined Aquifers

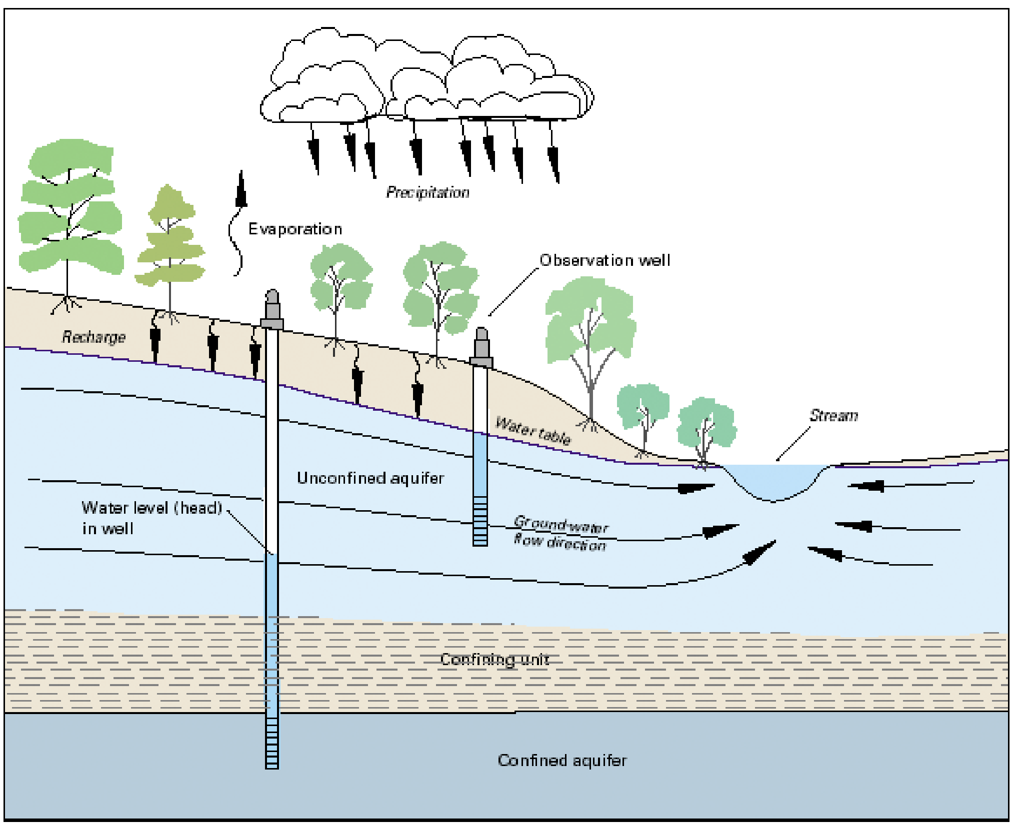
The saturated zone can have two types of productive aquifers within it, unconfined aquifers, and confined aquifers (see figure below). The unconfined aquifer is the region which is directly beneath the unsaturated zone with no barrier zones between them. Unconfined aquifers always remain at atmospheric pressure. The water table is the top surface of the unconfined aquifer. The height of the water table will vary with water subtractions from well pumping and water additions from excess infiltration that percolates down through the unsaturated zone and into the aquifer or saturated zone. Unconfined aquifers have a bottom barrier zone that slows downward movement of water and allows the water to build up into the unsaturated zone. With no barrier zone on top of the unconfined aquifer, the vertical movement of the water table from inputs and outputs occurs continually and with no pressure change.

Confined Aquifers

Confined aquifers are bounded above and below by barrier zones called confining layers. These confining layers are geologic materials which slow or restrict the movement of groundwater relative to the adjacent aquifer. Water pressure in a confined aquifer is pressure equal to the sum of atmospheric pressure plus the pressure exerted on the aquifer by the overlying confining aquifers. This is because in a confined aquifer the pressure is equal to the sum of atmospheric pressure plus the pressure exerted on the aquifer by the overlying confining aquifers. As a result, water levels in wells tapping confined aquifers always rise above the top of the aquifer (although not necessarily above the ground surface). These are called artesian wells. Confined aquifers are found below the unconfined aquifer. An aquifer zone can have more than one aquifer in it, but only one unconfined aquifer.

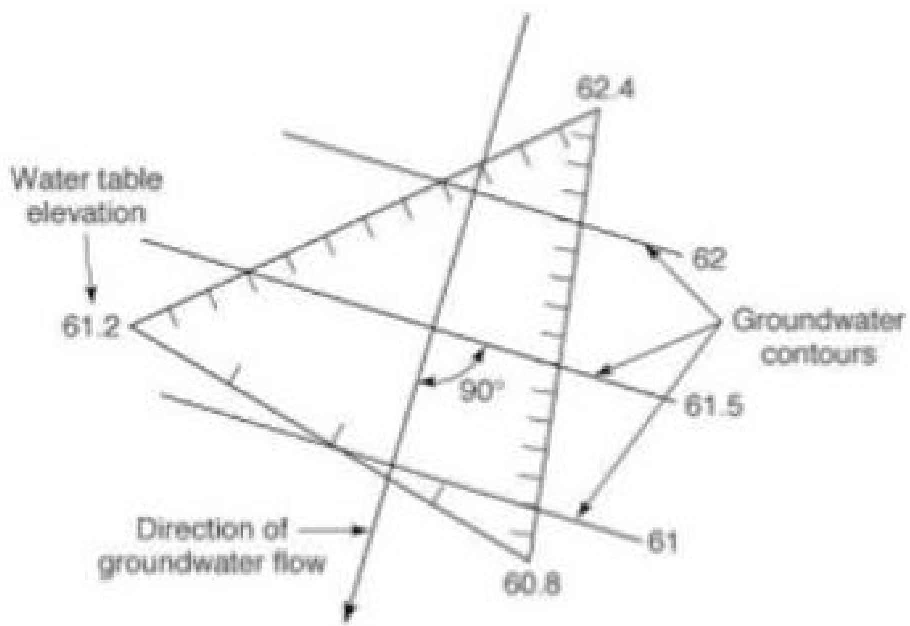
Perched Aquifers

Perched aquifers are areas above the water table that can collect a small account of water over a barrier zone of small areal extent. They generally are not productive sources for drinking water wells.



Aquifer Recharge
Aquifer recharge is the addition of water by percolation to the saturated zone from either the unsaturated zone or directly from surface water. This addition will cause the water table to rise as discussed above. Several aquifers may overlay each other, each with different directions of flow and different sources of recharge. Unconfined aquifers can be replenished over and over after water outputs (pumping, drainage, and base flow), by recharge inputs from the surface and from saturated layers below. Confined aquifers are more difficult to replenish because of the confining layers on the top and bottom. Defining the location of aquifer recharge areas may be very difficult if the subsurface geology is highly variable. Subsurface heterogeneity is common in glaciated landscapes such as Michigan and the Great Lakes Basin.

Groundwater Flow
Groundwater flow can occur over very large distances. Large aquifers can underlie areas as extensive as 100,000 square miles. In Michigan, the largest regional aquifer is less than one-third this size. The direction of groundwater flow may be determined by measuring the elevation of the water surface within a group of wells. The water elevation in each of at least three wells must be known in order to determine the local flow direction. From these data, contours of equal water surface height can be drawn. The local flow direction is straight down this surface, at right angles from the water height contours (see figure below). Determining the direction of groundwater flow can help in the resolution of existing pollution problems and aid in identifying vulnerable areas within a region.

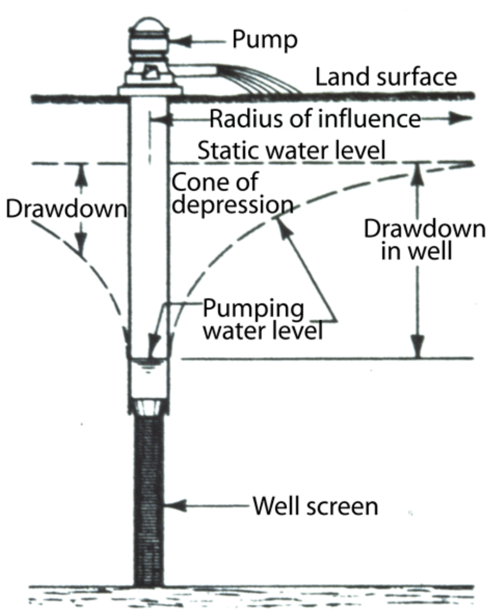


WELLS

Introduction
A well is column drilled down through the subsurface to the saturated zone. Wells are used as water sources and as monitoring stations for determining the direction of groundwater movement. Wells can be set into unconsolidated layers of material, like sand or gravel. These require a well screen to exclude the small, loosely packed materials around the well. A well screen is a slotted column beneath the well casing that blocks soil particles from traveling with the water through the pump. Wells drilled into completely consolidated bedrock have no need for a well screen. Typically, well depths in Michigan range from 30 to 500 feet, but most residential wells are less than 200 feet deep.

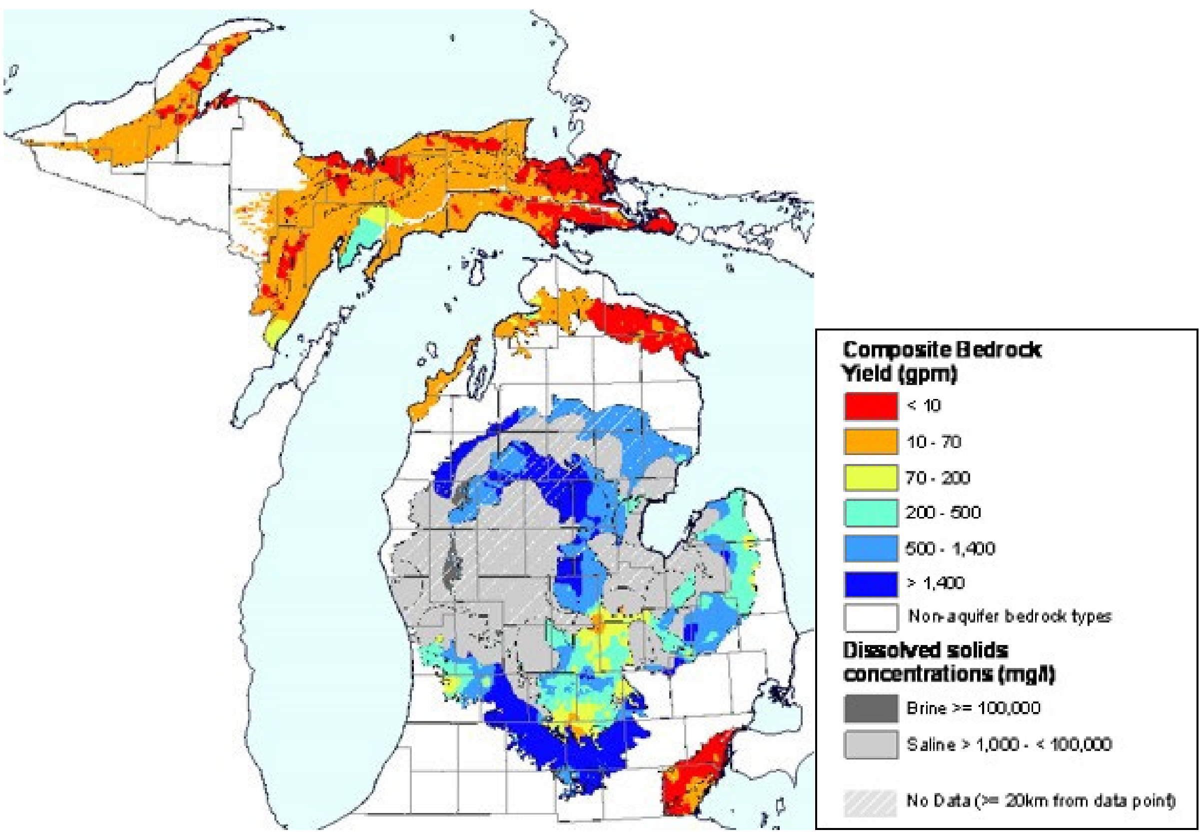
Aquifer Response to Wells
Confined aquifers and unconfined aquifers respond differently to wells. Water in a well penetrating an unconfined aquifer will rise to an elevation equal to the water table level which is at atmospheric pressure. Correspondingly, water in a well penetrating a confined aquifer will rise above the aquifer to an equilibrium elevation which is proportional to the pressure within the confined aquifer.

Unconfined Aquifer Pumping
During pumping of an unconfined aquifer, the water table will be drawn down forming a cone of depression around the well column (see figure below). The water removed from an unconfined aquifer comes not only from the movement of water through the saturated zone, but also from the dewatering of part of this zone, the compressibility of the aquifer material, and the expansion of the water upon pressure release. Above the sloping surface of the water table within the cone of depression, the soil material is no longer saturated with groundwater. Below the sloping surface of the water table, groundwater moves toward the well until eventually it enters the well screen and is lifted out. When pumping stops, the cone of depression fills with water from below as the aquifer returns to its equilibrium level (the water table). The drawdown around the well, established during pumping, causes an elevation difference which initiates water movement toward the well from surrounding areas. Increasing the pumping rate can enlarge and deepen the cone of depression. For a given set of aquifer characteristics, there is a pumping rate at which equilibrium is reached and the depth of dewatering stabilizes.



Confined Aquifer Pumping
In a confined aquifer, no cone of depression develops within the aquifer as a result of pumping. Pumping can, however, reduce the level to which water will rise in a neighboring well. Groundwater will move toward the pumped well from outside areas, but the entire confined aquifer remains saturated. The water removed from a confined aquifer is accounted for by the expansion of the water upon pressure release and the compressibility of the aquifer material. Water removal from confined aquifers results in compaction of the aquifer material. Unconsolidated materials (e.g., sand and gravel) are subject to more compaction than consolidated material (i.e., bedrock) because the cemented rock layers usually have a greater inherent strength.

Bedrock Aquifers
The availability of potable groundwater in bedrock unit is controlled, in part, by the porosity of the rock, the ratio of the volume of openings in the rock to the total volume of the unit. We differentiate between two different types of voids in rocks. Primary porosity refers to openings that were formed at the same time as the rock. The pore spaces between the grains of sand in a sandstone are an example. If the voids were formed after the material was lithified, they are termed secondary porosity. Examples of these secondary openings are fractures in a crystalline rock or solution openings in a limestone. The hydraulic conductivity of a rock expresses its capacity to transmit water. The size and interconnections of the primary and secondary openings largely control this parameter. In Michigan, as elsewhere, the porosity and hydraulic conductivity of the different bedrock units vary considerably. Another factor to consider is that much of the saturated thickness of the bedrock in Michigan contains non-potable brine. The figure below illustrates the pattern and extent of the major bedrock aquifers of Michigan.



The figure shows the accessibility of the bedrock aquifers in terms of the thickness of glacial materials which bury them in most places. The good aquifers shown on this map routinely provide potable groundwater of adequate quantity and quality. The marginal aquifers are those which provide low-quality water and/or have highly variable transmissivities (i.e., notable changes in hydraulic conductivity and/or aquifer thickness from place to place). The marginal 1 class consists of saturated, sedimentary rock units. The marginal 2 class represents the igneous and metamorphic rock types in the western Upper Peninsula which have little or no primary porosity; in these hard rock areas, groundwater is found only in joint and fracture zones.

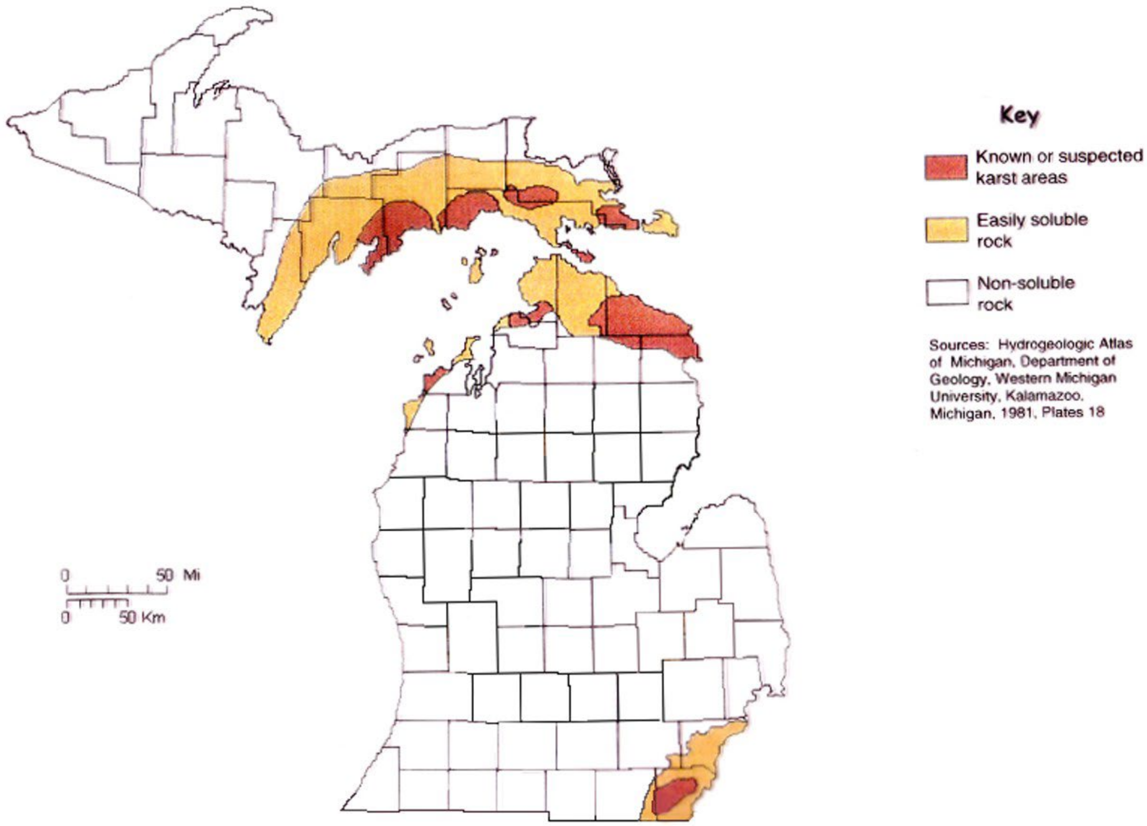
Bedrock aquifers are frequently tapped for domestic water supplies in areas where they are overlain by relatively thin (0-100 feet) drift. Examples include the Keweenaw Lowland in the western Upper Peninsula, many areas in the eastern Upper Peninsula, the vicinity of Presque Isle County in the northeast Lower Peninsula, the tip of Michigan's "thumb," the area around Monroe County in southeasternmost Michigan, and a swath of variable width extending southwestward from Saginaw Bay to the state line in Branch and Hillsdale Counties. In contrast, the bedrock aquifers below the northwestern and north central regions of the Lower Peninsula are typically buried beneath more than 400 feet of glacial drift and are, therefore, not generally accessible.

Many parts of the Lower Peninsula have little or no potable groundwater in the underlying bedrock, making these locales dependent on drift aquifers or surface water supplies. The most notable of these areas are the entire southwestern region and a countywide zone that traverses the southeastern sector of the state.

Areas of Special Concern
Within the Michigan Basin, there are numerous strata of carbonate rocks. These limestones and dolostones can be dissolved by water. In areas where the carbonate rocks are highly fractured, numerous solution widened joints develop. These may extend underground for long distances. Progressive solution leads to the development of small cavities and larger caves and caverns. As subterranean solution continues, some of these solution features can collapse causing subsidence of the overburden. A landscape exhibiting these landforms is called karst terrain.

The various solution features associated with karst regions provide numerous pathways for surface contaminants to infiltrate very rapidly into the subsurface. The rates of groundwater flow in these systems can approach those of some surface streams. Even more disturbing, the subterranean interconnections between these solution voids are generally unknown and unpredictable. As a result, hazardous materials which move into the groundwater in a karst region can travel very rapidly to wells located great distances from the contamination site. These conditions make the karst areas of Michigan (see map below) particularly vulnerable to potential contamination from human activities at or near the surface.

The darkest pattern depicts the known or suspected areas of karst in Michigan. The lighter pattern delineates regions of easily soluble rock types where similar underground solution features are possible. In areas where these lithologies are near the surface, subterranean karst development is probable. Notably, the karst areas along the south shore of the Upper Peninsula, in the general vicinity of Presque Isle County in northeastern Lower Michigan, and in Monroe County in southeasternmost Michigan are all overlain by relatively thin amounts of drift, usually less than 50 feet thick. Hence, there is minimal opportunity for the overburden to attenuate any percolating contaminants from the surface. Everyone who lives, works, or recreates in these parts of the state needs to be especially conscious of and careful with hazardous substances.



GLACIAL GEOLOGY

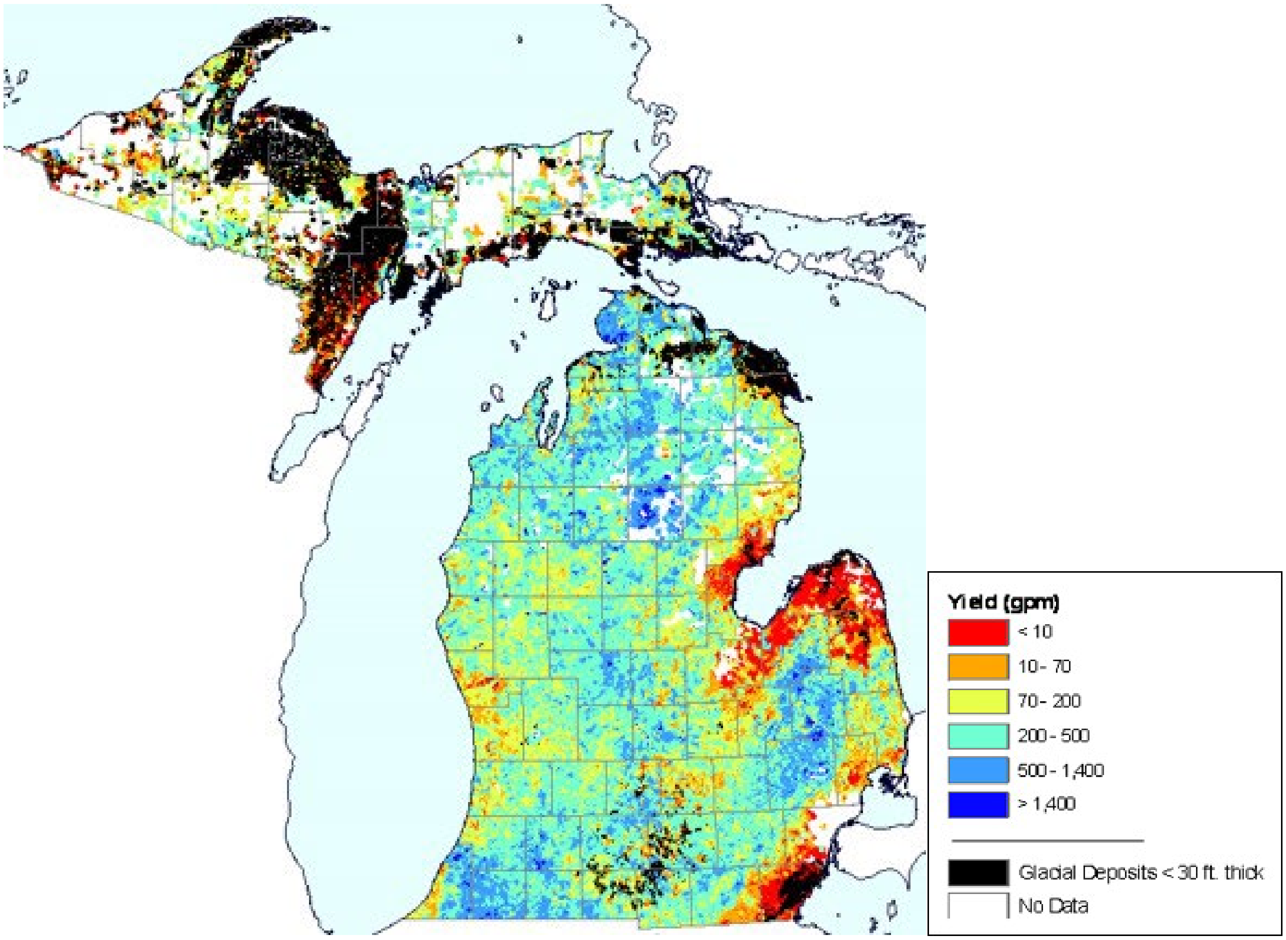
Drift Types and Thicknesses

The glaciers left most of Michigan buried in a variety of unconsolidated materials, clay, silt, sand, gravel, and mixtures which collectively are called drift. The thickness of the drift varies considerably across the state and is a principal factor in the economical availability of groundwater in bedrock aquifers. Also, the thicker the glacial materials are, the more likely it is that multiple drift aquifers will occur at depth. Drift thicknesses less than 100 feet are common in the Upper Peninsula.

The picture is very different in the Lower Peninsula. Here, many parts of the northern half of the peninsula are deeply buried beneath 400 to 600 feet of drift. Many townships in Wexford, Osceola, and Otsego counties exhibit drift thicknesses in excess of 800 feet This is in marked contrast to the very think (less than 10 feet) drift in Presque Isle and Alpena counties. In the southern half of the Lower Peninsula, the drift is generally less than 400 feet thick. In this part of the state, the drift is thickest (200 to 400 feet) in the interlobate regions which trend from Cass County to northern Kent County. The tip of the thumb in Huron County, as well as most of Monroe County in the southeastern corner of the state, exhibit drift thicknesses of 50 feet or less. A two-county wide zone of somewhat thin but variable drift thickness (generally less than 100 feet thick) trends southwestward from Saginaw Bay to Branch County.

Drift Aquifers

On a statewide basis, groundwater in drift aquifers is a plentiful resource as indicated by the map below. Most of the state is covered with glacial deposits which store and transmit groundwater in amounts and rates that could meet the requirements of a small domestic supply system. Of course, this is a great generalization and on a local basis, drift aquifers may be rare. The light-toned areas depict regions of the state where one or more of the glacial Great Lakes inundated the present upland surface and deposited clay rich materials. These lake plains are low relief surfaces underlain by dominantly fine textured drift which exhibits very low hydraulic conductivities. As a result, drift wells are not routinely possible in these sections of the state. The dark tone pattern reveals the distribution of areas underlain by 30 feet or less of glacial deposits. The Well Construction Code in Michigan specifies that all water supply wells must be cased to a depth of 25 feet. Considering the need for several feet of screen at the bottom of a well in unconsolidated material, these thin drift regions of the state provide very little opportunity to develop wells which could meet this construction standard.



Areas of Special Concern

We have seen that most of Michigan is covered with glacial deposits. From a statewide perspective, bedrock exposed at the surface is relatively rare. This implies that the water table (the upper surface of the groundwater) is most often found in the drift. The vulnerability of groundwater to contamination from the surface or near surface (i.e., human activities) is controlled primarily by the hydraulic conductivity of the materials through which infiltration occurs and the thickness of the unsaturated zone. Highly permeable soils allow surface contaminants to migrate rapidly into the subsurface. Less porous soils, on the other hand, inhibit the infiltration of contaminants. The depth to the water table (i.e., the thickness of the unsaturated zone) is a measure of the vertical distance that contaminants must travel in order to reach groundwater. The elevation of the water table is a function of surface topography and the altitude of the local groundwater discharge zones. In general, the configuration of the water table mimics the form of the surface, but with much less local relief. For certain types of chemicals, the amount of organic matter in the soil modulates how effectively it can attenuate the potential contaminant.

Considering these factors, the ice contact, course drift terrains, are some of the most vulnerable landscapes in Michigan. They are composed of highly porous soils which contain relatively little organic matter. Compared to proglacial outwash formations which are also composed of coarse material, the ice contact landforms present a much higher degree of subsurface heterogeneity. They are typically underlain by a complex interfingering of varying textures which makes the groundwater flow regime very complicated. This combination of inherent vulnerability coupled with subsurface, three-dimensional complexity produces landscapes which are particularly challenging in terms of groundwater protection strategies.

Hydrogeologic Definitions

Artesian Aquifer
An aquifer where groundwater is not open to atmospheric pressure but contained within an impermeable layer (also known as a confined aquifer) that causes the groundwater to be under sufficient pressure to rise above the level at which it is encountered. A flowing artesian well is a well completed in such an aquifer where water will rise above the ground surface.

Cone of Depression
In flowing through a porous media, the hydraulic gradient varies directly with the velocity (according to Darcy's Law). With increasing velocity, the hydraulic gradient increases as flow converges toward a well. As a result, the lowered water surface develops a continually steeper slope toward the well. The form of this surface resembles a cone-shaped depression.

Darcy's Law
The flow of water through a column of saturated sand is proportional to the difference in hydraulic head at the ends of the column and inversely proportional to the length of the column.

Drawdown
The extent of lowering of the water level when pumping is in progress or when water is discharging from the flowing well. Drawdown is the difference, measured in feet, between the static water level and the pumping level.

Flow Velocity
The rate in distance per unit of time that groundwater moves through a soil or rock.

Head
Pressure of water on an area due to the height at which the water stands above the point where the pressure is determined.

Hydraulic Gradient
The rate of change in pressure head per unit distance of flow at given points in a given direction.

Permeability
A rock type or soil's capacity for transmitting a fluid. The coefficient of permeability is the rate of flow in gallons per day/square foot.

Piezometric Surface
The surface to which the water from a given aquifer will rise under its full head. (Also known as potentiometric surface.)

Porosity
The ratio, measured in percent, of soil or rock void volume per total volume.

Pumping Level
The level at which water stands in the well when pumping is in progress. In a flowing well, it is the level at which water may be flowing from the well.

Radius of Influence
The distance from the center of the well to the limit of the cone of depression.

Recovery
After pumping is stopped, water levels rise and approach the static water level observed before pumping started.

Specific Capacity
Specific capacity of a well is its yield per unit of drawdown, usually expressed as gallons per minute (gpm) per foot of drawdown. Dividing the yield by the drawdown, each measured at the same time, gives the value of the specific capacity. As an example, if the pumping rate is 160 gpm at 20 feet of drawdown, the specific capacity is 8 gpm/ft. drawdown at the time the measurements are taken.

Static Water Level
The level at which water stands in a well when no water is being taken from the aquifer by pumping or free flow. It is usually expressed as the distance from the ground surface to the water level in the well. For a flowing well, the static water level is above the ground surface.

Transmissivity
The capacity of an aquifer material to transmit water under the influence of a pressure gradient.

Well Interference
Drawdown in a pumping well due to drawdown from another pumping well.

Well Yield
The volume of water per unit of time discharged from a well, either by pumping or by free flow. The pumping rate is commonly measured in gpm. Other units used are gallons per hour (gph) for small yields and cubic feet per second (cfs) for large yields.

Water Table Aquifer
The upper surface of the aquifer is defined by the water table itself and is at atmospheric pressure (also known as an unconfined aquifer).

Chapter 3: WELL PERMITTING

LHDs are responsible for issuing water well construction permits for single family residential homes, Type II public water supplies, and Type III public water supplies. Most LHDs also issue permits for irrigation and industrial water wells. The permitting process can vary greatly from LHD to LHD. However, a general overview of the well permitting process is as follows:

1. Individual applies for a well construction permit prior to drilling the well.
2. LHD evaluates the permit application and conducts an Office Predrilling Site Review (OPSR).
3. LHD may or may not make a visit to the proposed well site prior to issuing the permit.
4. LHD issues the well permit.
5. Well installation is completed, and contractor submits a water well and pump installation record to the LHD.
6. LHD evaluates the well record for accuracy and completeness.
7. LHD conducts an onsite final inspection of the system.
8. Water samples (based on well permit requirements) are collected by the well owner, well driller or LHD.
9. LHD deems the well installation either approved or unapproved, based on the well record, water sample results, and a final inspection, if applicable. If unapproved, the LHD describes the reasons why along with required corrective actions.

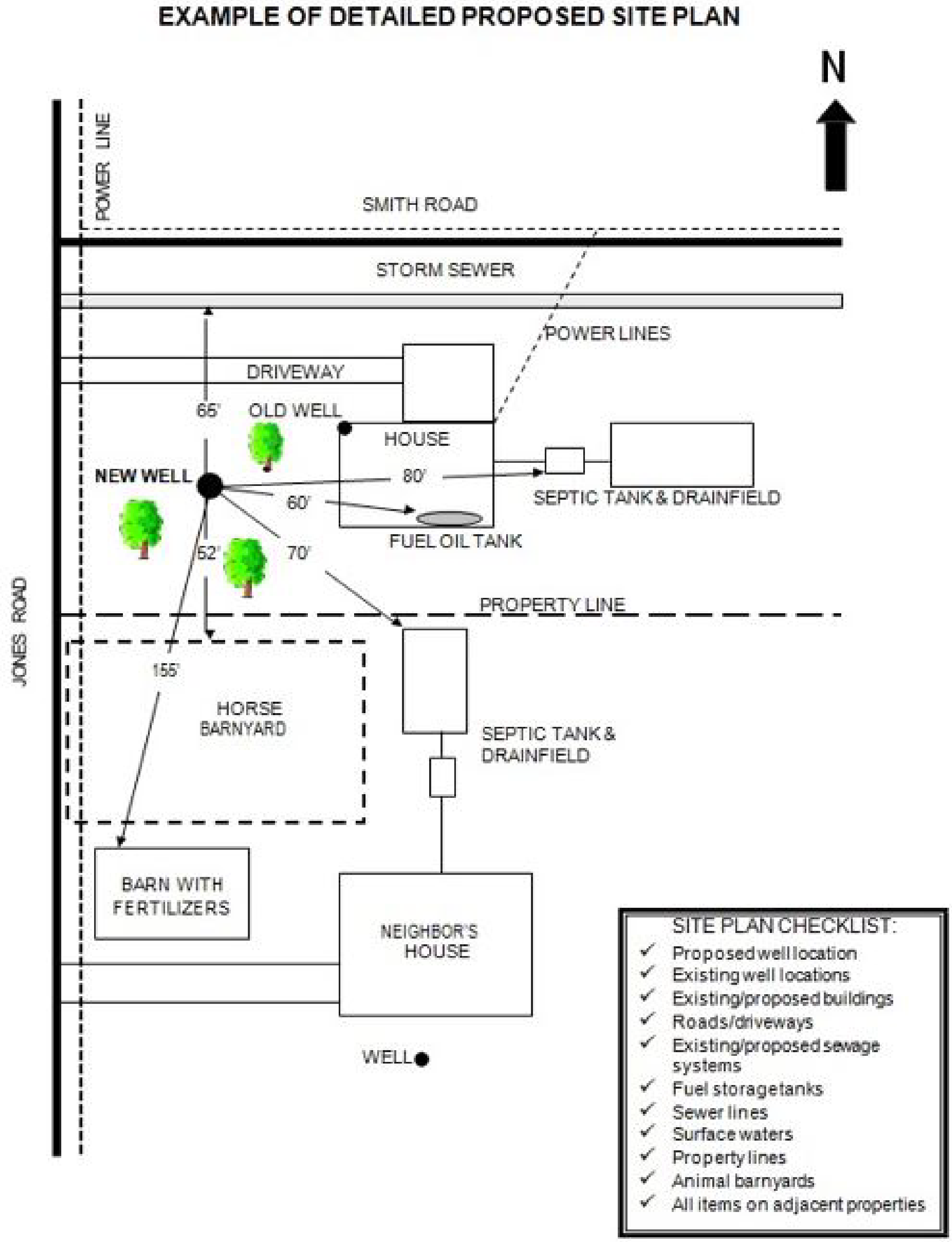
A Predrilling Site Review is the proactive phase of the well permitting process that assesses the proposed water well drilling site, ***before*** drilling is started, to determine if:

1. There is a likely potential to encounter a water quality or quantity problem.
2. The water well site is near a known potential source of groundwater contamination. (A list of state of Michigan websites where sanitarians can search for contamination information is provided in this chapter.)
3. An "institutional control" established under Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, is in effect in the vicinity of the water well.
4. Plat restrictions or restrictive covenants addressing minimum water well depth or other water well construction features are in place.
5. The water well location complies with minimum isolation distance requirements as specified in the State Well Code.
6. The water well will be accessible for maintenance.
7. The proposed water well will be constructed by a registered Contractor (or the property owner only if the location is their primary residence).

An OPSR consists of, but is not limited to, a review of the following factors:

1. A detailed site plan (see example below) showing the location of the proposed water well, distances from the water well to contamination sources (e.g., septic systems, sewer lines, fuel or chemical storage tanks, animal feedlots, pesticide application areas, etc.), buildings, roadways, and property lines. Sources of contamination on adjacent parcels, if known, must be included.
2. Deed restrictions or restrictive covenants.
3. Water well records.
4. Land use limitations such as institutional controls.
5. Contaminant source inventories (see “State of Michigan Resources for Water Wells and Potential Sources of Contamination” in this chapter).
6. Hydrogeological studies (if submitted by the permit applicant).

A Field Predrilling Site Review consists of the same components as an OPSR, except that an onsite assessment of the proposed water well site is made to verify the site plan details.



STATE OF MICHIGAN RESOURCES FOR WATER WELLS AND POTENTIAL SOURCES OF CONTAMINATION

Water Well Resources
Wellogic (2000 and newer water well records): (EGLE.State.MI.US/Wellogic/Login.aspx)

Scanned Water Well Records (1999 and older water well records): (EGLE.State.MI.US/Well-Logs/)

Water Well Record Data (shapefiles created from Wellogic for mapping purposes:
(GIS-Michigan.OpenData.ARCGIS.com/Search?Collection=Dataset &q=Wellogic)

Water Well Viewer (View Well Records on Map): (MCGI.State.MI.US/WaterWellViewer/)
Zoom into an area, use the "Tools" and "Identify Features on Map" buttons.

Public Water Supply Wellhead Protection Areas (shapefiles for mapping purposes):
(https://GIS-EGLE.Hub.ARCGIS.com/datasets/868e2d670a2641d48e0b150a84769e18_0/explore)

Potential Sources of Contamination
Contamination Investigation Program: (Michigan.gov/EGLE/About/Organization/Drinking-Water-and-Environmental-Health/Contamination-Investigation)

Michigan Environmental Mapper: (MCGI.State.MI.US/EnvironmentalMapper/)

Part 201 Facilities: (EGLE.State.MI.US/RIDE/Home)

Storage Tank Information Database: (EGLE.State.MI.US/RIDE/Home)

Part 117 Septage Application Sites:
(Michigan.gov/EGLE/-/Media/Project/Websites/EGLE/Documents/Programs/DWEHD/Septage/Septage-Hauler-Directory.pdf)

Onsite Wastewater Systems: Contact your Local Health Department

Part 615 Oil and Gas Wells: (EGLE.State.MI.US/GeoWebface)

Part 111 Hazardous Waste Sites: (EGLE.State.MI.US/WDSPI/Home.aspx)

Part 115 Landfills: (EGLE.State.MI.US/WDSPI/Home.aspx)

Part 31 Groundwater Discharge Sites: (MIEnviro.Michigan.gov/Nsite/Map/Help)

PFAS Contamination: (Michigan.gov/PFASResponse)

ISOLATION DISTANCES

Michigan law (Rule 122) requires that certain minimum isolation distances be maintained when constructing a new well near a potential contamination source, such as a fuel storage tank, septic system, or an animal feedlot.

The actual location of the water well will often be determined by factors other than sources of contamination or geologic conditions. Avoiding certain land surface features such as steep slopes and poorly drained areas are considerations in the location of the well. Whenever possible, wells should be located at higher elevations than the surrounding areas to decrease the potential for contamination.

In general, minimum isolation distances should not be the standard. For example, a well installation near a groundwater contamination site should have the isolation distance maximized to provide the well owner with the best possible chance of maintaining a safe water supply.

Groundwater Flow Direction
Knowing the direction of groundwater flow can be very valuable when installing wells near sources of contamination. Groundwater usually flows towards streams, rivers, and lakes, but it does not always mirror the flow of water on the surface. Locating a well downgradient from the contaminations source at a further horizontal distance is an option. However, locating the well upgradient from the contamination may be the better option even if the isolation distance is less.

Local Health Department Authority
LHDs have the authority to increase isolation distance based on various factors such as groundwater conditions or contamination sources. LHDs also have the authority to decrease the isolation distance from a well to a potential source of contamination using deviations. Deviations are issued on a case-by-case basis. Criteria for the issuance of deviations are set forth in Rule 113 for Part 127, and R 325.10809 in Act 399.

Public vs. Private Water Supplies
Different types of wells may have different isolation distances. For example, a single-family household well may require 50-feet minimum isolation from the septic tank and drainfield while a multi-family apartment building may require minimum 75-feet isolation.

Act 399 PA 1976 contains minimum isolation distances for public water supplies (Type I, Type II, and Type III).

MINIMUM WELL ISOLATION DISTANCES
(From Contamination Sources and Buildings)
Part 127, Act 368, P.A. 1978 and Act 399, P.A. 1976

The following lists sources of contamination and the well isolation distances required from those sources by state codes. The Michigan Department of Environment, Great Lakes, and Energy and LHDs have authority to issue deviations from these minimum isolation distances on a case-by-case basis. Criteria for issuance of deviations are set forth in R 325.1613 of the Rules for Part 127, and R 325.10809 of the Rules for Act 399.

* = For the isolation distances marked with a single asterisk, the isolation distance is for a source of contamination which is not specifically listed in the rules. However, the source of contamination is interpreted as belonging in a general contamination source group (e.g., a sewage holding tank is the same as a septic tank) which is listed in the rules, and therefore, the isolation distance listed in this document is ***required***.

** = For the isolation distances marked with a double asterisk, the isolation distance is from a source of contamination which is not specifically named in the rules. However, the Michigan Department of Environment, Great Lakes, and Energy has established a ***recommended*** isolation distance based on the contaminant involved, the risk to public health, and other factors. Under the general authority of a health officer's responsibility to protect the public health, health officers may modify this recommended isolation distance, either increasing or decreasing it, on a case-by-case basis.

CONTAMINATION SOURCE	Required MINIMUM Isolation Distance (Feet)		
	Part 127, Act 368 PA 1978	**Act 399, PA 1976**	
		IIb and III	I and IIa
Agricultural chemical or fertilizer storage or preparation area	150	800	2000
Animal waste lagoon or manure storage	*150	800	2000
Animal or poultry yard	50	75	200
Brine wells or injection well	**150	**800	**2000
Building or projection thereof	3	3	3
Cemetery and graves	**50	*75	*200
Cesspool	50	75	200
Chemical Storage	150	800	2000
Contaminant plumes, known (Part 201, LUST sites, etc.)	**300	**800	**2000
Drainfield	50	75	200
Drywell	50	75	200
Footing drain	10	10	10
Fuel/chemical storage tanks – Underground or above grade and associated piping depot/tank farm	300	800	2000
1,100 gallons or larger, without secondary containment	300	800	2000
1,100 gallons or larger with secondary containment	50	800	2000
less than 1,100 gallons that store motor or heating fuel for noncommercial purpose or consumptive use on premises where fuel is stored	50	800	2000
less than 1,100 gallons that store motor fuel for commercial purpose	*50	800	2000
located in a basement, regardless of size	*50	800	2000
Grease trap	50	*75	*200
Kennel	50	*75	*200
Landfill or dump sites (Active or Inactive)	800	800	2000
Liquid waste draining into the soil	50	*75	200
Metering station for pipeline	*300	*300	*300
Municipal wastewater effluent or sludge disposal area (land surface application or subsurface injection)	300	800	2000
Municipal wastewater lagoon	*300	800	2000

Oil or gas well	300	300	300
Other wastewater handling or disposal unit	50	*75	*200
Petroleum product processing or bulk storage	300	800	2000
Pipeline for gas, oil	*300	*300	*300
Privy/outhouse	50	75	200
Seepage pit	50	75	200
Septic tank	50	75	200
Septage waste (land application area)	800	800	2000
Sewage holding tank	50	*75	*200
Sewage lagoon serving a single-family dwelling	50	75	200
Sewage lagoon effluent – land application area	50	800	2000
Sewage or liquid waste draining into soil	50	*75	*200
Sewage pump chamber, transfer station, or lift station	50	75	200
Sewers Buried gravity sewer (sanitary or storm) - Service weight or heavier ductile-iron or cast iron, or schedule 40 PVC, all with watertight joints	10	75	200
Buried pressure sewer (sanitary or storm) Watertight joints (pressure tested after installation to 100 pounds (lbs.) per square inch [psi]), equivalent to Schedule 40 or SDR 21, and meets or exceeds ASTM Specifications D1785-91 or D2241-89	10 (by written deviation only)	75	200
Buried gravity or pressure sewer (sanitary or storm), constructed of materials not meeting the specifications listed in the two categories above, or the materials are unknown	50	75	200
Sump pit Receiving other than household waste (footing drain, roof drain, etc.)	10	10	10
Receiving household waste (laundry, softener backwash, sink waste, etc.)	50	75	200
Surface water (lake, river, stream, pond, ditch, etc.)	10	75	200
Unfilled space below ground surface (except an approved basement, basement offset, or crawl space beneath single family dwelling)	10	10	10

*Note: The above listed isolation distances are **minimum** distances. The regulatory agency has the authority to increase the minimum isolation distance based on factors such as: geology, groundwater flow direction, well construction, type of contaminant, etc.*

DEVIATIONS

LHDs have the authority to issue deviations for minimum isolation distances for individual well installations. Deviations should not be issued for political reasons, economic considerations, or public relations. The deviation shall be requested in writing, prior to well construction. Types of documentation submitted to the LHD for a deviation approval include why the rule cannot be met, well location, distances to sources of contamination, detailed site plan, geologic conditions, neighboring well details, and proposed well construction details. Depending on the situation, a hydrogeological study and test wells may also be required.

Deviation Rules

Rule 113. (1) A health officer may issue a deviation if the spirit and intent of these rules are observed and the public health, safety, and welfare are assured.

Water Service Line

A water service line may remain not in compliance with the provisions of these rules when extensive changes or repairs to a water supply system are made only if the water service line is located beneath a permanent structure or pavement.

Isolation Distances

A well may be located closer to a potential or known source of contamination if the dimensions of the property do not permit compliance and if ***any*** of the following conditions exist:

- Groundwater flow direction is away from the well.
- The depth of the well and depth of grouting will provide protection of groundwater quality and the public health.
- The well is replacing a well on a site where a habitable structure exists. It is recommended that the maximum isolation distance be obtained.

A well may be located 10 feet to a pressurized sewer that meets ***all*** of the following requirements:

- Pressure tested, not less than 100 psi and watertight
- ASTM specification D 1785-91 or D 2241-89
- Schedule 40 or SDR 21

A health officer may require a study of the hydrogeological conditions of a site to support a deviation issued pursuant to the provisions of this sub rule.

A well may be located closer than 3 feet to a building if ***all*** of the following conditions exist:

- Well is a replacement well
- Cannot meet minimum distance
- Access for maintenance is provided

A well may be required to be located ***more*** than the specified minimum distance from a source of contamination if the minimum specified distance will not protect groundwater quality or the public health due to local groundwater conditions, geology, or other factors.

LHDs should never routinely issue deviations after the well is installed if the minimum isolation distance can be met by relocating the well.

Casing Depth
Casing less than 25 feet below the ground surface if the well will not be used to supply water to habitable structures or for human consumption and if ***both*** of the following conditions exist:

- Water supply system is identified as not being suitable for human consumption
- Water supply system is separated from any potable water supply system

Casing less than 25 feet below the ground surface if there is reason to believe that potable water of suitable quantity does not exist at a reasonable depth of more than 25 feet and if ***either*** of the following conditions exist:

- Isolation distance is increased
- A confining layer is present above the aquifer

Casing extends more than 25 feet below the ground surface if there is reason to believe that non potable water is or may be present in the upper bedrock.

Flowing Well Discharge
A flowing well discharge is only allowable if the well owner or well owner's representative demonstrates one of the following:

- Control of the flow is not practical (with supporting documentation)
- Control of the flow will likely result in the production of sand or turbidity in the water (with supporting documentation)
- Discharge is for a beneficial use

Deviation Documentation
Deviations from the rules shall be documented, in writing, by a health officer and shall state the reasons for each deviation. A health officer may require special well construction features as a condition for the issuance of a deviation and may require well construction features that are more stringent than these rules when deemed necessary to protect the groundwater quality or the public health. Reasons for the issuance of a deviation or special well construction features as a condition for the issuance of a deviation by a health officer shall be based upon ***any*** of the following factors:

- Site hydrogeology
- Site topography
- Site dimensions
- Soil characteristics
- Depth of well
- Type of well
- Well pumping rate
- Well drilling method
- Distance from contamination sources
- Presence of groundwater contamination
- Other similar factors

Chapter 4: WATER SYSTEM SIZING

Introduction
It is important that water supply systems are properly sized. Well owners are often concerned about whether there will be enough water for their needs. The area geology determines how successful a well drilling contractor may be in obtaining a suitable water supply from a well.

"Enough" water means a sufficient quantity with sufficient pressure to meet the following needs:

- Everyday use – drinking, cooking, and water for plumbing
- Seasonal use – lawn and garden watering, car washing, and swimming pool
- Other special uses – animal watering, crop irrigation, and water treatment devices that require backwashing

A day's use may be concentrated into a period of one to two hours, often in different areas of the house at the same time (laundry, bathroom, and lawn). The water supply system must be able to meet this type of peak demand.

In addition to providing for regular household use, wells sometimes supply water for heating and cooling purposes. Some energy-conscious homeowners install groundwater geothermal systems, which extract and concentrate heat energy from water and make it available for heating or cooling purposes.

According to the Well Construction Code in Michigan, there is no minimum gpm a well must produce. This is because a few areas of the state (e.g., "Thumb," Upper Peninsula, and SE Michigan) have groundwater conditions that do not produce more than just 2-3 gpm. However, the Well Construction Code does have a provision that requires the well be "adequate in size, design, and development for the intended use." EGLE's "Administrative Rules for Onsite Water and Sewage Disposal for Land Divisions and Subdivisions" require wells to demonstrate a minimum sustained pumping rate of 10 gpm for not less than a 4-hour period of time, or a combination of well yield and storage to meet peak demand. That is why it is very important for a well owner to discuss their needs with the well drilling contractor prior to drilling the well.

In designing a water supply system, the following factors should be considered:

- Peak demand of the house or facility
- The capacity of the well
- The total dynamic head the pump must overcome
- Storage tank capacity

In cases where local groundwater conditions do not produce enough water for the needs of the owner, well drilling contractors should take the necessary steps (e.g., increase storage capacity or screen length) to provide the well owner with as much water as possible. It is very important that contractors inform the well owner of any low quantity issues prior to drilling.

Residential Water System Sizing
A properly designed residential water supply system should deliver water at the desired quantity, quality, and pressure to any outlet on the system during periods of heaviest use. To accomplish this, the peak demand for the home is determined and the well and pump are sized to meet or exceed the demand. If local geological conditions prohibit the development of a water supply with quantity to meet the demand, additional storage facilities are necessary.

Determining the Pump Capacity

A simple method of determining pump capacity is based on the number of water using fixtures or outlets. The pump capacity (in gallons per minute or gpm) should equal the total number of fixtures in the home.

EXAMPLE:
The Smith residence has two bathrooms (each with a water closet, tub/shower, and lavatory), kitchen sink, garbage disposal, dishwasher, washing machine, laundry sink, and three outside hose bibs. A total of 14 fixtures are present. Therefore, the minimum pump capacity should be 14 gpm.

Peak demand periods occur when several fixtures are used at the same time. The average time of high water usage from fixtures such as showers, dishwashers, washing machines, etc., is 7-minutes. The 7-minute peak demand and minimum pump size for modern residences may be obtained from Table 1.

TABLE 1

Number of Bathrooms	7-Minute Peak Demand (gallons)*	Minimum Pump Size to Meet Peak Demand Without Supplemental Storage (gpm)
1	45	7
1.5	70	10
2 to 2.5	98	14
3 to 4	122	17

* Includes water usage for kitchen sink, washing machine, and dishwasher. Additional demand for farm, irrigation, and sprinkling must be added to peak demand figures if usage will occur during peak demand periods.

Pump Capacity Meets or Exceeds Demand

If the actual pump capacity is equal to or exceeds the minimum pump size indicated in Table 1, supplemental storage is not required. The pressure tank should then be sized to provide a tank draw-off equal to the pump capacity for a 1- to 2-minute pump cycle. See “Determining Storage Capacity” below.

EXAMPLE
The well for the Smith residence is capable of sustaining a 14-gpm pump. Table 1 indicates the 7-minute peak demand for the Smith’s two-bathroom home is 98 gpm. Since the 14-gpm pump will supply 98 gallons during the 7-minute peak period, supplemental storage is not necessary. A 1-minute pump cycle would produce 14 gallons of water. Therefore, the pressure tank selected should provide a minimum draw-off (available water volume) of 14 gallons. If a 2-minute pump cycle were desired, the pressure tank should be sized to provide 28 gallons of available water. Manufacturer’s specifications should be consulted to determine which model pressure tank will supply the necessary volume at the desired operating pressure.

Pump Capacity Less Than Demand

If the actual pump capacity is less than the minimum pump size indicated in Table 1, supplemental storage is necessary to meet peak demands. The difference between the 7-minute peak demand and the amount of water provided by the pump during a 7-minute period is the volume that must be provided from storage. The pressure tank should then be sized to provide a tank draw-off equal to the difference between the 7-minute peak demand and the 7-minute pump capacity.

EXAMPLE
The well for the Jones residence is capable of sustaining a 10-gpm pump. The 7-minute peak demand for the Jones residence is 98 gpm. During the 7-minute period, the pump will produce 70 gallons of water. 98 – 70 = 28 gallons. Twenty-eight gallons must be supplied from storage during the 7-minute peak demand period. Therefore, the pressure tank selected should provide a minimum draw-down (available water volume) of 28 gallons.

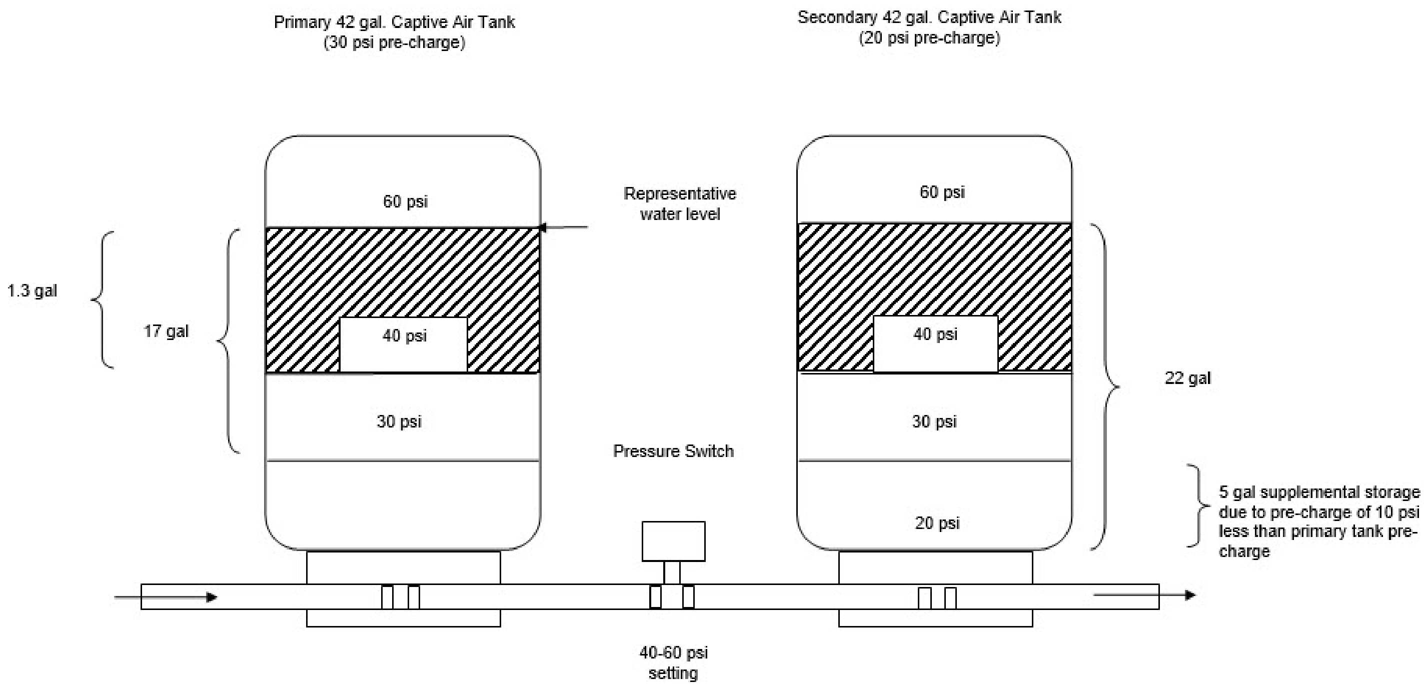
The additional volume required can also be provided by pre-charging the pressure tank and adjusting the pressure switch settings. Pre-charging is the addition of air to the pressure tank. If the pre-charge pressure is about 5 psi below the pump cut-in pressure, supplemental supply is obtained from the tank. When the demand exceeds the pump capacity the pressure will drop, and the supplemental supply from the tank will be used to meet the demand.

EXAMPLE
It was determined that the minimum tank draw-off for the Jones residence should be 28 gallons. If a 120-gallon plain steel tank (no diaphragm) were installed and operated at 30-50 psi without a pre-charge, about 10 percent of the total tank volume, or 12 gallons (from manufacturer's specifications) would be available from the tank. By lowering the operating pressure to 20-40 psi and pre-charging the tank to 15 psi the usable tank capacity will increase to 37.4 gallons or 31 percent. This volume would then meet the 7-minute peak demand.

If an additional pressure tank is installed for supplemental storage, the pre-charge of the second tank should be lower than that of the primary tank. The differential pressure switch range should also be set closer. This will increase the overall operating range of the system and provide additional water for peak demand.

EXAMPLE
The Smith residence has a 7-minute peak demand of 70 gallons. The Smiths complain of running out of water and have requested that additional storage be added. The well produces 5 gpm and a 42-gallon diaphragm-type captive air tank is currently installed. The system is operating at 30-50 psi and the tank has a pre-charge of 30 psi. During the 7-minute peak demand, the pump will produce 35 gpm. 70 – 35 = 35 gallons. Thirty-five gallons must be produced from storage during the 7-minute peak demand period. Therefore, the present tank plus the additional tank must provide at least 35 gallons of water. The usable capacity of the existing tank is about 31 percent or 13 gallons. Therefore, the supplemental storage must provide 22 gallons of water. If an additional 42-gallon tank, pre-charged to 20 psi, is installed and the pressure switch adjusted to 40-60 psi, the usable capacity of the primary tank will increase to 17 gallons and the second tank will provide about 22 gallons. The pressure tanks will provide water over a 40-psi differential, from 20-60 psi, and the total volume of available water from the pressure tank has now increased to 39 gallons. When the pressure drops, to the pump cut-in pressure of 40 psi, there will be about 5.7 gallons left in the primary tank and 10.7 gallons in the secondary tank. If the demand lowers the pressure to 30 psi, the first tank will essentially be out of water and 5 gallons will remain in the secondary tank.

If the pressure continues to decrease to 20 psi, both tanks will be out of water and the only supply will be from the pump. The diagram below illustrates this installation.



Determining Total Dynamic Head
Total Dynamic Head (TDH) is the total equivalent height that a fluid is to be pumped, considering friction losses in the pipe. The TDH of a water system must be considered when determining the size of pumping equipment to be installed. It determines the various head losses that the pump must overcome.

TDH = elevation head + friction head loss + pressure head

A. Elevation head is the vertical distance which the water must be pumped. It is the elevation difference in feet between the pumping level in the well and the pressure tank.

B. Friction head loss is the loss of pressure due to the flow of water through pipe and fittings. Determine diameter, length, and type of pipe material through which the water flows from the well to the pressure tank. Using the pump flow rate as determined from the Residential Unit Method or Fixture Method, refer to the Friction Loss Chart Through Pipe Chart and the Friction Losses Through Pipe Fittings Chart to determine friction head loss due to pipe and fittings. Friction loss can be overcome by using a larger pipe size or changing piping materials. (Note: In small water systems with few fittings, the head loss due to the fittings may be disregarded.)

C. Pressure head is the maximum operating pressure of the water system converted from pressure (psi) to feet of head. If the pressure switch setting is 30-50 psi, then the maximum pressure is 50 psi. Convert psi to feet of head using the following conversion: 1 psi = 2.31 feet of head. Therefore, pressure head equals maximum operating pressure x 2.31 feet

D. Other head losses to be considered:

Water softener	10 psi x 2.31 = head in feet
Iron filter	20 psi x 2.31 = head in feet
Hot water heater	2 psi x 2.31 = head in feet

FRICTION LOSS THROUGH PIPE

1.25-inch to 2-inch pipe

Loss of Head in Feet, Due to Friction Per 100 Feet of Pipe

1.25 Inch				1.5 Inch				2 Inch			
GPM	Steel	Copper	Plastic	GPM	Steel	Copper	Plastic	GPM	Steel	Copper	Plastic
	C=100	C=130	C=140		C=100	C=130	C=140		C=100	C=130	C=140
	ID=1.38"	ID=1.36"	ID=1.38"		ID=1.61"	ID=1.60"	ID=1.61"		ID=2.067"	ID=2.062"	ID=2.067”
4	.564	.364	.304	4	0.267	0.165	0.144	10	0.431	0.268	0.233
6	1.2	.765	.649	6	0.565	0.358	0.305	15	0.916	0.569	0.495
8	2.04	1.31	1.1	8	0.962	0.611	0.52	20	1.55	0.962	0.839
10	3.08	1.98	1.67	10	1.45	0.923	0.785	25	2.35	1.45	1.27
12	4.31	2.75	2.33	12	2.04	1.29	1.1	30	3.29	2.03	1.78
14	5.73	3.64	3.1	14	2.71	1.71	1.46	35	4.37	2.71	2.36
16	7.34	4.68	3.96	16	3.47	2.2	1.87	40	5.6	3.47	3.03
18	9.13	5.81	4.93	18	4.31	2.75	2.33	45	6.96	4.31	3.76
20	11.1	7.1	6	20	5.24	3.31	2.83	50	8.46	5.24	4.57
25	16.8	10.7	9.06	25	7.9	5	4.26	55	10.1	6.22	5.46
30	23.5	15	12.7	30	11.1	7	6	60	11.9	7.34	6.44
35	31.2	20	16.9	35	14.7	9.35	7.94	70	15.8	9.78	8.53
40	40	25.6	21.6	40	18.9	12	10.2	80	20.2	12.5	10.9
45	50.2	32.1	27.1	45	23.4	14.9	12.63	90	25.1	15.6	13.6
50	60.4	38.7	32.6	50	28.5	18.1	15.4	100	30.5	18.9	16.5

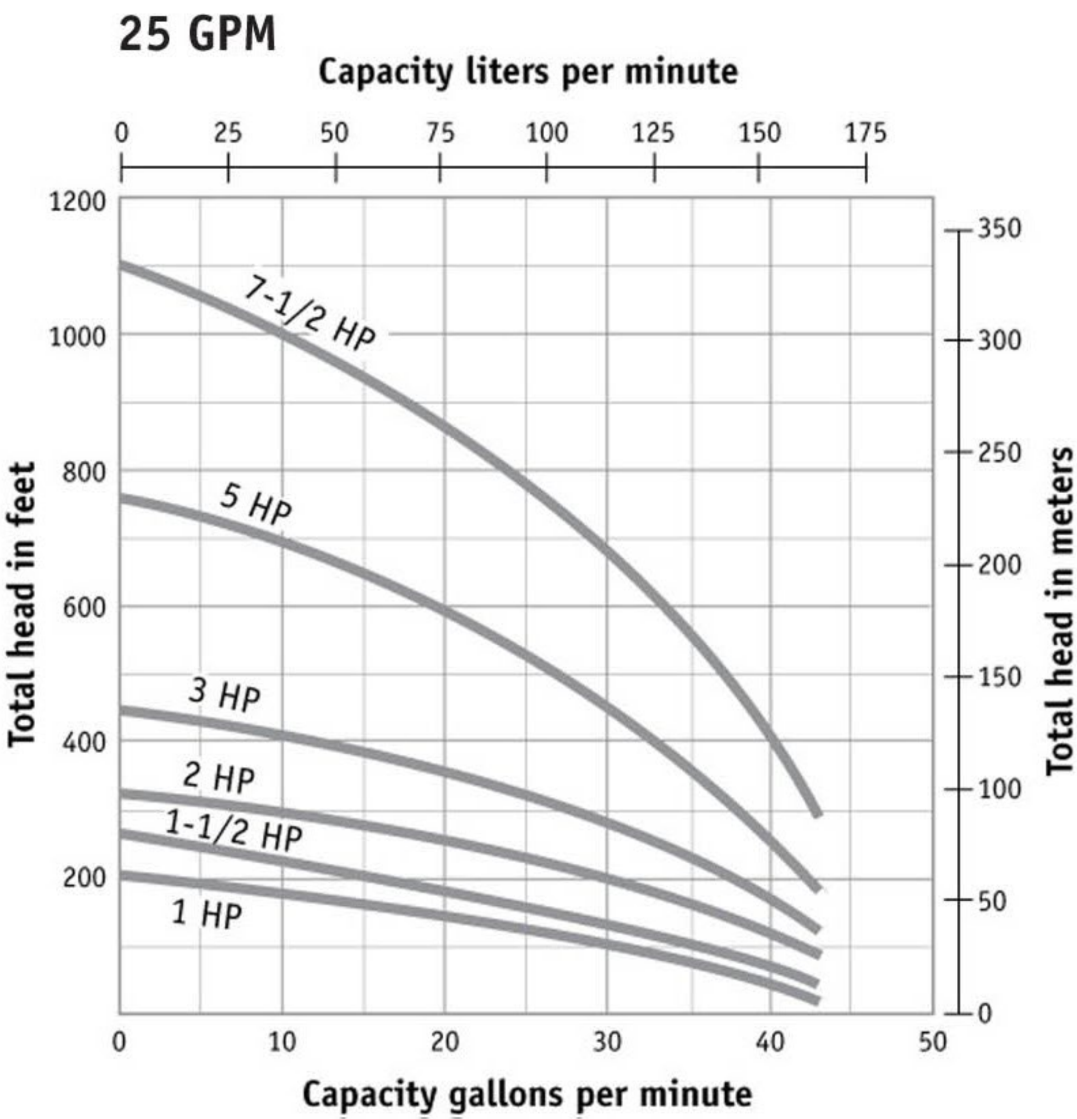
FRICTION LOSS THROUGH PIPE FITTINGS

Size of Pipe	Standard Elbow	Medium Radius Elbow	Long Radius Elbow	45 Degree Elbow	Tee	Return Bend	Gate Valve Open	Globe Valve Open	Angle Valve Open
LENGTH OF STRAIGHT PIPE GIVING EQUIVALENT RESISTANCE FLOW									
.5”	1.5	1.4	1.1	.77	3.4	3.8	3.5	16	8.4
.75”	2.2	1.8	1.4	1.0	4.5	5.0	.47	22	12
1”	2.7	2.3	1.7	1.3	5.8	6.1	.6	27	15
1.25”	3.7	3.0	2.4	1.6	7.8	8.5	.8	37	18
1.5”	4.3	3.6	2.8	2.0	9.0	10	.95	44	22
2”	5.5	4.6	3.5	2.5	11	13	1.2	57	28
2.5”	6.5	5.4	4.2	3.0	14	15	1.4	66	33
3”	8.1	6.8	5.1	3.8	17	18	1.7	85	42
3.5”	9.5	8.0	6.0	4.4	19	21	2	99	50
4”	11	9.1	7.0	5.0	22	24	2.3	110	58
4.5”	12	10	7.9	5.6	24	27	2.6	130	61
5”	14	12	8.9	6.1	27	31	2.9	140	70
6”	16	14	11	7.7	33	37	3.5	160	83
8”	21	18	14	10	43	49	4.5	220	110
10”	26	22	17	13	56	61	5.7	290	140
12”	32	26	20	15	66	73	6.7	340	170
14”	36	31	23	17	76	85	8	390	190
16”	42	35	27	19	87	100	9	430	220
18”	46	40	30	21	100	110	10.2	500	250
20”	52	43	34	23	110	120	12	560	280
22”	58	50	37	25	130	140	13	610	310
24”	63	53	40	28	140	150	14	680	340
30”	79	68	50	35	165	190	17	860	420
36”	94	79	60	43	200	220	20	1000	500
42”	120	95	72	50	240	260	23	1200	600
48”	135	110	82	58	275	300	26	1400	680

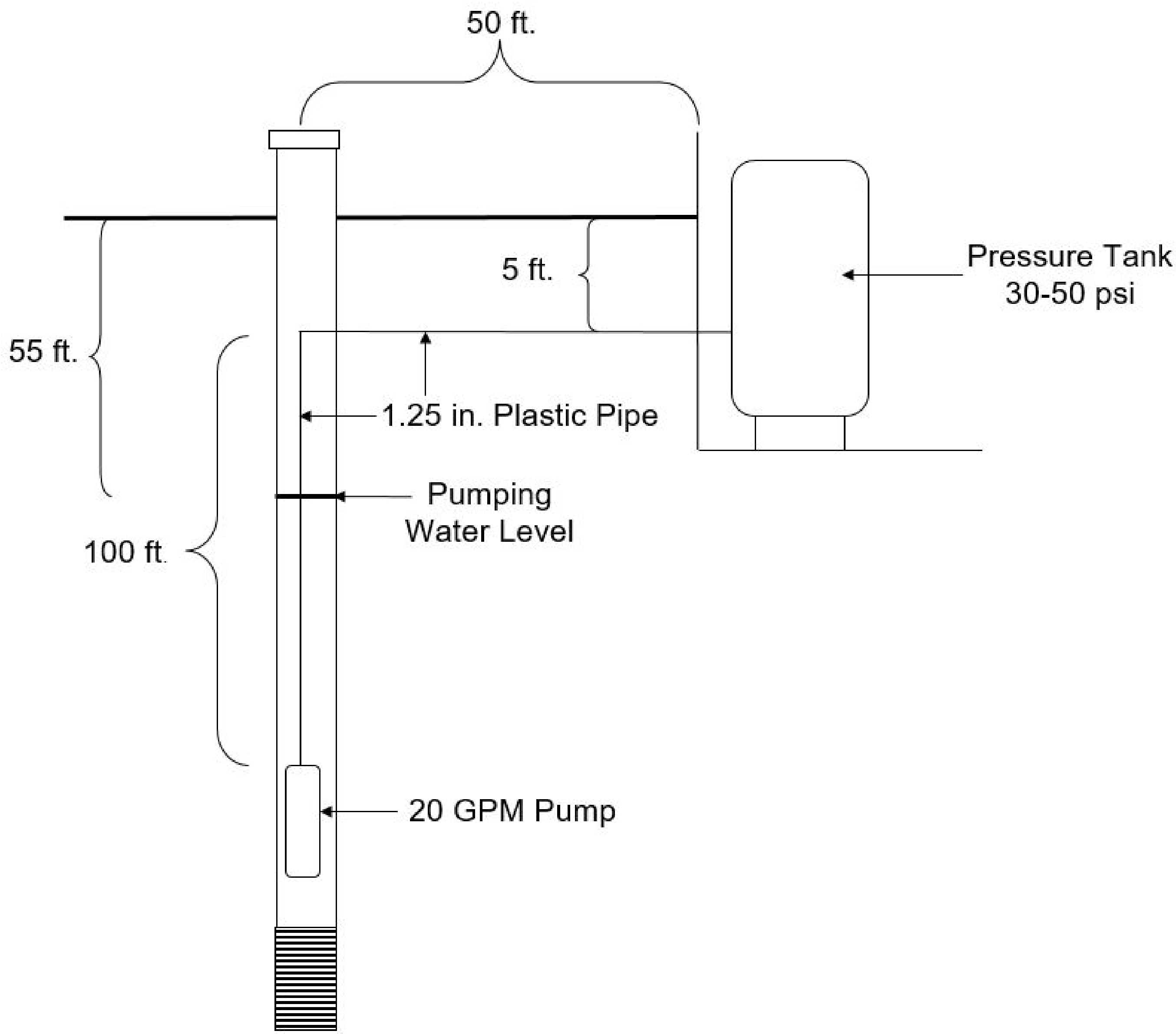
Pump Selection Using a Pump Curve
To determine if the proposed well pump is properly sized, it is necessary to refer to the pump manufacturer's performance curve or chart. Pump curves are available on most manufacturer's websites. The total dynamic head and desired pump capacity are applied to the pump curve to determine proper pump selection based on required electrical power input and optimum efficiency.

It is recommended that the sanitarian check the pump make and model number, horsepower, and pump capacity as listed on the Water Well and Pump Record to determine if adequately sized pumping equipment has been installed.

To determine proper pump size, locate the point on the pump curve where the pump capacity and total dynamic head intersect and select the pump which will provide the required capacity of water under the particular head conditions. If the point of intersection falls ***above*** the curve line, select the next highest pump size. An example pump curve is shown below.



TOTAL DYNAMIC HEAD PROBLEM

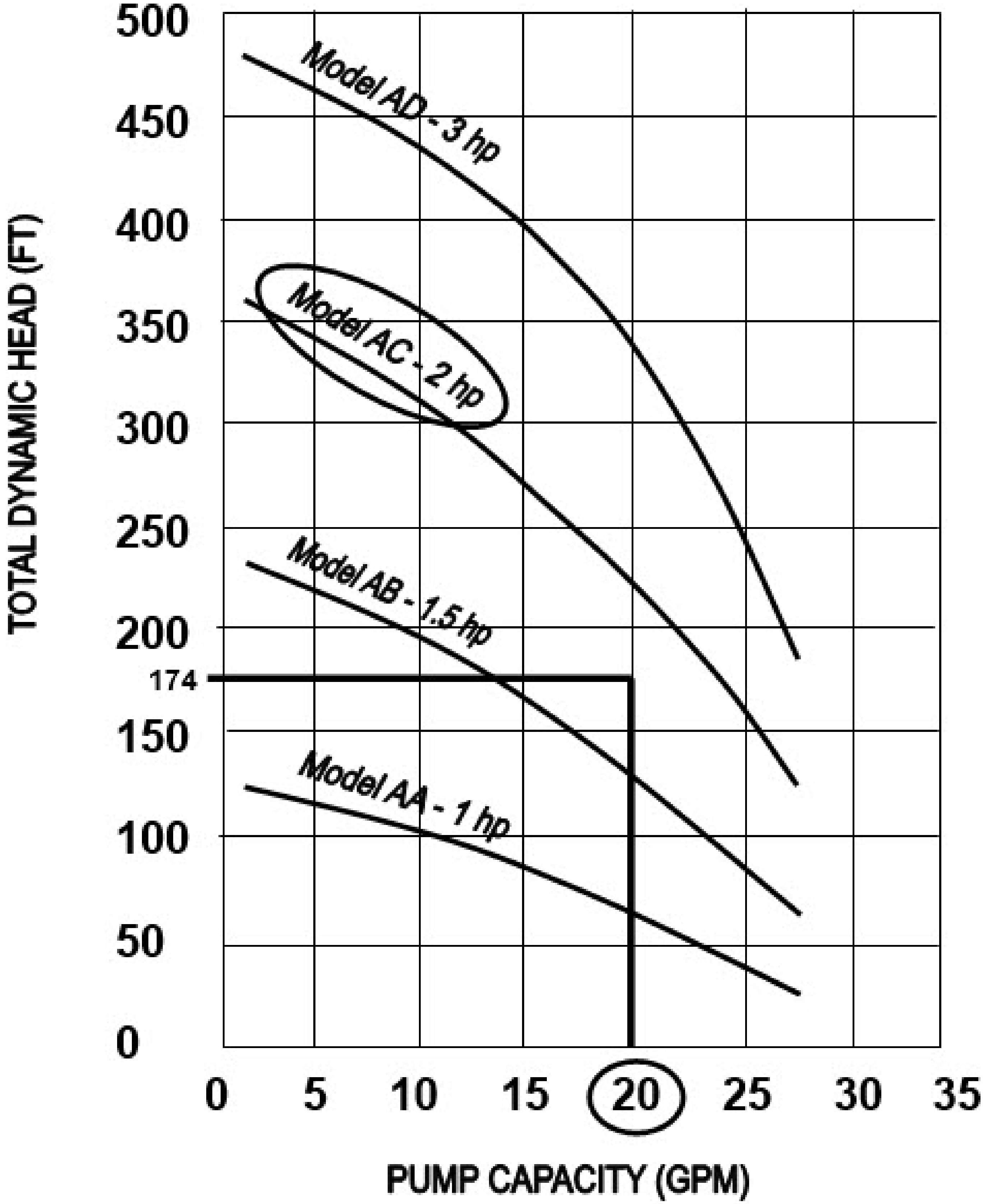


- WORKSHEET -
TOTAL DYNAMIC HEAD

DETERMINE ELEVATION HEAD		
1. Vertical feet from the pumping water level to the pressure tank.		ft.
DETERMINE FRICTION HEAD		
2. Pump capacity flow rate through pipe.		gpm
3. Diameter of water service line from well to the pressure tank.		in.
4. Material type of the water service line.		
5. Apply the answers to questions 2, 3 and 4 to a friction loss chart to find the friction head per 100 feet of water service line.		ft./100 ft.
6. Length of water service line.		ft.
7. Use the friction loss chart to determine the friction head for the water service line (multiply answers for 5 and 6).		ft.
8. Diameter of the drop pipe from the pump to the pitless adapter.		in.
9. Material of the drop pipe.		
10. Apply the answers to 2, 8, and 9 to a friction loss chart to find the friction head per 100 feet of pump drop pipe.		ft./100 ft.
11. Length of pump drop pipe.		ft.
12. Friction head for the water service line (multiply the answers for 10 and 11).		ft.
13. Total friction head.		ft.
DETERMINE PRESSURE HEAD		
14. Pressure switch pump cut-out setting.		psi
15. Determine the pressure head by converting the answer from 12 lbs. per square inch to feet of head by multiplying it by 2.31 ft./psi.		ft.
DETERMINE TOTAL DYNAMIC HEAD		
16. Determine TDH by adding answers to 1, 13, and 15.		ft.
17. Determine pump model from pump curve.		

- ANSWER -
TOTAL DYNAMIC HEAD

DETERMINE ELEVATION HEAD		
1. Vertical feet from the pumping water level to the pressure tank.	50	ft.
DETERMINE FRICTION HEAD		
2. Pump capacity flow rate through pipe.	20	gpm
3. Diameter of water service line from well to the pressure tank.	1.25	in.
4. Material type of the water service line.	plastic	
5. Apply the answers to questions 2, 3 and 4 to a friction loss chart to find the friction head per 100 feet of water service line.	6	ft./100 ft.
6. Length of water service line.	50	ft.
7. Use the friction loss chart to determine the friction head for the water service line (multiply answers for 5 and 6).	3	ft.
8. Diameter of the drop pipe from the pump to the pitless adapter.	1.25	in.
9. Material of the drop pipe.	plastic	
10. Apply the answers to 2, 8, and 9 to a friction loss chart to find the friction head per 100 feet of pump drop pipe.	6	ft./100 ft.
11. Length of pump drop pipe.	100	ft.
12. Friction head for the water service line (multiply the answers for 10 and 11).	6	ft.
13. Total friction head.	9	ft.
DETERMINE PRESSURE HEAD		
14. Pressure switch pump cut-out setting.	50	psi
15. Determine the pressure head by converting the answer from 12 from lbs. per square inch to feet of head by multiplying it by 2.31 ft./psi.	115	ft.
DETERMINE TOTAL DYNAMIC HEAD		
16. Determine TDH by adding answers to 1, 13, and 15.	174	ft.
17. Determine pump model from pump curve.	Model AC – 2hp	


500
450
400
350
300
250
200
174
150
100
50
0
TOTAL DYNAMIC HEAD (FT)
Model AD - 3 hp
Model AC - 2 hp
Model AB - 1.5 hp
Model AA - 1 hp
0
5
10
15
20
25
30
35
PUMP CAPACITY (GPM)

Determining Storage Capacity
The basic functions of a storage tank are to minimize wear of electrical starting components, increase pump life by preventing rapid stopping and starting (short cycling), and provide water under pressure for delivery between pump cycles. Generally, there is more friction to overcome, and therefore, more electrical energy is required for starting larger pumps as opposed to smaller. As a result, larger pumps should be allowed to operate for longer periods of time than smaller domestic pumps. In a properly designed system, the storage tank should be sized to insure a minimum pump running time consistent with the cycling rate recommended by the manufacturer. Where no cycling rate is specified, the below table may be used as a guide:

Gallons per Minute	Pump Running Time (Minute)
10-20	1
21-50	2
51-75	3
76-100	4

Bladder or Diaphragm Type Tank with Pre-charge
The available water capacity in gallons (drawdown) should equal or exceed the pump capacity times minimum pump running time. The available water in a pre-charge tank at a 30-50 psi setting is about 25 percent of the total tank volume. Figures on amounts of available water under various pressure settings can be obtained from the tank manufacturers' specifications.

> EXAMPLE
> 25 gpm x 2-minute running time = 50 gallons of available water
> Total volume (T) x 25 percent = 50 gallons
> T = 50 ÷ 0.25 = 200 gallons
> Total volume of bladder or diaphragm tank with pre-charge = 200 gallons

Conventional Steel Tank (no bladder or diaphragm) with Pre-charge
Available drawdown should equal or exceed the pump capacity times minimum pump running time. The available water in the steel tank with pre-charge with a 30-50 psi setting is about 20 percent of the total tank volume when the high water level is maintained at 55 percent of total capacity. *(Note:* If the high water level becomes greater than 55 percent, less usable capacity is available, i.e., at 70 percent, usable capacity is 13 percent and then the tank is becoming water logged).

> EXAMPLE
> 25 gpm x 2 min. running time = 50 gallons of available water
> Total volume (T) x 20 percent = 50 gallons.
> T = 50 ÷ .20 = 250 gallons
> Total volume of conventional steel tank with pre-charge = 250 gallons

Conventional Steel Tank with No Pre-Charge
Available drawdown should equal or exceed the pump capacity times minimum pump running time. The available water in the steel tank without pre-charge with a 30-50 psi setting is about 10 percent of the total tank volume.

EXAMPLE
25 gpm x 2-minute running time = 50 gallons of available water
Total volume (T) x 10 percent = 50 gallons
T = 50 ÷ 0.10 = 500 gallons
Total volume of conventional steel tank without pre-charge = 500 gallons

The examples given use 30-50 psi as the assumed pressure switch setting. Variations in system operating pressure and pre-charging of pressure tanks will alter the amount of available water (drawdown) from the pressure tank. Pre-charging of the tank increases the draw-off and increasing the operating pressure of the system decreases the tank drawdown. Operating pressure and tank pre-charge pressure must be taken into consideration when evaluating proposed storage facilities.

Constant Pressure Systems
Constant pressure (CP) technology for water well systems eliminate pressure fluctuations. Two methods are used to control the water pressure in CP systems: variable frequency drives (VFD), also known as variable speed pumps, and pressure control valves (PCV). A system using a VFD provides constant pressure over a fairly broad range of flow rates by electronically changing the speed of the motor as the water demand changes. The second means of furnishing CP is by installing a pressure control valve (PCV). PCVs are installed upstream of the pressure tank, between the pump and the pressure switch. They respond to downstream pressure by automatically opening or closing a valve to maintain system pressure. PCVs are used with standard submersible pumps that do not have variable speed motors.

VFDs and PCVs are designed to provide consistent pressure to the building occupants and eliminate pressure fluctuations that occur with a conventional system. CP system manufacturers advertise that they provide steady "city-like" water pressure, which does not fluctuate as in a conventional water well system. Space limitations are minimized with the VFD pumps because a large pressure tank is not necessary to make the system work correctly. A much smaller pressure tank can be used to control a VFD system. A VFD system may also save on electrical costs by minimizing the number of starts and stops. Another VFD benefit is the reduction of water hammer.

Conventional pressure tank sizing methodology is not applicable to VFD systems, because the need to achieve a minimum pump run time (as with conventional fixed speed pumps) is not a concern. To determine appropriate pressure tank sizes for VFD systems follow the manufacturer’s installation specifications.

Pressure tank sizes are not reduced for PCV installations unless there is continuous water usage, such as community and large industry process water usage or irrigation systems that are using water continually. Therefore, the pump must be sized to meet the requisite peak demand/well capacity requirements and the pressure tank is sized to meet the pump manufacturers sizing requirements.

Some PCVs have internal check valves that violate State Well Code provisions. Product specifications should be checked to ensure that the particular PCV proposed to be used does not have a check valve and will comply with state regulations.

Chapter 5: WATER WELL DRILLING METHODS

There are several different types of drilling methods used in Michigan. This section covers the various well drilling methods.

Rotary

Rotary drilling is the most popular well drilling method in Michigan. Mud rotary is widely used in the Lower Peninsula where substantial overburden exists, while air rotary rigs are found primarily in the Upper Peninsula and the few high bedrock areas of Lower Michigan.

The principle of rotary drilling is based upon a rotating drill stem made of lengths of drill pipe about 15 feet long. A bit is attached to a heavy stabilizer or drill collar at the end of the column of drill pipe. The extra weight and larger outside diameter of the stabilizer just above the bit helps to maintain a straight drill hole. The drill stem is hollow and has a drilling fluid of either mud or air circulating down the drill stem out through the nozzles in the bit and up along the outside of the drill stem. The rotating action of the bit breaks up the material and the drilling fluid carries the cuttings to the surface where they settle out in a mud tank.

Several types of bits are available to the rotary driller. The bit most generally used in Michigan is the tri-cone roller bit. The type and number of cutting teeth on the bit cones vary depending upon the type of formations to be penetrated.

The upper end of the drill stem is attached to a kelly on a table drive rig and swivel which are mounted on a large mast. Hydraulic controls lower or raise the drill stem and operate the rotary motion. When a hole has been drilled the full length of the kelly, the drill stem is raised, the joint between the kelly and drill pipe is broken, and an additional length of drill pipe is added. The drive mechanism for the drilling operation is provided either at the rotary table (table drive) or at the swivel (top head drive). The rig also contains a cable called a casing line which is used to raise and lower sections of drill pipe and casing.

In rotary drilling, the borehole size is larger than the casing size. In drift formation, the entire hole is completed before casing is installed. In rock wells, the length of hole to be cased is drilled, the casing is installed, then the bit size is reduced, and the rock portion of the well is completed.

Mud rotary utilizes a drilling fluid of bentonite clay and water. The mud serves several purposes: (1) remove cuttings from the drill hole, (2) prevent collapse of the drill hole and reduce water loss to the formations by forming a filter cake on the borehole wall, (3) suspend cuttings when drilling is stopped, (4) cool and clean the drill stem and bit, and (5) lubricate bit bearings and mud pump parts. After the cuttings are allowed to settle in the mud tank, the mud is recirculated via a mud pump to the swivel at the top of the kelly, then down through the drill stem. The mud tank is usually rectangular in shape with a mud volume of 200-800 gallons and may contain several baffles to aid in separation of cuttings from the drilling mud before it enters the pump intake for recirculation. A device known as a sand separator may be used to further remove sands and other "parasites" from the drilling mud. Samples of cuttings may be obtained directly from the borehole before the fluid and cuttings spill into the mud tank.

Most larger rotary rigs have an air compressor to enable the contractor to also use air as the drilling fluid. The high velocity of the air as it exits the bit is sufficient to blow the cuttings away from the bit and carry them up to the surface where they settle out around the borehole. Air rotary is used primarily for drilling in consolidated (rock) formations. In rock wells with substantial overburden, mud will be used for drilling through the drift, and after the casing is set the drilling operation will be converted to air rotary for completion of the rock portion of the well. Clean water is often used for drilling the rock portion of the hole after setting the casing.

Air hammer drilling, sometimes referred to as down hole drilling, is used extensively in Michigan's hard rock areas. The bit used in this drilling method is essentially a pneumatic hammer operated at the end of the drill stem. Compressed air operates a piston which strikes the top of the bit at a very rapid rate. The cutting tips on the bit are made of tungsten-carbide which are extremely resistant to abrasion. The combined hammering and rotation of the bit results in penetration of hard rock at a rate faster than any other drilling method.

Reverse-circulation is another form of rotary drilling. It differs from conventional hydraulic rotary in that the drilling fluid travels in the opposite direction. The drilling fluid travels up the inside of the drill stem with cuttings, through the pump and is discharged into the settling pond or tank. After cuttings are settled, the drilling fluid flows into the borehole and down to the bit. The pressure of the fluid against the bore hole wall prevents caving. The few reverse-circulation drilling rigs found in Michigan are used primarily for drilling large diameter municipal, industrial, and irrigation wells.

Cable Tool

Cable tool drilling, also known as percussion drilling or spudding, is a widely used well drilling method in Michigan. Michigan has more cable tool rigs than any other type of drilling machine. Some rigs are a combination rotary-cable tool, enabling the operator to use the rotary along with the casing driving ability of the cable tool. Although it is a slower drilling method, the cable tool is less costly and simpler to operate than a rotary drill rig and is suitable for most geologic conditions.

The cable tool operates by raising and dropping a heavy drill string in the drill hole. The drill string, with bit on the bottom and rope socket (or swivel socket) on top, is suspended in the hole with a cable. The cable is threaded over the crown sheave located at the top of the mast, down to the walking beam, and onto the cable drum where it is stored. The up-and-down drilling action imparted to the drill stem and cable by the walking beam. The walking beam is pivoted at one end, has a cable sheave at the other end and is connected to the crank gear with a pitman. Rotation of the crank gear causes the walking beam to move up and down. Additional cables called sand lines or casing lines are used to raise and lower casing, bailers, plungers, or other tools.

The rhythmic raising and dropping of the bit loosen up sand or clay and breaks up rock into "cuttings" and mixes them with water added by the driller to form a slurry. The cuttings are then removed from the hole with a dart-valve bailer or other type of bailing device. Formation type is determined by visual inspection of cuttings from the bailer and the drilling contractor's knowledge of the rig's operation, such as the difficulty or ease of drilling the particular formation. The up-and-down motion combined with the left-lay cable and rope socket cause the drill stem and bit to rotate slightly on each vertical stroke. This rotation helps maintain drill hole roundness.

The portion of the drill hole above the bedrock must be cased to prevent caving. Casing is driven into the drill hole with the use of heavy drive clamps bolted onto the drill stem, while granular bentonite is maintained around the casing as it is driven. The drill stem is lowered into the casing until the drive clamps strike the top of the casing. The raising and dropping of the heavy drive clamps and drill stem drives the casing into the drill hole. Prior to driving, a drive shoe of hardened, tempered steel is attached to the bottom of the first length of casing to protect it from damage. The upper end of the casing is protected by inserting a temporary drive cap. The usual cable tool drilling operation involves drilling past the end of the casing, bailing the hole to remove cuttings, driving casing, cleaning the hole, then resuming drilling. Generally, a few feet of open hole is drilled beyond the casing before casing is driven. The driving, drilling, and bailing operations are repeated until the desired depth is reached.

In screened wells, the pull-back method is generally used. This involves driving casing to the bottom of the portion to be screened. A screen of smaller diameter than the casing is placed into the casing. The top end of the screen is fitted with a K-packer or other device which seals between the screen and casing. The screen is pushed to the bottom of the casing, then the casing is "bumped" up to expose the screen to the formation. The bailer is then used to begin development of the screen.

Auger

Continuous-flight, spiral auger well drilling rigs are found in those parts of western, central, and northern Lower Michigan where sand is the predominant glacial drift material. In some areas, augers are used to drill the upper portion of the well and then the well is completed with the cable tool method. In other areas of the state, augers are used to drill the entire well.

The auger method utilizes spiral augers, usually in 5-foot lengths. The auger stem is turned by a hydraulically-controlled rotary drive head. After drilling the length of an auger, the auger joint is broken, and another 5-foot section is added. Cuttings spiral their way up to the surface where they appear around the borehole, making formation identification relatively simple. If enough clay is present in the formation, the drillhole will remain open when augers are removed. Dry sands and other caving formations may be a problem for the auger driller and will occasionally result in the loss of long flights of augers. When the auger encounters saturated sand (the water bearing formation to be screened), drilling generally can be continued for a short distance but the hole will not remain open in the saturated formation when the augers are removed. The auger flight is then broken down and removed from the drillhole after drilling the depth of the well or when changing to another type of drilling operation.

Casing is then placed into the drillhole. Some driving of the casing may be necessary because of caving of portions of the drillhole or lack of straightness of the drilled hole. A drillable plug is generally placed in the end of the casing prior to placement in the drillhole. After placement of the casing, it is then filled with water and the screen driven out through the plug and exposed to the water bearing formation. Keeping the casing filled with water prevents heaving of sand into the casing when the plug is knocked out. Another method used by some drillers (but not recommended) is to thread the screen directly to the well casing, thereby installing the screen and casing in one operation. The well is then pumped to remove the fine material from around the screen and to determine if water quality and quantity are suitable.

Jetting

Jetting is a drilling method suited for the sandy areas of southwestern Michigan. Jetting remains a popular method for drilling small diameter wells due to its simplicity and inexpensive cost of equipment. Many of the portable, do-it-yourself drilling machines advertised in magazines utilize the jetting method.

Jetting and hollow-rod equipment are quite similar except that drilling water is pumped with the jetting method and the direction of water flow is opposite. The jetting method involves using a high velocity stream of water to break up the formation material and wash the cuttings away. A chisel-shaped bit with holes to serve as nozzles is attached to the end of a string of hollow drill pipe. Water pressure is provided to the nozzles by using a high-pressure pump. Water exits from the nozzles and loosens the material being drilled while keeping the bit clean. The bit is raised and lowered and rotated slightly to maintain a round hole. The cuttings are washed to the surface on the outside of the drill pipe and flow into a settling pit or tank. Cutting samples are easily obtained at this point. A 55-gallon drum is often used for this purpose. After cuttings are allowed to settle, the water is recirculated through the pump, swivel, drill pipe and down to the bit. Jetting can also be done without recirculation of the drilling water; however, a continuous supply of clean water must be available at the site.

The casing is usually installed as the drilling proceeds. A drive shoe is attached to the bottom end of the casing and a drive cap inserted in the top. A drive block clamped to the drill pipe is used to force the casing into the drill hole. The depth of the open hole drilled before casing is installed depends on the type of formation and whether bentonite has been added to the water as a drilling fluid to keep the hole open. The drilling/driving sequence is extremely time consuming in caving formations, especially at greater depths since the drill string must be disassembled and removed from the well before driving casing and must be reassembled before resuming drilling.

Hollow-Rod

Hollow-rod, sometimes referred to as the hydraulic-percussion drilling method, is used throughout Michigan's Lower Peninsula, with the largest concentration of hollow-rod rigs being found in the central and southern portion of the state. The hollow-rod is an old drilling method that can be time consuming in some situations but remains popular due to its simplicity and relatively low cost of equipment. Most hollow-rod wells are 2-inch diameter, but 4-inch casings are installed occasionally. This method is well suited for sand and soft clay formations with relatively few boulders. It can also be used for drilling rock wells, but progress is slowed considerably. Wells several hundred feet in depth have been completed by the hollow-rod method.

The drill string used in hollow-rod drilling is similar to that used in jetting, except that the chisel bit has a ball check valve in it. Water or a clay-water mixture is kept in the annular space between the drill rods and well casing to help prevent the uncased portion of the hole from collapsing. The water is supplied to the annulus by gravity intake from a small mud tank. A 55-gallon drum is often used as a settling tank.

Drilling is done by lifting and dropping the drill stem and bit. The drill pipe used has triple wall thickness to add weight to the drill string. The drill string is also rotated slightly by hand during each stroke to maintain a round drill hole. As the bit drops, the ball check opens, and mud and cuttings enter the hollow drill rods. On the upstroke, the check valve closes and keeps the cuttings in the drill rods.

Eventually the drill rods fill up and the slurry is discharged into the mud tank at the surface where the cuttings settle out. Samples of cuttings can easily be obtained from the mud tank. The continuous reciprocating drilling motion maintains circulation of the drilling fluid from the bit, up the drill rods to the mud tank, from the mud tank into the annulus, and down to the bit. The direction of flow is opposite that in the jetting operation and no pressure pump is required.

Casing is driven as drilling progresses by clamping a weighted drive block to the drill rods. When another length of casing is added, the drill rods must be disassembled and removed from the hole. The drill rods are then reassembled, casing is driven, the drive block is removed, and drilling is resumed. Close observation of formation samples and water/drilling fluid circulation by the drilling contractor is essential to determine when groundwater has been encountered. When water-bearing strata is reached, drilling fluid is usually lost to the formation. At this point, it is necessary to install a well screen, if in an unconsolidated formation, and begin the well development process. Hollow-rod rigs are equipped with walking beams; thus, a plunger is most generally used to develop the well.

Downhole Hammer

Use of the down hole air hammer with rotary equipment provides a combined percussion-rotary method that penetrates rapidly in consolidated formations. Test holes are usually 6 inch in diameter when using this method. In most cases, however, conventional water-based drilling fluids must be used with a roller bit when drilling through unconsolidated overburden above bedrock. Exceptions to this occur when an air hammer is used to drive the casing after materials are blown out of the casing or when the rig is equipped with a casing driver.

This method allows contractors to drill more wells and be able to drill them deeper and faster. Instead of using a mud pump, they use compressed air.

Dual Tube Rotary

In this method, the drill pipe and bit are joined and advanced simultaneously. The conventional top drive drills the open hole and the lower rotary drive is used to set casing without any requirement for casing hammers, under-reamers, or drilling mud. Advantages of this drilling method are the ability to drill in tough conditions, quicker penetration rates, straighter holes, and a large compressor is not needed because the lower drive operates on hydraulics.

Either air or water can be used as the drilling fluid in this modification of reverse circulation technique. There is usually no grinding of cuttings, and the drilling fluid, if not air, can be clear water.

Sonic

A sonic drill uses high frequency mechanical oscillations, developed in the special drill head, to transmit resonant vibrations and rotary power through the drill tooling to the drill bit. The operator controls the frequencies to suit the specific conditions of the geology. An air spring in the drill head isolates the vibrations from the rest of the rig. The vibrations fluidize the soil particles at the bit face, allowing fast and easy penetration in most geological formations including boulders and rock.

One of the main advantages of the sonic drill is its ability to produce continuous core samples of both unconsolidated and consolidated formations with detail and accuracy. The core samples can be analyzed to provide a precise and detailed stratigraphic profile of any overburden condition including dry or wet saturated sands and gravels, cobbles and boulders, clays, silts, and hard tills.

Directional

Directional drilling is the technique of drilling at an angle from the vertical by deflecting the drill bit. Directional wells are drilled for a number of reasons: to develop and offshore lease from one drilling platform; to reach a payzone beneath land where drilling cannot be done, e.g., beneath a railroad, cemetery or lake, or to drill around a blockage in an existing wellbore. A pilot hole is drilled under the natural feature and then backreamed to make the hole large enough to accommodate the pipe. Once the hole is large enough the pipe is pulled through the hole.

Hand Driving

Driven wells are common in many areas of Michigan, especially around lakes where groundwater may be close to the surface. Simple installation methods and the low cost of materials make them attractive to homeowners or cottage owners who wish to install their own water supplies. However, since the well point and casing are driven into the ground, soil conditions are a major factor in suitability of the site. The site must be generally sandy and free of boulders or bedrock to be suitable for a driven well. Hard clay, silt, and very fine sand are generally difficult to drive through.

The installation of a driven well often begins by augering a hole with a hand auger or posthole digger as far as possible. A drive point, consisting of a reinforced well screen with a steel point on the end, is coupled to a 5-foot length of galvanized casing. The most common casing size for driven wells is 1-1/4 inch inside diameter. A drive cap is placed on the top of the casing and a heavy weight is used to strike the top of the drive cap, driving the point into the ground. When the drive cap is driven close to the ground and driving cannot be continued, another length of casing is added, and driving is resumed. Special drive couplings are used to join sections of casing.

Hand driving is usually accomplished by using a weighted driver consisting of a 3- or 4-foot piece of 3-inch diameter pipe capped on the top end. Extra weight is placed in the top portion of the driver. The driver fits over the casing and is guided by it. Another type of driver has a steel rod on the bottom that slides into the casing through a hole in the drive cap. Raising and dropping the driver is done with the use of handles welded on the sides of the driver. The weighted driver may also be suspended from a tripod and tackle arrangement. The use of a sledgehammer for driving is not recommended since it may result in bent or broken casing from glancing blows.

As driving progresses, penetration becomes increasingly difficult due to friction between the drive point/casing and the soil. Depths beyond 40 feet become difficult when driving by hand. Driving a well is always a gamble since a boulder can easily damage the well point or completely stop the driving. When a driven well attempt is aborted, the casing and well point must often be left in the ground since retrieval is difficult without additional equipment.

A weighted string is used periodically during driving to determine if water has been encountered. When water has been reached, the string will come up wet. The well screen must then be developed to remove the fine material. This is accomplished by pumping and surging. A hand pump or shallow well jet pump may be used for development. Pumping and/or surging is continued until the water, which at first is full of sand and silt, runs clear. If an auger was used to start the hole, it is necessary to grout the annular space between the drillhole and casing. Bentonite or neat cement may be used for this purpose.

The major disadvantages of driven wells are as follows: (1) they are generally shallow, therefore more vulnerable to surface or near surface contamination; (2) the screens tend to encrust with carbonates at a faster rate due to their small diameter; and (3) their yield is limited (<10 gpm), since they can be pumped only with a shallow well jet pump or hand pump.

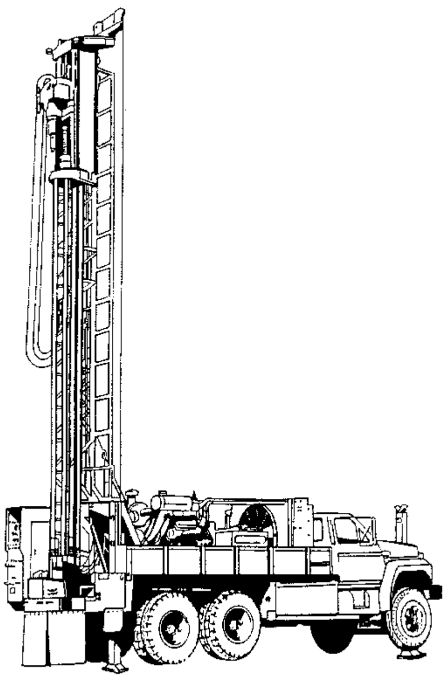
Comparison of Water Well Drilling Methods

	Cable Tool	Rotary	Auger	Hollow Rod	Jetting	Hand Driving
Other names	Percussion Spudding Churn Drill	Hydraulic rotary (mud rotary, air rotary, down hole hammer, reverse circulation)	Continuous-flight auger	Hydraulic-percussion	Jet-percussion	Driven well point, stab well
Drilling motion	Raising-dropping of drill stem and bit	Rotating drill string and bit	Rotating of augers and bit	Raising-dropping of drill rods and bit	Jetting action of water exiting bit	Well point and casing driven into ground to displace soil material
Drill string	Cable with suspended drill string (rope socket, drill stem, bit)	Swivel-kelly drill rods-stabilizer-bit (top head or table drive)	Top head drive-auger flights-bit	Swivel-drive block drill rods-bit	Swivel-drive block drill rods-bit	Drive cap-5-foot casing lengths drive point
Casing installation	As drilling proceeds	After drillhole is complete	After drillhole is complete	As drilling proceeds	As drilling proceeds	As driving proceeds
Casing installation method	Driven	Gravity (some driving)	Gravity (some driving)	Driven	Driven	Driven
Drilling fluid type	Water	Bentonite water (mud rotary), air (air rotary or down hole hammer), water (rev. rotary)	NA	Down annulus-up drill rods	Down drill rods-up annulus	NA
Direction of fluid flow	Stationary	Down drill rods-up annulus (opposite in rev. rotary)	NA	Down annulus-up drill rods	Down drill rods-up annulus	NA
Retrieval of cuttings	Bailer	Flow into mud pit with drilling fluid	Deposited on ground surface	Flow into mud pit with drilling fluid	Flow into mud pit with drilling fluid	NA

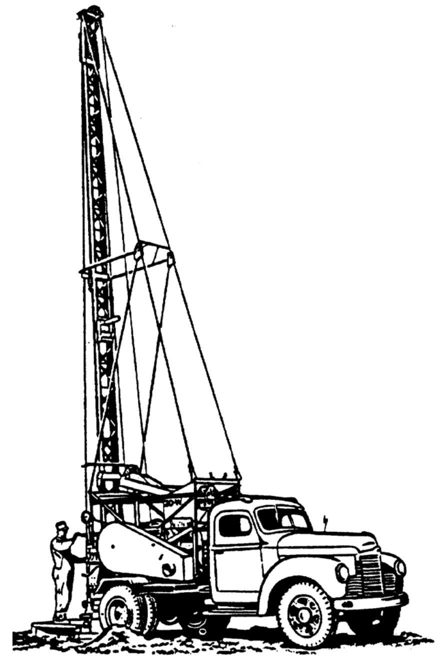
Advantages and Disadvantages of Common Drilling Methods

Drilling Method	Advantages	Disadvantages
Cable Tool	***Inexpensive Equipment:*** 1/5 cost of rotary rig, less grouting equipment needed, large water truck unnecessary, lower fuel consumption, lower operating cost. ***Limited Tooling Required:*** Bits can be resurfaced, less expensive tooling, used items readily available. ***Less Material Removed During Drilling:*** Generally, no oversized borehole, material removed from casing inside diameter, lighter soils can be bailed from casing. ***Repair Work:*** Cable tool rigs ideal for casing reaming, screen replacement, and development.	***Slow Drilling Speed:*** Bedrock drilling – 1/7 as fast as rotary drilling, Glacial drift drilling – 1/5 as fast as rotary drilling ***Depth Limitations with Single Casing String:*** Driving generally difficult in caving formations, ability to drive casing is limited by tool weight and ground friction. ***Outer Casing Needed for Gravel Packing or Full-Length Grouting:*** 3- to 4-inch larger casing needed to maintain annulus and must be extracted during grouting. ***Steel Casing Material Only:*** PVC casing cannot be used unless installed in an oversized borehole without driving.
Jetting and Hollow Rod	***Inexpensive Equipment:*** 1/5 cost of rotary rig, less grouting equipment needed, large water truck unnecessary, lower fuel consumption, lower operating cost. ***Limited Tooling Required*:** Bits can be resurfaced, less expensive tooling, used items readily available, many tools refabricated. ***Less Material Removed During Drilling:*** Generally, no oversized borehole, material removed from casing inside diameter. ***Repair Work:*** Jetting rigs ideal screen replacement and development.	***Slow Drilling Speed:*** Bedrock drilling – uncommon, requires heavy drill bar, 1/7 as fast as rotary drilling. Glacial drift drilling – 1/5 as fast as rotary drilling, limited use in gravel formations. ***Depth Limitations with Single Casing String:*** Driving generally difficult in caving formations, ability to drive casing is limited by tool weight and ground friction. ***Outer Casing Needed for Gravel Packing or Full-Length Grouting:*** 3- to 4-inch larger casing needed to maintain annulus and must be extracted during grouting. ***Steel Casing Material Only:*** PVC casing cannot be used unless installed in an oversized borehole without driving.

Rotary	***Speed of Drilling**:* 5 to 7 times faster than cable tool, capable of several hundred feet per day (dependent on geologic material). **Options of Well Design**: Screen can be telescoped or attached, separate screens can be installed, filter packing to enhance formation production, downhole casing hammer method. ***Grouting**:* Oversized borehole requires grouting of annular space surrounding casing, most adaptable to various grout placement methods, practical for grout placement through casing.	***Cost of Equipment**:* 5 times as costly as a cable tool or jetting rig, bit cost and tooling more expensive. ***Maintenance and Support**:* Much more extensive and costly than cable tool, higher fuel consumption, water truck needed.
Auger (Solid Stem and Hollow Stem)	***Speed of Drilling**:* Fast for shallow holes without cobbles or gravel and with low water table, auger/cable tool or jetting combination rigs are common ***Limited Equipment**:* Less expensive than rotary, minimal amount of equipment needed.	***Limited Depth**:* Poor results in caving formations, gravel, or high water table, less than 100 feet.



Rotary Rig



Cable Tool Rig

Chapter 6: WATER WELL COMPONENTS

This section covers the major water well components when installing a water well.

Borehole
Borehole is a vertical boring to reach the aquifer (water bearing geologic material). In a well terminating into rock, an open borehole will extend beyond the bottom of the well casing.

Well Seal or Well Cap
Well seal is a mechanical device to prevent contamination from entering the well casing that is installed after well completion. All well caps and seals shall be weathertight, tightly secured, and vermin proof.

Casing
Well casing is steel or plastic pipe installed to keep borehole wall from collapsing and houses the submersible pump and drop pipe.

Comparison of PVC Plastic Casing and Steel Casing:	
PVC	**Steel**
Noncorroding	Corrodes
Lower strength	Higher strength
Fewer water quality complaints	More water quality complaints
Rotary construction only	Suitable for any drilling method

Grout
Grout is impermeable cement or clay placed in annular space between borehole and casing to prevent well contamination, maintain separation of aquifers, and preserve artesian aquifers.

Filter Pack
Filter pack is silica sand often placed around the outside of the screen for filtration and stabilization. The main objective to filter packing is to install a material more permeable than the native formation into the area immediately surrounding the well screen. Filter pack not only prevents fine sands from entering the well screen but it also stabilizes the borehole.

Some of the benefits of filter packing are:

- Greater porosity
- Higher hydraulic conductivity
- Reduced entrance velocity
- Easier grouting
- Longer well life
- Reduced sand pumping

Packer
A neoprene packer (often called a K-packer) is a device that seals the space between the casing and telescoped screen to keep sand out of the well. The packer is attached directly to either the top of the well screen or the top of a riser pipe. Lead packers are no longer allowed in Michigan.

Screen
A well screen is a filtering device that serves as the intake portion of wells constructed in unconsolidated or semi consolidated aquifers. A screen permits water to enter the well from the saturated aquifer, prevents sediment from entering the well, and serves structurally to support the unconsolidated aquifer material.

Slot openings have been designated by numbers that correspond to the width of the openings in thousandths of an inch. A No.10 slot, for example, is an opening of 0.010 inch. For small-diameter screens covered with wire mesh, the number of openings in the mesh per inch are designated by gauze numbers.

Geological Material	Slot Size	Opening (inches)
Clay and Silt	-	0.003
Fine Sand	6 7 8 10	0.006 0.007 0.008 0.010
Medium Sand	12 15 18 20	0.012 0.015 0.018 0.020
Coarse Sand	25 35	0.025 0.035
Very Coarse Sand	50	0.050
Very Fine Gravel	90	0.090
Fine Gravel	150 250 375	0.150 0.250 0.375

When selecting the proper screen to install, the following selection criteria need to be considered:

- Maximize the percent of open area.
- Nonclogging openings
- Corrosive resistance
- Column and collapse strength
- Screen opening (slot size) based on aquifer material
- Screen diameter that provides a water entrance velocity of less than 0.1 foot/second

Fact or Fiction? – “*Doubling the well diameter appreciably increases well yield.”*

Answer
Doubling the well diameter increases the well yield **only 10 percent**.
Doubling the screen length increases the well yield **100 percent**.

TYPICAL MUD ROTARY WELL CONSTRUCTION SEQUENCE

1. Well drilling **rig** is set up
2. Drilling **fluid** is mixed
3. Oversized **borehole** is drilled
4. **Aquifer** is identified
5. Borehole is **flushed** free of cuttings

Drilling Borehole

6. **Casing** is installed
7. **Screen** is installed (if well terminates in drift formation)
8. **Filter pack** is installed (optional)
9. Annular space is **grouted** with bentonite or neat cement

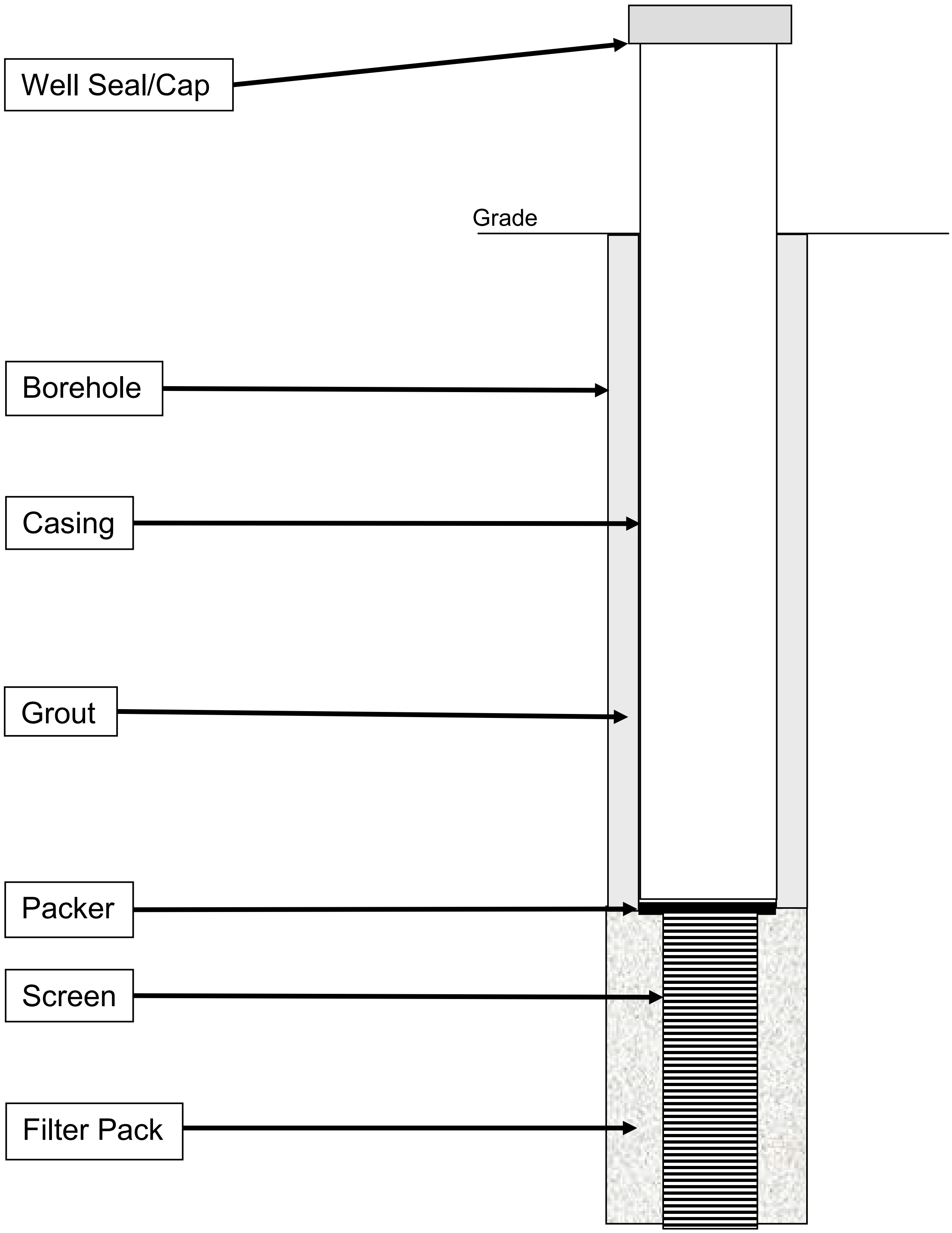
Installing Casing

10. Well is **developed**
11. **Yield** test is performed
12. Water **samples** are taken

Grouting Annular Space

TYPICAL WELL CROSS SECTION

NOTE: If the well terminated into bedrock, the packer, filter pack, and screen would not be present, and an open borehole would extend below the casing.



TYPES OF WATER WELLS

	DRILLED	DRIVEN	LARGE DIAMETER
Diameter	Most are 4 – 5 inch	1.25 – 2 inch	30 inch
Casing Material	Steel or PVC plastic	Steel only	Fiberglass
Termination	Drift (sand, gravel) or bedrock	Drift only	Drift only
Depth	125 feet. average	Less than 35 feet	Less than 100 feet, 50 feet average
Installation Method	Well drilling rig	Driven with sledgehammer or another weighted device	Bucket auger rig
Installed By	Water well contractor	Well owner	Water well contractor
Contamination Susceptibility	Most sanitary type	More susceptible to contamination than drilled wells	More sanitary than old dug (crock) wells
Other	Much more common than driven or large diameter wells	Common around lakes and high water table areas; limited yield of 7 gpm or less	Installed in very low yield areas; deviation required for installation; requires unique pitless adapter for corrugated casing

Drilled Well with PVC Casing

Drilled Well with Steel Casing

Augered Well
with Fiberglass Casing

DRILLING SITE EVALUATION

This outline was developed to aid the LHD sanitarian in conducting an evaluation during the construction of a water well. These are typically called Random Construction Inspections (RCI).

1. **Permits**
   a. Was a permit issued for the site?
   b. Were there any restrictions or conditions listed on the permit?
   c. Did the drilling contractor see the permit and is he aware of the permit conditions?

2. **Registration**
   a. Is the drilling contractor registered?
      1. Check EGLE directory of registered contractors.
      2. Contractor's registration card – in possession.
   b. Is the drilling rig registered?
      1. Check for current decals on both sides of rig.
      2. Check for contractor's registration number (or name) on both sides of rig.
      3. Rig registration card – should be present in rig.

3. **Drilling Site Location**
   a. Is the well location adequately isolated from sources of contamination and does location comply with permit conditions?
   b. Will the well be accessible for maintenance?
   c. Is the drilling site isolated from utility lines i.e., buried and overhead? Was MISS DIG contacted prior to drilling?

4. **Drilling Method**
   a. What type of drilling method is being used i.e., cable tool, rotary, auger, hollow rod, jetting, driving?

5. **Well Records**
   a. Is driller routinely checking cuttings samples?
   b. Is driller recording geologic information? (Check cuttings around site or in mud tank.)
   c. Record date, location, owner's name, contractor's name to check on well record submittal.

6. **Well Construction Details**
   a. Grouting
      1. What depth of grouting is required on this site?
      2. What type of grouting material will be used? (neat cement – bentonite)
      3. What water-to-grout ratio will the contractor use? (Is proper grout density achieved? Check with mud scale.)
      4. What grouting method will be used?
      5. Is the proposed grouting method consistent with the grouting material, drilling method, borehole size, etc.?
      6. Does the contractor have necessary grouting equipment (mixer, pump, grout pipe, hoses) and materials at the drilling site?
      7. Does grout material appear at surface when pumping grout through tremie pipe or down casing?
      8. Is grout placed around casing as it is being driven (cable tool, jetting, hollow rod)?

b. Well Casing

1. Is approved material being used? (steel or PVC plastic)
2. Check casing markings – (ASTM specifications., weight/feet, wall thickness, manufacturer, or supplier's name).
3. Are proper installation methods being used?

c. Well Screen

1. What type of screen is being used?
2. How is the screen installed?
3. What types of fittings will be used? (K-packer, washdown fittings, etc.)
4. What slot size will be used?
5. Filter pack used?

d. Drilling Water

1. Was drilling water obtained from an approved source?
2. Is drilling water chlorinated? (Check chlorine residual.)

e. Well Development

1. Which development method will be used (air, surge block, baler, plunger, water jetting, overpumping)?
2. Is final well capacity adequate for the intended use?
3. Is water free of sand and turbidity upon completion of development?

f. Well Disinfection

1. What disinfection method is used?
2. What type of disinfectant is used? (liquid bleach, granular chlorine, pelletized chlorine)
3. Check final chlorine residual.

7. Pump and Pressure Tank Installation

a. What type of pumping equipment is proposed? (submersible, jet pump, rod pump, hand pump)
b. How will the casing be terminated? (pitless adapter, well house, basement offset)
c. Is proposed pump size adequate to meet needs of facility?
d. Does proposed pressure tank have adequate drawdown?
e. Is plastic piping material approved for potable water usage and is pressure rating adequate?

8. Sanitary Procedures

a. Is the contractor using procedures that will reduce the introduction of bacteria or other undesirable substances into the water supply? (Removing excess pipe dope, using clean well screen and drop pipe, elevating pipes off of ground surface, using clean rags and gloves, disinfecting gravel pack material, etc.)

9. Abandoned Wells

a. Is there an abandoned well on the site that should be properly plugged?

Chapter 7: WELL GROUTING

Introduction

Grouting is the placement of a sealing material such as neat cement or bentonite into the annular space between a well casing and the borehole created during well construction. Grouting is an effective and necessary measure for the protection of public health and groundwater quality.

In some areas in Michigan bedrock either outcrops or is very close to the surface. Wells drilled in these areas are extremely vulnerable to contamination from surface water or near-surface water contamination. Proper grouting of the casing into the bedrock to a point below the upper fractured zone prevents contaminants from flowing into the well.

It should be understood that no single grouting method or material is suitable for all well installations in Michigan. Since geological conditions and drilling methods used in Michigan vary greatly, well drilling contractors must develop procedures specific to their operation while still meeting the intent of the grouting regulations.

Grouting with neat cement is required in areas where bedrock is close to the surface (less than 25 feet from surface) and in situations where upper bedrock formations produce water of unsuitable quality. Wells constructed with methods that produce a borehole larger than the casing (rotary, spiral auger, bored) must be grouted from the bottom of the annular space to the ground surface. Driven wells or those drilled by cable tool or hollow rod, where the casing is driven into the smaller diameter borehole, should be grouted by placing dry granular bentonite around the well casing as it is being driven. In some instances (e.g., drilling through a known contaminated formation using cable tool or similar methods) it is necessary to install a larger temporary conductor pipe, which will be removed during the grouting operation.

Purpose of Grouting

- ✓ Provides sanitary protection for the water supply from surface or near-surface contamination sources.
- ✓ Protects the water bearing formation by preventing movement of water between aquifers.
- ✓ Seals off a formation which is known to have been contaminated or which produces water of undesirable quality.
- ✓ Preserves the hydraulic characteristics of the aquifer and provides a seal against loss of artesian pressure.
- ✓ Increases the life of the well casing by protecting it from corrosion in areas of acid soils or where other corrosive conditions exist.
- ✓ Provides structural support for casing when neat cement is used for grouting PVC plastic well casing.

EGLE has identified several cases where improper grouting or lack of grouting in both consolidated and unconsolidated formations is suspected of causing leakage of contaminants downward along the well casing into potable water aquifers.

Grouting Rules

The rules which govern the grouting of residential water wells in Michigan are contained in the Ground Water Quality Control Act, Part 127 of Act 368, P.A. 1978, as amended, and rules (originally Act 294, P.A. 1965). The current grouting regulations have been in effect in Michigan since 1994.

Rules 101 – 106 (definitions)

Grouting means the placement of grout into the annular space that surrounds a permanent casing for the purpose of sealing the annular space to prevent the entrance or migration of surface water, near surface water, and contaminants to the groundwater and to maintain the natural protection of aquifers.

Grout means a material that has a low permeability, such as neat cement, bentonite grout, bentonite chips, bentonite pellets, granular bentonite, or other materials which has equivalent sealing properties and which are approved in writing by the health department before use.

Bentonite Grout means a slurry which consists of bentonite and water and which has a high solids concentration and a minimum density that meets specifications approved by the department. A slurry of drilling fluid bentonite and water or drilled cuttings, either singularly or in combination, is not bentonite grout.

Concrete Grout means a mixture of cement, sand, and water in the proportion of 1 bag of cement (94 lbs.), an equal volume (1 cubic foot) of dry sand and gravel aggregate, and not more than 6 gallons of clean water.

Neat Cement means a mixture of 1 bag of Portland or Portland Limestone cement (94 lbs.) and not more than 6 gallons of fresh water. Drilling fluid bentonite that is not more than 5 percent by weight of cement and additional water that is not more than 0.6 gallons for each 1 percent of bentonite may be added to neat cement. Other additives and admixtures shall be approved by the department before use.

Rule 133a Construction of wells; grouting

- No devices to suspend grout.
- No inducing collapse of the borehole wall.
- Grout from bottom to top in a continuous operation.
- Density of grout shall be consistent.
- Borehole shall be at least 2 inches larger than the casing size.
- Borehole shall be at least 2-7/8 inches larger than the casing when a grout pipe outside the casing is used.
- An annular space between a permanent casing and temporary casing shall be grouted during temporary casing removal by pumping neat cement or bentonite grout, or by pouring bentonite chips, bentonite pellets, or granular bentonite, into the annular space. Granular bentonite shall not be poured into an annular space that contains drilling fluid or water.
- Neat cement shall be allowed to set a minimum of 24 hours. If bentonite is added, the grout shall set a minimum of 48 hours.

Rule 134a Oversized borehole

- Grout the entire length of the casing for a standard well installation.
- Grout not less than 10 feet above the top of the screen in a gravel-pack well to the level of the pitless adapter.
- The depth of grouting may be increased or decreased by the health officer.

Rule 135 Driven casing

- Maintain dry granular bentonite around the permanent well casing at all times that it is being driven.
- Where a temporary casing or temporary borehole is used, the borehole or temporary casing shall be at least 3 inches larger than the permanent casing and extend not less than 25 feet below the ground surface or into a confining layer identified by the health officer. Grouting of the annular space between the permanent casing and the temporary casing or borehole shall comply with the provisions of Rule 133a.

Rule 137 Bedrock wells

- Where bedrock is encountered within 25 feet of the ground surface, an oversized borehole shall be drilled, and the casing shall be grouted with neat cement for a minimum depth of 25 feet.

Rule 137a Verification of well grouting

Contractor may be asked to excavate the well head for inspection if:

- Visible open annular space
- Failure to detect grout 2 feet or more below the water service line
- Dye detected in the well water after testing
- Well log indicates that the well has not been grouted or lacks information or contains incomplete information

Rule 138 Flowing artesian wells

Shall be grouted to:

- Protect the artesian aquifer from loss of artesian head
- Prevent erosion of the borehole or the area in the vicinity of the well
- Confine the flow to within the casing

Grouting Public Water Supplies

Grouting of public water supplies is addressed in Act 399 by Rule 822, which states, "All wells that serve public water supplies shall be grouted by a method approved by the department to obtain a tight bond between the well casing and the undisturbed natural earth formations, thus preventing the entrance of any surface water or near surface contaminants to the groundwater source."

EGLE has a policy for "Grouting of Community Water Supply Wells" available on the EGLE website.

Grouting Materials
Neat cement and bentonite are the two main materials used for making grout slurries.

Portland Cement, ASTM Type I or API Class A and B – Portland cement is a mixture of lime, alumina, magnesia, and sulfur trioxide. The components are combined and heated, and the resulting "clinker' is ground up and mixed with gypsum to make various types of cement. Type I cement is used in neat cement grout and concrete grout mixtures. Neat cement slurry is superior to bentonite as a grouting material in high bedrock situations, especially fractured limestone. It forms a hard rock-like seal around the casing which will not wash out from groundwater flow in the formation. A curing time of 24 hours is required before resuming drilling.

As the water to cement ratio increases, the compressive strength of the cement will decrease and shrinkage during curing and permeability of the cement will increase. When cement is mixed with water, a number of chemical reactions take place. As the mixture cures and changes from a liquid to a solid, heat is given off. This is referred to as the "heat of hydration" and will result in an increase of the temperature of the casing and the surrounding soil. The amount of heat given off is dependent upon several factors, such as cement composition, use of additives, and thickness of the grout envelope. The American Petroleum Institute (API) recommends a water to cement ratio of 0.46 by weight or 5.2 gallons of water per 94 lbs. sack of cement (5.2 gallons of water x 8.33 lbs./gallons = 43.3 lbs. divided by 94 lbs. of cement = 0.46).

The maximum recommended water to cement ratio for neat cement is 0.53, or 6 gallons of water per 94 lbs. sack of cement. Under certain conditions it may be necessary for the well drilling contractor, consulting engineer, or regulatory agency to increase the amount of water used in the grout mixture. Factors, such as temperature, type of geologic formations, extent of fracturing, use of additives, and water quality, will affect performance of the grout material and should be considered when planning the grouting operation.

Portland Cement ASTM Type III or API Class C – This is referred to as high-early strength cement. The cement clinker is finely ground to provide smaller particle size than Type I cement. This increases surface area and provides high-early strength with a faster curing rate. A 24-hour curing time is required before resuming drilling when using either of these. For Class C cement, API recommends a water to cement ratio of 0.56, or 6.3 gallons of water per sack. For Type III cement, the water to cement ratio may range from 0.53 (6 gallons/sack) to 0.62 (7 gallons/sack). Bentonite is commonly used as an additive (1-2 percent) with these types of cement. The amount of water necessary to hydrate the slurry properly increases with addition of bentonite.

Portland Limestone Cement, ASTM Type IL – Portland Limestone Cement is a binary blended product consisting of Portland cement and limestone. Portland cement meeting the specification of the products listed above are considered suitable for use in Type IL. Limestone content for the material is documented as more than 5 percent but less than or equal to 15 percent by mass of the blended cement. Type IL cement is considered the replacement for Type I and used in neat cement grout and concrete grout mixtures.

Bentonite – Sodium bentonite is the principle ingredient in drilling mud or fluid used in rotary drilling. It is hydrous silicate of alumina and is comprised mainly of the clay mineral montmorillonite. The suitability of sodium bentonite as a grouting material comes from its ability to swell up to 15 times its dry volume when hydrated. It will maintain a gel-like seal around the casing if moisture is retained. Natural clays found in Michigan generally do not have the swelling properties to make them suitable as grouting material. Most bentonite used in the drilling industry is mined in the western United

States. Bentonite used in Michigan shall be at least 85 percent montmorillonite and meet API specifications standard 13A. A slurry consisting of bentonite and water may be used as a grouting material if it has a minimum weight of 9.4 lbs./gallon. Field experience has shown that settling of solids frequently occurs, resulting in an open upper annulus and need for the well drilling contractor to regrout.

Bentonite products have been marketed that are specifically designed for grouting. These grouts have a solids content of over 20 percent by weight and settling problems are greatly reduced. Therefore, these high solids bentonite grouts are recommended. Slurry weight of 9.4 lbs./gallon as measured with a mud scale is required. Bentonite grouts should not be used in some porous formations, such as fractured limestone, where the bentonite may be washed away from the casing due to excessive groundwater movement.

Cement Grout Additives

Bentonite

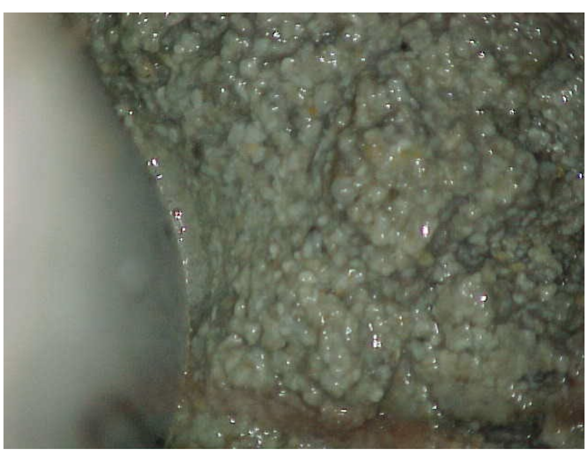
This is added to cement to increase set volume, reduce shrinkage, decrease density, and decrease water loss from the cement. Up to 5 percent bentonite by weight may be added to cement slurries, although 1-2 percent is the more commonly used, preferred amount.

Accelerators

Calcium chloride ($CaCl_2$) is added to cement to speed up the setting time and increase early strength. Two percent $CaCl_2$ by volume added to cement will result in a compressive strength after 24 hours approximately equal to that of cement without $CaCl_2$ after 48 hours. Calcium chloride is useful when grouting in cold weather since it will speed cement curing. The use of $CaCl_2$ or other accelerators should be avoided when PVC well casing is used. The more rapid hydration of the cement will also be reflected in a rapid increase in temperature of the cement. This may result in deformation of plastic well casing.

Retarders

Cement setting times can be slowed with retarders. Cement retarders control the time when a slurry will set hard, keeping the slurry viscous and pumpable in expected borehole temperatures and for the time required to place the slurry. Retarders allow water well contractors to better predict thickening times by decreasing the rate of cement hydration.



Bentonite Pumped into Annulus

Bentonite Return at Surface

Properties of Common Grouting/Plugging Materials

MATERIAL	DESCRIPTION	ATTRIBUTES
Type I Cement	General purpose cement	No longer a common cement. Midwest manufacturers are no longer producing bagged Type I cement. Type IL is the alternative offered by manufacturers.
Type III Cement	High early strength.	Not a common cement. Ground to finer particle size which increases surface area and provides faster curing rate.
Type IV Cement	Low heat of hydration.	Not a common cement. Used where the rate and amount of heat generated by cement must be kept to a minimum. Develops strength at a slower rate than Type I.
Type K Cement	Expansive cement.	Not a common cement. Basically, Type I cement with additives to provide for rapid expansion. "Type K Komponent" is used for plugging abandoned wells.
Concrete	Neat cement with sand added. Fifty percent sand by weight.	Less costly than neat cement. Provides a good seal. May not be poured from the surface through standing water due to separation problems. Can cause excessive pump wear.
Type IL Cement	Most common type of cement used for grouting/plugging.	Forms good seal. Easier to mix and pump than bentonite. Required as grout where bedrock is encountered within 25 feet of the surface and for plugging all wells terminated in bedrock. Same cementitious qualities as Type I.
Bentonite Powder	Contain mixtures of sodium and calcium bentonite with other clays.	Drilling "gel." Various forms used in Michigan as the main component of most drilling muds.
Bentonite Granular	Raw mined and particles are coarse granular (8 mesh is usual).	Intended for slurry applications to grout or plug wells. Low permeability. Slower water absorption and delayed swelling in comparison to powdered bentonite.
Bentonite Chips	Large particle versions of granular products (0.25-0.75 inch).	Intended to be poured into a borehole or casing for plugging. Chips hydrate in place and swell to form a low permeability, highly stable seal. Water needs to be added above the water table.
Bentonite Pellets	Powdered bentonite compressed into a pellet (0.25-0.75 inch).	Uniform in size. Same application as bentonite chips. Bridges easier and are more expensive than chips.

Water Well Grouting Materials Specifications

PRODUCT	WATER RATIO	WEIGHT/GALLON
Neat Cement	6.0 gallons max/sack of cement	15.0 lbs.
	5.2 gallons recommended/sack of cement	15.6 lbs.
Neat Cement and 1 percent Bentonite	6.0 gallons max/sack of cement	15.0 lbs.
Neat Cement and 2 percent Bentonite	6.5 gallons max/ sack of cement	14.7 lbs.
Neat Cement and 3 percent Bentonite	7.15 gallons max/sack of cement	14.4 lbs.
Neat Cement and 4 percent Bentonite	7.8 gallons max/sack of cement	14.1 lbs.
Neat Cement and 5 percent Bentonite	8.5 gallons max/sack of cement	13.8 lbs.
Neat Cement and CaCl (accelerator)	6.0 gallons max/sack of cement CaCl – 2 to 4 lbs./sack of cement	15.0 lbs.
Bentonite	Refer to the manufacturer’s specifications for water ratios and weights.	
Concrete	1 sack of cement and an equal volume of sand per maximum 6 gallons water	17.5 lbs.

Weighing Neat Cement

Grouting Methods
Most water well grouting methods were developed by the oil well drilling industry. As water well drillers and public health officials became aware of the benefits of grouting, oil well grouting techniques were adapted for the water well industry. Several firms specializing in oil and gas well cementing can provide assistance to the water well driller when a large volume of cement grout is required.

Grout slurries must be placed into the annular space from the bottom of the zone to be sealed, upward to the surface in one continuous operation. Pouring grout directly into the annulus from the surface is not approved since it may result in bridging and prevent the grout from reaching the bottom. Several methods discussed below will provide for placement of grout from the bottom of the annular space.

Cement grout must be adequately mixed and free of lumps prior to placement. Equipment to be used for mixing grout may range from a wheelbarrow and shovel to specially designed hoppers and jet-type mixing pumps. The grouting method and amount of grout required for a particular job will dictate the type of equipment to be used. Pumping equipment must be able to handle a viscous slurry, develop high pressures (100-300 psi), and have an adequate capacity. Diaphragm, piston, worm gear, or helical type pumps are best suited for pumping cement slurries, but heavy duty open-vane centrifugal pumps can also be used under some conditions.

It is important that the drilling contractor demonstrate complete organization in his grouting procedure. A successful grouting job requires a sequence of events to occur without mechanical failure of cement mixing and pumping equipment. The contractor must also be prepared by having enough cement on site to complete the grouting without interruption and enough water for grout mixing and cleanup.

Centering guides should be used on the casing to assure centering of the casing within the borehole and complete encasement within the grout envelope. Prior to placement of the grout, the annular space should be checked to make sure that bridging or caving of material from the borehole wall has not occurred. When cement is used as a grouting material, adequate time must be allowed for cement curing prior to resuming drilling operations.

The following grouting methods are visually shown in the Well Construction Code book.

Displacement Method – In this method a borehole at least 2 inches larger than the nominal casing size is drilled. In caving formations, a temporary conductor casing (or surface casing) is installed to keep the borehole open during the grouting operation. The estimated volume of grout required is placed directly into the bottom of the borehole by shoveling, pouring or the use of a dump bailer after the temporary surface casing is in place. The permanent casing with a drillable plug (a wooden plug is often used) is lowered into the borehole to displace the grout. The plug also prevents grout from entering the inside of the permanent casing. In some cases, the weight of the casing alone is not sufficient to displace the grout and the casing must be filled with water and forced into the hole by the pull-down mechanism on the rig. As the casing is lowered, the grout moves up the annular space from the bottom of the borehole toward the surface. The surface casing is removed promptly to expose the grout to the borehole wall. After the required curing time, the plug is drilled out and the drilling operations resume. This is one of the simplest grouting methods and is suitable for situations where the bottom of the borehole can be visually inspected prior to grouting (25-40 feet deep) and where little or no water is present in the borehole.

Grout Pipe Method (Gravity) – In this method the grout is placed in the annular space by gravity through a funnel attached to a grout pipe (or tremie) that is suspended in the annular space. A 1 inch or 1-1/4 inch rigid pipe is used as the grout pipe. The borehole diameter must be large enough to accommodate the grout pipe. A 2-inch or larger annular space will usually be sufficient, which requires a borehole that is 4-5 inches larger than nominal size of the casing. The use of welded casing aids in providing maximum annular space for grouting. The grout pipe is extended down between the permanent casing and conductor casing. The grout is placed through the funnel and tremie in one continuous operation, beginning at the bottom of the zone being sealed. The bottom end of the grout pipe should be kept full of grout and remain submerged in grout during the operation. The grout pipe is gradually withdrawn as the grout fills the annular space. This is accomplished by disjointing it in typically 10-foot sections. The conductor pipe should be removed as the grout is being placed in the annulus. Grout should be added until it appears at ground surface. Where a pitless adapter is to be installed, grout may be terminated a few feet below surface. Drilling is resumed after curing of the cement.

Grout Pipe/External Placement Method (Pumping) – This is the most commonly used grouting method. The same procedure as described above is followed except that the grouting material is placed in the annulus with the aid of a grout pump rather than by gravity flow alone. Screening the cement before it is placed into the mixing hopper will help to prevent clogs and interruption of the grout pumping procedure. The grouting procedure begins with the tremie pipe being lowered to the bottom of the annulus. As the grout material is placed by pumping, the tremie pipe should be sequentially raised to prevent it from becoming stuck in the annulus. Typically, thin cement grout appears initially at the surface. Grouting may stop when consistently thick cement grout is observed. A grout scale is useful in determining adequacy of the grout weight. A slurry of neat cement grout mixed at a ratio of 6 gallons of water to one 94 lbs. sack of Portland or Portland Limestone cement will weigh approximately 15 lbs. per gallon.

Pressure Cap Method – In this method, the grout is placed through a grout pipe that is inside the permanent casing. An airtight pressure cap is placed in top of the casing with the grout pipe extending through it to the bottom of the casing. The casing is suspended off the bottom of the borehole. A valve on the pressure cap allows water or drilling mud to be circulated down the grout pipe and out through the pressure cap, filling the casing and annulus. The valve is then closed to keep the casing filled with water or drilling mud, without an interruption in pumping, cement is substituted for water or drilling mud and is injected down the grout pipe until the grout appears at the surface. The water or mud in the casing prevents the grout from entering the open casing bottom. After the grout appears at the surface, just enough water or mud is pumped through the grout pipe to flush cement from it. The grout pipe is then pulled back through the pressure cap to raise the end out of the cement and prevent it from being cemented in. Pressure is maintained in the well casing until the grout has cured. Drilling is resumed after the required setting time.

Grout Shoe Method – This method involves pumping the grout through a grout pipe inside the casing, which is fitted with a drillable cementing shoe (or float shoe) and raised above the bottom of the borehole. The cementing shoe has a backpressure valve, which prevents grout from backing up into the casing when the grout pipe is removed. The grout is forced around the bottom of the casing and upward in the annular space until it appears at the surface. The grout pipe is then detached from the cementing shoe and raised to the surface. After the required setting time, the cementing shoe is drilled out and the work on the well continued.

Displacement Plug Method – This method involves pumping the grout directly down the permanent well casing, which is raised off the bottom of the borehole. Grout is forced upward in the annular space to the surface and displaces drilling mud or water that has been circulated prior to grouting. The volume of grout required for the job is pumped into the casing. A displacement plug (or separator plug) is placed on top of the grout column in the casing. The plug is made of a drillable material such as plastic, rubber or wood. A measured volume of water equal to the volume of the casing is pumped into the casing, forcing the plug to the bottom of the casing, and expelling the grout into the annular space. Pumping continues until grout appears at the surface. The water in the casing is maintained under pressure until the cement has set. In this method, a zone of weak cement may exist at the interface of the grout and drilling mud if all of the drilling mud is not wasted at the surface. However, upon completion this zone will be located at the upper end of the annulus rather than at the critical location at the bottom of the casing. If additional grout is added, this weak cement may be pumped onto the ground surface. In this method, it is critical that volumes of grout and displacement water be accurate.

Calculating Grout Volume
The table below may be used to estimate the total volume of grout slurry required to fill the annular space between the permanent well casing and the borehole. The bags of grout required can be determined by dividing volume listed in the table below by the grout manufacturers suggested yield per bag. Be sure the yield per bag is in cubic feet for this calculation. If not, recall that 1 cubic foot of water = 7.48 gallons. An amount equal to 20 percent of the calculated volume may have to be added to allow for borehole irregularities.

ANNUAL SPACE VOLUME (Cubic Feet) DIAMETER IN INCHES											
WEL CASING DEPTH IN FEET	CASING	2	2	4	4	5	5	6	6	6	8	8
	HOLE	4	6	6	8	8	10	8	10	12	10	12
	25	1.4	4.1	2.1	6.0	4.5	9.4	2.7	7.6	12.6	3.5	9.5
	50	2.8	8.3	4.3	11.9	9.0	18.8	5.5	15.3	27.3	7.0	19.0
	75	4.2	12.4	6.4	17.9	13.5	28.2	8.2	22.9	40.9	10.5	28.5
	100	5.6	16.5	8.6	23.8	18.0	37.6	11.0	30.6	54.6	14.0	37.9
	125	7.2	20.7	10.8	29.8	22.5	47.1	13.7	38.3	68.2	17.5	47.4
	150	8.5	24.8	12.9	35.8	27.0	56.5	16.4	45.9	81.8	20.9	56.9
	175	9.9	29.0	15.1	41.8	31.5	65.9	19.2	53.6	95.5	24.4	66.4
	200	11.3	33.1	17.2	47.7	36.0	75.3	21.9	61.2	109.1	27.9	75.9

Grouting Wells – Neat Cement Requirements

The table chart may be used for estimating the number of bags of cement required for grouting the annular space between the permanent well casing and the borehole. These figures are based on a mixture of one bag (94 lbs.) of cement to 6.0 gallons of clean water, which yields a volume of 1.28 cubic feet. The quantity of cement is calculated for a clean borehole. It is a common practice to add an amount equal to 20 percent of the calculated volume to allow for borehole irregularities and severely fractured formations.

NEAT CEMENT VOLUME
NUMBER OF BAGS OF CEMENT
(Based on 6 gallons of water per bag of cement that yields 1.28 cubic feet or 9.5 gallons)

CASING	2	2	2	4	4	4	5	5	5	6	6	6	8	8	8
HOLE	4	5	6	6	7	8	7	8	9	8	9	10	10	11	12
25	1.1	2.1	3.3	1.7	3.1	4.7	2.0	3.5	5.4	2.2	4.0	6.0	2.7	5.0	7.5
30	1.3	2.5	3.9	2.0	3.6	5.6	2.4	4.2	6.5	2.6	4.8	7.2	3.3	6.0	9.0
40	1.8	3.2	5.2	2.7	4.9	7.5	3.2	5.6	8.7	3.5	6.4	9.6	4.4	8.0	12.0
50	2.2	4.1	6.5	3.4	6.2	9.4	4.0	7.0	10.9	4.3	8.0	12.0	5.5	10.0	14.9
60	2.7	5.0	7.8	4.1	7.4	11.3	4.8	8.4	13.1	5.2	9.6	14.5	6.6	12.0	17.9
70	3.1	5.8	9.1	4.7	8.6	13.2	5.6	9.9	15.3	6.0	11.2	16.9	7.7	14.0	20.9
80	3.6	6.6	10.4	5.4	9.9	15.0	6.4	11.3	17.4	6.9	12.3	19.3	8.8	16.0	23.9
90	4.0	7.5	11.7	6.1	11.1	16.9	7.2	12.7	19.6	7.8	14.3	21.7	9.9	18.0	26.9
100	4.4	8.3	13.0	6.8	12.3	18.8	8.1	14.1	21.8	8.6	15.9	24.1	11.0	20.0	29.9
120	5.4	10.0	15.6	8.1	14.8	22.5	9.7	16.9	26.2	10.4	19.1	28.9	13.2	24.0	35.9
140	6.3	11.6	18.3	9.5	17.3	26.3	11.3	19.7	30.5	12.1	22.3	33.7	15.4	28.0	41.9
160	7.1	13.3	20.9	10.8	19.8	30.1	12.9	22.5	34.9	13.8	25.5	38.6	17.6	32.0	47.8
180	8.0	15.0	23.5	12.2	22.2	33.8	14.5	25.3	39.2	15.5	28.7	4..4	19.8	36.0	53.8
200	8.9	16.6	26.1	13.5	24.7	37.6	16.1	28.1	43.6	17.3	31.9	48.2	22.0	40.0	59.8
220	9.8	18.3	28.7	14.9	27.2	41.3	17.7	31.0	48.0	19.0	35.1	53.0	24.2	44.0	65.8
240	10.7	20.0	31.3	16.2	29.6	45.1	19.3	33.8	52.3	20.7	38.3	57.8	26.4	48.0	71.7
260	11.5	21.6	33.9	17.6	32.1	48.9	20.9	36.6	56.7	22.5	41.4	62.7	28.6	52.0	77.7
280	12.4	23.3	36.5	18.9	34.6	52.6	22.5	39.4	61.0	24.2	44.6	67.5	30.8	56.1	83.7
300	13.3	25.0	39.1	20.3	37.0	56.4	24.2	42.2	65.4	25.9	47.8	72.3	33.0	60.1	89.7

Evaluation of Well Grouting
Observed During Well Construction

1. What grouting method and material and mix recipe is being used? Is it in compliance with the Well Construction Code and any permit specifications?

2. Check for suitable grouting equipment (pump, mixer, grout pipe).

3. Determine volume of grout expected to complete the job. Allow for 15-20 percent loss to the formation. Is there enough grout on job site?

4. Use grout scale (mud balance) to weigh slurry before it is pumped into annulus. Grout scales may be obtained from the sources listed.

5. Observe grout return to surface. Initial return will be a thin, watery consistency. Once the slurry visibly appears like the slurry being pumped into the well, weigh the return to verify that the weight out equals the weight being pumped in.

6. Record the amount of grout used and other grouting-related details needed to complete grouting section of the water well drilling or plugging record.

Office Review of Water Well Record
When reviewing the section concerning grouting of the annulus on the water well record, the following may be indicators that the well has not been properly grouted:

1. The section has not been completed.
2. The section indicates that the annulus was not grouted as required by the Well Construction Code i.e., the entire casing length or to within 10 feet of the bottom of the casing for screened wells.
3. The number of bags of grout used is not sufficient to fill the estimated volume of the annulus. By calculating the volume of the annulus, and comparing that to the amount of grout used, a determination can be made as to whether or not a sufficient volume of grout was used to seal the annulus. The previous charts show annular space volumes and neat cement volume requirements. Bentonite grout volumes vary by manufacturer. If needed, LHDs should be able to calculate the annular space volume to determine if the amount of grout used was appropriate.

When an office review of a water well record discloses that a well may not have been properly grouted, investigate the violation by field inspection and/or consultation with the well drilling contractor, and order correction as needed.

Field Evaluation of Grouting Upon Well Completion
Two methods of the field evaluation of grouting are generally used: Visual Observation and Probing.

Visual Observation
The initial effectiveness of visual observation of grouting is limited to what can be observed at the ground surface. Any of the listed conditions may lead to the drilling contractor being required to excavate around the casing using a backhoe to allow more complete evaluation of the grout job. Some examples of visual observation include:

1. Look for the presence or absence of grout material laying on the ground surface in the vicinity of the well casing. During the grouting procedure, the well drilling contractor is required to pump the grout material to the bottom of the well using a grout pipe, force the

grout upward through the annulus and finish with the grout material appearing at the ground surface. The grouting procedure may stop when the consistency of the grout material at the ground surface is the same as the consistency of the grout material in the grout mixer i.e., pumped in equals flowing out. There often is thin or excess grout visible in the vicinity of the well when the driller is finished grouting. However, a visual evaluation can be limited in effectiveness if the area around the casing has been disturbed since the well was completed, such as when the pitless adapter was installed, when general site grading was conducted, or due to site clean-up in the area around the casing.

2. Soil collapse around the casing may indicate improper grouting. This may suggest that the annulus was not properly sealed and that soil from around the well casing may have collapsed into the open portion of the annulus.
3. Solution channels or washouts that are visible around the well casing may indicate problems with grouting. They suggest that surface water may be flowing downward around the outside of the well casing. The water may be flowing from the surface into a near surface aquifer or all the way down to the bottom of the well. In any case, borehole erosion can occur, resulting in a pathway for surface water-carried contaminants to get into the well.
4. You may be able to see unapproved grout materials in the vicinity of the well, such as bentonite slurry residue, when neat cement was required.
5. You may observe empty bags of an unapproved grout material left lying around the drilling site.
6. You may obtain information from the owner, neighbors, other contractors, or other persons who may have visually observed an improper grouting procedure. For example, the owner may relay to you that they observed the well drilling contractor shoveling cuttings into the annulus or pouring dry granular bentonite from the surface along the side of the well casing.


Grout Subsidence


Grout Subsidence

Use of Grout Probes

IMPORTANT: To reduce the risk of electrocution, it is recommended that probes be used for occasional field checks and to focus on wells that the LHD has reason to believe may not have been grouted. EGLE advises that probing be limited to installations where the pump has not yet been installed. Lock Out/Tag Out procedures, on the electrical box, pursuant under MIOSHA regulations must be followed when probing after the pump is installed.

Sanitarians are advised to use the following precautions when grout probing:

- Do not probe around wells located beneath overhead electrical lines.
- Have the property owner shut off the power to the submersible pump before you probe.
- Do not use excessive force when an obstruction is encountered. Obstructions are usually rocks, tree roots, pitless adapter clamps, or casing couplings, but you may also encounter electrical or gas lines.
- Use insulated handles on the augers or probes.
- Do not probe around flowing artesian wells. You may cause a break-out of flow around the outside of the casing.
- Use proper lifting techniques when pulling probes out of the hole to avoid back injury.

A small diameter, hollow-core soil probe with extensions is an effective tool for evaluating water well grouting after a well has been completed. Samples of the grouting material can be recovered for identification.

As part of normal well completion practice, grout will be removed from the upper few feet of a well casing during installation of the pitless adapter. We recommend that grouting evaluation begin about 2 feet below the pitless adapter/water service line connection. Taking normal excavation depths into account, you would not expect to find any grout above this level.

The grout probe is used to evaluate the presence of approved grout material, without damaging the seal provided by the grout.

Grout Probing Method

Probing should be done on the side of the casing away from the dwelling and offset 90 degrees from the electrical service connection. This will reduce the chances of hitting either the water service line or the electrical power supply wire. Probe carefully in the upper 4 feet until you have determined that you have gotten past these two potential danger/damage possibilities. Note that you may also encounter a pitless adapter U-bolt or a casing coupling within this zone. Once past this zone it is less likely that you will encounter hazards. It may take several tries to get the probe past the pitless adapter or casing couplings.

It may be advantageous to use a shovel, or a standard 4-inch diameter bucket soil auger to start the grout probe hole. This facilitates getting the end of the probe past the pitless adapter. However, be cautious to avoid cutting or wrapping the power supply electrical wires around the auger.

The probe is guided down along side of the well casing in a vertical position to a point below the pitless adapter. Once the probe is below the pitless adapter, it should be removed, and the probe barrel cleared of any soil material. The probe is then reinserted, and a sample of any material found below the pitless adapter is collected for evaluation. Again, clear the probe barrel, and reinsert the probe to obtain another sample. This process is continued until a good quality grout material has been located. Threaded extension pipes can be used to increase the depth of probing. When an open annulus or material with little resistance has been encountered, use caution when adding extensions to avoid losing the probe string down the hole.

Normally, once a good quality grout material has been found using the probe, it is not necessary to probe any deeper into the annulus. The probe is generally not extended more than 3 feet into the good quality grout material.

Where an open annular space exists or where drilling mud or cuttings were used to seal the annulus, the probe may fall freely or with little effort. Open annular spaces are frequently detected where grout slurries have failed, where formation materials have collapsed creating a bridge, or below bridged grout that was poured into the annulus from the surface.

Grout Material Evaluation
The following descriptions are useful for identifying grout samples collected with the soil probe:

Bentonite Grout – An acceptable bentonite grout seal will appear as a pliable clay with a gelatin, oatmeal, or peanut butter consistency, tan to gray in color. If granular bentonite or coarse grade bentonite was used, the individual particle configuration may be recognized. If coarse grade bentonite was poured into the annulus and remained non-hydrated, it will usually be difficult to penetrate with the probe. An unacceptable bentonite drilling mud slurry or drilling mud/cuttings slurry will appear as a thin, watery clay mixture tan to gray in color.

Neat Cement Grout – An acceptable neat cement or cement/bentonite grout will be a hard rock-like material, gray to greenish-gray in color that can be penetrated with the probe only for the first few hours after completion of the grouting. After the cement sets, the probe is only useful for identifying the top of the grout.

There may be instances where the use of the hollow core sampler is not practical due to the presence of rocks or other obstructions. In these cases, it may be possible to use a solid rod tile probe to evaluate the presence or absence of an open annulus around a well casing. Most tile probes have a threaded end that the point is threaded on to. Probe extension rods are available. The main drawback of using a tile probe is that you cannot collect samples of material for examination.

After evaluating for the presence of grout using a probe, fill in the hole in the grout that is created by the probe. Pour granular bentonite into the hole and periodically tamp it with the probe. Since the probe generally does not penetrate into the grout material more than 1 to 2 feet, a large quantity of bentonite is generally not needed. When a standard 4-inch diameter bucket soil auger is used along the upper portion of the annulus (above the pitless adapter), the parent material removed from that portion of the hole may be used to fill the hole.

A pair of wrenches is useful for disassembling the probe extensions and a screwdriver comes in handy for clearing the soil or grout material from the probe core. A wire brush and a can of WD 40 or equivalent are useful for cleaning the threads on the probe extensions and to assure that you can get the sections apart when you are done.

NOTE: Extreme caution must be used to avoid contact with overhead utility lines. Where overhead lines are present, be careful when extracting the probe because you didn’t have to worry about it when you were assembling the sections one-by-one at ground level. However, once placed down the annulus it may be 25 feet or longer. When you go to pull it out the probe is now one tall piece! Use common sense and remember safety first.

If using a soil probe where a submersible pump has been installed, be cautious of unprotected buried electrical wires that may be near the well casing. Although you would expect the electrical wire to extend toward the building and away from the well casing the contractor may have looped excess electrical wire around the back side of the casing. Be extremely careful when resistance to the probe is encountered. Treat all wires as “live” and don’t take chances by forcing probes through or around them. Always keep probe handles wrapped with electrical tape or non-conductive handle wraps.

Interpretation of Grout Probing Results

When a field evaluation determines that a well has not been properly grouted, the sanitarian shall contact the well drilling contractor and order correction of the violation using the following guideline:

Condition	Corrective Measure(s)
Probing revealed that approved grout material is present but is more than a few feet below the pitless adapter. Annulus open and dry and no obstructions (side wall collapse, bridged material).	Option 1: Extend tremie pipe to depth that grout was found, and pressure grout up to the surface. Option 2: If the grout is within 10 feet of the pitless adapter, pouring grout from the surface is acceptable. Slowly pour coarse grade or granular bentonite into the annulus, tamping with a length of pipe as needed to prevent bridging. Continue this sealing method until the grout material reaches the pitless adapter or ground surface.
Probing revealed no grout material. Annulus open and contains muddy water or what appears to be a watery bentonite material that has not set-up. Probing deeper revealed thicker grout material that has settled 25 feet down the annulus. No bridging.	Extend a tremie pipe to the depth that the grout was found, and pressure grout from that point back to the ground surface or to a point just below the pitless connection.
Probing fails to locate any grout material. Annulus open to the depth probed. Muddy water may or may not be present.	Option 1: Driller must meet sanitarian at the site and demonstrate to the satisfaction of the sanitarian that the well was in fact grouted, but that the grout material has settled to a point below where the sanitarian had probed. Generally, the contractor will place a tremie pipe in the annulus and extend the tremie down to the apparent bottom of the open annulus. Through jetting action or other means, it is best if a grout sample can be obtained to demonstrate that grout is present, and that the borehole has not simply collapsed. Once that determination is made, the contractor can be authorized to pressure grout from the bottom of the annulus back to the ground surface or level of the pitless adapter. Option 2: Properly plug the deficient well and annulus, then construct a new well. Plugging of the ungrouted well is not an easy task since the annulus around the casing has not been properly sealed. Sealing the inside of the casing only does not protect the aquifer from surface contamination, since contaminants from the surface may still enter the aquifer through the unsealed annulus. The sealing of this open annulus must be addressed during the abandonment process and may require the removal or perforation of the casing if there is no other way to properly seal the annulus.

Probing reveals no grout below the pitless adapter. Annulus is not open. The annulus contains sand, cuttings, or other consolidated material and some grout. Deeper probing of the annulus reveals that uniform, approved grout material is present 25 feet down hole, but apparently settled in the annulus, above which the wall of the annulus apparently collapsed.	Option 1: Reestablish a clean, open annulus by flushing the annulus (jetting) with water or drilling fluid, and then regrouting the upper 25 feet of now open annulus. Field experience has demonstrated that cleaning material out of a filled annulus to reestablish the open annulus is a difficult and time-consuming procedure which is seldom successful. However, it is the well driller's option to pursue this corrective measure if he/she so chooses. Option 2: Plug the well and drill a new well. Casing removal or perforation is required as part of the plugging procedure to assure that the ungrouted annulus is properly plugged.
Probing the annulus fails to locate any grout material, and the probing reveals that the annulus contains sand, drill cuttings, or other material that has filled the annulus.	The well has not been properly grouted, and there is no practical way to reestablish an open annulus along the entire casing length for regrouting purposes. The well drilling contractor must be contacted and ordered to plug the well. As noted above, casing removal or perforation is required as part of the sealing procedure to assure that the ungrouted annulus is properly plugged.

Common Problems Associated with Grouting

Bentonite Grout Problems

1. Using too much water. Each bentonite grout product has a specific maximum amount of water to use in the mixing of each bag of the grout. It is extremely important that bentonite grout is mixed according to the manufacture's specifications. Exceeding this maximum amount will lead to the following problems:
   - Reduction in the percentage of solids in the grout. Instead of the grout having a solids content of 20 to 30 percent, the solids content may be as low as 5 percent.
   - Reduction in the weight per gallon of the grout. Bentonite grout must meet the manufacturers minimum required weight, but in no case shall it be less than 9.4 lbs. per gallon with 15 percent solids. Some high solids bentonite grouts will exceed this weight.
   - Preventing the proper "set" or "curing" of the grout material. The grout will remain in a "soupy" consistency, instead of turning into a "peanut butter like" consistency.

When a bentonite grout with too much water has been placed in the annulus, the bentonite solids will settle to the bottom of the annular space, and excess water is absorbed by the vadose zone of the soil, leaving a long column of open annulus above the solids.

2. Bentonite grout "setting up" before being pumped into the annulus. This may occur because of one of the following reasons:
   - Taking an excessive amount of time between mixing of the grout and pumping it into the annulus. Each bentonite grout product differs in the time required before "setting" or "curing" starts, ranging from a few minutes to 30 minutes. If pumping is delayed until "setting" has started, the pump may not be able to move the grout because of the high head conditions, or the grout may not flow to the pump intake.

- Excessive mixing temperatures. If mix water is warm, the time before "setting" of the grout starts is significantly sped up because of the more rapid hydration (absorption of water) of the bentonite.
- "Sheering" of the bentonite during mixing. Some pumping or mixing methods tend to sheer (grind into smaller particles) the bentonite. This allows the bentonite to hydrate at a rate faster than intended, causing the bentonite grout to set up in a shorter period of time. Use of centrifugal pumps or jet mixers are common causes of sheering.

3. Grout mixture not "setting" properly after being placed in the annulus. This leads to settling of the bentonite solids to the bottom of the annulus, leaving an open annulus around the upper portion of the casing. Possible causes for grouts not setting properly include:
   - Using too much water in mixing the grout.
   - Excessive chlorine in the mix water (above 50 parts per million [ppm]).
   - The pH of the mix water is too low. The pH of the mix water should be 8.5 to 9.0.
   - The mix water has hardness (calcium carbonate), which interferes with the hydration of the bentonite. Mix water must be free of hardness. Mix water should be treated with soda ash to remove hardness before being mixed with the dry bentonite.
   - Tannins or excessive salts (greater than 7,000 ppm) in the mix water. Tannins and salt break down the bentonite.

4. Failure to remove drilling mud and cuttings from the annulus prior to grouting. When using the "tremie pipe down the annulus" method of grouting, drilling mud and cuttings must be flushed out of the annulus using clean water prior to grouting.

If only clean water is in the annulus at the beginning of the grouting operation, the water, being lighter than the grout, is pushed up the annulus ahead of the grout as the grout is pumped into the bottom of the annulus.

A drilling mud/cuttings mixture can be heavier than bentonite grout. If it is left in the annulus, the bentonite grout will channel up around the outside of the tremie pipe instead of pushing the column of the drilling mud/cuttings up and out of the hole. When this occurs, a quantity of the cuttings and drilling fluid is left in the annulus. These solids settle to the bottom of the annulus, leaving a water filled or open space where the drilling mud/cuttings once stood. The heavier grout material above the open space then recedes into the opening, leaving an open annulus at the top of the casing.

5. Receding of the grout placed in the annulus i.e., grout was pumped into the annulus from the bottom to the top but was not present in the upper annulus a day later. This may be caused by any one or a combination of the following (most were discussed above):
   - Loss of water from the grout mixture into the vadose zone of the soil. The vadose zone is the dry portion of the soil above the saturated portion of the soil. When the grout is placed in the annulus, it has not yet set-up (hydrated). Normally, with time, the bentonite absorbs the water in the grout mix, and the grout solidifies to a peanut butter like consistency. If the water is removed from the grout before it can be absorbed into the bentonite, this hydration does not take place, and the bentonite falls to the bottom of the annulus or attaches to the sidewall of the annulus. Either way, only an open annulus remains.
   - Failure of the grout to properly hydrate (using too much water, poor mix water quality, etc.).
   - Failure to remove drilling mud/cuttings from the annulus prior to grouting.

Neat Cement Grout Problems

- Using too much water. A mixing ratio of not more than 6 gallons of water to one 94 lbs. bag of Type I, Type IL, or Type 1A cement must be used. Too much water will weaken the cement, reduce the solids content (minimum weight must be at least 15 lbs. per gallon), and increase the likelihood of settling.
- Insufficient mixing. The cement slurry must be sufficiently agitated to completely mix the cement with the water. If lumps of dry cement are in the grout when pumping begins, the lumps may plug the grout pump, the tremie pipe, or screens in the mixing tank. All lumps must be broken up or removed with a screen before entering the grout pump.
- Failure to sufficiently clean equipment after grouting. Obviously, any residuals of the neat cement grout left in the grouting system will harden, causing equipment failure, plugged pipes, etc. Extreme care must be taken to remove **all** residuals of cement from grout pumps, mixing tanks, pipes, etc., after the grouting operation is completed.

Tremie Pipe Installation Problems

Installation of the tremie pipe to assure grout placement along the entire length of the casing may be a problem for some well drilling contractors. To meet minimum Well Construction Code requirements, the tremie pipe must extend to the bottom of the space to be grouted. The following have proven to be effective methods of tremie pipe placement used by Michigan registered well drilling contractors:

- Installing the tremie pipe to the bottom of the open bore hole prior to casing placement. Rigid (PVC, galvanized, etc.) tremie pipe is generally used.
- Installing the tremie pipe at the same time the casing is being placed in the open borehole by attaching the tremie pipe to the bottom of the casing. The tremie pipe is taped to the bottom of the casing, and then tugged free after placement. Generally, polyethylene plastic pipe or collapsible vinyl pipe is used for this tremie pipe placement method.
- Installing the tremie pipe down the inside of the casing, using draw down seals or a seal on top of the casing to prevent the grout from coming up into the casing.
- Installing the tremie pipe after the casing has been installed by "fishing" rigid tremie pipe down the annulus. The use of this method is limited to shallower wells. For deep wells the end of the tremie pipe tends to get "hung up" on the side of the borehole, casing couplings, etc., preventing the tremie pipe from getting to the bottom of the casing.

Chapter 8: WELL SCREENS

Introduction

A well screen is a filtering device that serves as the intake portion of wells constructed in unconsolidated or semi-consolidated aquifers. The screen permits water to enter the well from the saturated aquifer, prevents sediment from entering the well, and serves structurally to support the aquifer material. The importance of a proper well screen cannot be overemphasized when considering the efficiency of a well and the long-term cost to its owner.

Well screens are manufactured from a variety of materials and range from crude hand-made contrivances to highly efficient and long-life models made on machines. The value of a screen depends on how effectively it contributes to the success of a well. Important screen criteria and functions include:

CRITERIA	FUNCTIONS
Large percentage of open area	Easily developed
Non-clogging slots	Minimal incrusting tendency
Resistant to corrosion	Low head loss through the screen
Sufficient column and collapse strength	Control sand pumping in all types of aquifers

Continuous-Slot Screen

The continuous-slot screen is widely used throughout the world for water, oil, and gas wells, and is the dominant screen type used in the water well industry. It is made by winding rolled wire, triangular in cross section, around a circular array of longitudinal rods. The wire is attached to the rods by welding. Welded screens are commonly fabricated from stainless steel.

Slot openings are manufactured by spacing successive turns of the outer wire to produce the desired slot size. Slot openings have been designated by numbers which correspond to the width of the openings in thousandths of an inch. A No. 10 slot screen, for example, is an opening of 0.010 inch.

Continuous-slot screens provide more intake area per unit area of screen surface than any other type. This type of screen has maximum open area. For best well efficiency, the percentage of open area in a screen should be the same as, or greater than, the average porosity of the aquifer material. Water flows more freely through a screen with a large intake area compared to one with limited open area. The entrance velocity is low, therefore head loss for the screen is at a minimum, thus minimizing drawdown inside the well casing.

Other Types of Well Screens

Several other types of well screen exist. Some are manufactured, and others are hand perforated from casing or other materials. These screens may be adequate in some geologic formations but may provide only marginal success under many other hydrogeological conditions. Limited open area, poor slot configuration, and short-lived screen material contribute to their limited success.

Slotted Plastic Pipe

Slotted plastic pipe is also used to screen wells in some areas particularly in clay rich soils where no aquifer zone can be identified. Slotted plastic screens are not affected by corrosive water, are easy to install, and are relatively inexpensive. Slotted plastic screens have less than half the open area of continuous-slot screens. In addition, plastic pipe materials are from 1/6 to 1/10 as strong as stainless steel well screens.

Well Points

Well points are made of a variety of types and sizes. The welded continuous slot screen is made as a well point by attaching a forged-steel point to the lower end of a screen and a threaded pipe shank to the upper end. This type of construction is the most efficient hydraulically. The most common sizes are 1-1/4 inch or 2-inch. They are constructed of either low-carbon steel or stainless steel. Although they can withstand hard driving, they should not be twisted while being driven or used in areas where boulders or large stones are expected.

Slot Size and Sieve Analysis

Slot size selection is a critical step in assuring maximum well performance. The screen is typically designed to hold back 50 percent of the formation, and the entrance velocity of the screen should not exceed 1/10 or 0.1 feet per second. The velocity is calculated by dividing the well yield in gpm by the screen open area in square inches.

The slot size of the screen is based on a size analysis of the formation samples. By analyzing the component sizes of the grains in the sample, a grain-size distribution curve can be drawn. Several methods can be used to obtain information on the grain size distribution. The most widely used method involves passing the materials through a stacked set of brass or stainless steel sieves.

During the sieving process, each sieve filters out a certain percentage of the entire sample; the finest material collects in the bottom pan. Sieve analysis not only provides the basis for determining the slot size, but also other factors affecting screened well design. Sieve analysis is also used for filter pack design.

Screen Installation

There are different types of screen installation methods used, although certain procedures may be more practical or more economical in certain areas or when particular drilling rigs are used. The exact procedures to be followed when installing a well screen depend on the nature of the aquifer materials, the method used to drill the well, the dimensions of the borehole, the hydraulic conditions in the aquifer, and the casing and screen materials.

Pull-Back Method (Telescoped)

The pull-back method of screen installation is a safe method of installation that reduces problems resulting from heaving sediment, sloughing of the borehole walls, and setting the screen at the wrong depth. This method also permits the screen to be removed and replaced, if necessary without disturbing the sanitary grout seal outside the well casing.

The pull-back method involves installing the casing to the full depth of the well, lowering (telescoping) the well screen inside the casing, and then pulling back or lifting the casing far enough to expose the screen to the water-bearing formations. The casing must be strong enough to be set the full depth of the well and then be pulled back the length of the screen.

Some contractors use a rise pipe (blank) attached to the top of the screen so the entire screen can be exposed without slipping out of the bottom of the casing. On top of the screen, a neoprene packer is installed to provide a sand-tight seal between the top of the screen and the casing. Two or more packers are used in series to eliminate problems caused by small deviations in the dimensions of the casing or packer resulting from improper handling.

Single String Installation (Attached)
Sometimes the screens are attached directly to the bottom of the casing. Screens that are smaller in diameter than the casing can be welded or threaded directly to the casing by mounting a cone adaptor or flared weld ring to the top of the screen. Screens that are the same size as the casing can be welded or threaded directly to the bottom of the casing. The casing and screen are then set in the hole. For naturally developed wells, the formation is induced to cave in around the screen and casing immediately after the screen is set. When wells are filter packed, the pack material is placed before the formation is induced to cave.

Filter Packed Wells
Many wells are designed for a filter pack, thereby altering the screen installation process. Filter-packed wells differ from naturally developed wells in that a silica sand is placed around the well screen to a predetermined thickness. The geologic conditions, drilling method, and type of screen determine whether a filter pack should be used.

The filter pack provides both filtration and stabilization of the screen. The main objective of filter-packing is to install material more permeable than the native formation into the area immediately around the well screen. The advantages of filter-packing a well are: greater porosity, higher hydraulic conductivity, higher yield, reduced entrance velocity, reduced sand pumping, and easier grouting. Filter pack must be chlorinated prior to placing it into the open annulus to ensure that contaminants are not introduced into the well during the filter-packing process. Filter pack is not easily chlorinated during well development since all of the filter pack may not be accessible to chemical treatment.

PVC Screen

Driven Well Point

Stainless Steel Screen

WELL DEVELOPMENT

Introduction
Well development is the act of repairing damage to the formation caused by drilling procedures and increasing the porosity and permeability of the materials surrounding the intake of the well.

Well development is confined mainly to a zone immediately adjacent to the well where the formation has been disturbed during drilling.

All new wells should be developed before being put into production to achieve sand-free water at the highest specific capacity. Maintaining a high specific capacity assures that the well will be energy efficient.

Factors that Affect Development
There are two major well completion methods – natural development and filter packing. The completion method is chosen based on the aquifer, type of drilling rig, and type of screen.

In natural development, a highly permeable zone is created around the screen from materials in the formation. Development removes most particles smaller than the screen openings, leaving the coarsest material in place. A little farther out, some medium-sized grains remain mixed with coarse material. Beyond that zone, the material gradually grades back to the original character of the formation. Finer particles brought into the screen in this process are removed. Development continues until fines are no longer removed from the formation. Development stabilizes the formation and prevents further movement of sediment. Following development, water moving toward the screen encounters sediment with increasing hydraulic conductivity and porosity. More water can be removed from the well, and the well will be more efficient.

In filter packing, a special sand having high porosity and permeability is placed in the annulus between the screen and the natural formation. Development of the disturbed formation outside the pack is still mandatory to achieve maximum specific capacity.

Well Development Methods
There are different types of development methods used based on aquifer type and type of drilling rig. Unfortunately, some development techniques are still used in situations where other, more recently developed procedures would produce better results. Any development procedure should be able to clean the well so that sediment intrusion into the well is kept to a minimum.

Air Development by Surging and Pumping
Many drillers used compressed air to develop wells in consolidated and unconsolidated formations. Alternating surging and pumping with air has grown with rotary drilling. In air surging, air is injected into the well to lift the water to the surface. As it reaches the top of the casing, the air supply is shut off, allowing the aerated water column to fall thus forcing water in and out of the screen. Air-lift pumping is used to pump the well periodically to remove sediment from the screen or borehole and is accomplished by installing an airline inside a pipe in the well.

High-Velocity Jetting
Development by high-velocity jetting may be done with either water or air. Jetting with water is almost always accompanied by simultaneous air-lift pumping so that clogging of the formation does not occur. This dual process is one of the most effective methods of well development. The jetting

procedure consists of operating a horizontal water jet inside the screen so that water shoots out through the screen openings.

Jetting with air is an alternative to water jetting. If water is not readily available, air jetting is a practical procedure that produces good results. Air jetting initiates air-lift pumping, which helps remove sediment from the well.

Mechanical Surging
Mechanical surging is another method of development which forces water to flow into and out of a screen by operating a plunger up and down in the casing. The tool commonly used is a surge block or plunger. A heavy bailer may be used to produce the surging action, but it is not as effective as the surge block. The initial surging action should be gentle, allowing any material blocking the screen to break up, go into suspension, and then move into the well. The force exerted on the formation depends on the length of the stroke and the velocity of the surge block. As water begins to move easily both into and out of the screen, the surging tool is usually lowered in steps to just above the screen.

Overpumping
Overpumping is the simplest method of removing fines from the water bearing formations. It is pumping at a higher rate than the well will be pumped when put into service. Any well that can be pumped sand free at a higher rate can be pumped sand free at a lower rate. Overpumping, by itself, seldom produces an efficient well or full stabilization of the aquifer because most of the development action takes place in the most permeable zones closest to the top of the screen.

Backwashing
Effective development procedures should cause reversals of flow through the screen openings that will agitate the sediment, remove the finer fraction, and then rearrange the remaining formation particles. Reversing the direction of the flow breaks down the bridging between large particles and across screen openings that results when the water flows in only one direction. Backwashing breaks down bridging, and the inflow then moves the fine material toward the screen and into the well.

A surging action consists of alternately lifting a column of water a significant distance above the pumping water level and letting the water fall back into the well. The pump should be started at reduced capacity and gradually increased to full capacity to minimize the danger of sand-locking the pump.

Although overpumping and backwashing is used widely, and in certain situations may produce good results, their success in high-capacity wells is limited when compared to other development methods.

Summary
Patience, intelligent observation, and the right tools are required to develop a well correctly. Developing beyond the minimum time to remove fines will help to increase the chances of obtaining a coliform-free water supply. Well development is not expensive, considering the often-remarkable results that can be obtained in improving yields and eliminating sand pumping. Similarly, aquifer development is often overlooked as an effective way to increase yields substantially.

Chapter 9: WELLHEAD COMPLETION

Introduction
The wellhead is the portion of the water well extending above ground. Because of a contamination risk, state law prohibits buried wellheads.

The well cap is designed to keep rainwater, insects, and small animals out of the well. Newer well caps have screened air vents that allow atmospheric air to enter the well as water is withdrawn from the well. This results in a more sanitary water supply. Broken well caps or damaged screens should be replaced. All well caps in Michigan must be approved prior to use.

Wellhead Completion and Pumping Equipment Rules

Rule 157(a)
Well caps and seals shall be:
- Weathertight
- Vermin proof
- Provide for venting
- Tightly secured to casing

Rule 157
A casing vent shall be provided on all well caps and seals
Except:
- Deep well, single pipe packer jet installations
- Flowing wells

Rule 157
A vent shall be:
- Screened
- Pointed downward
- Terminate 12 inches above ground or floor
- 24 inches above any known flood level

Rule 151 Room housing pumping equipment or well casing
- Above ground surface or in an approved basement offset
- Pumping equipment may be in a crawl space if water does not accumulate
- Must provide for access to system components for maintenance and repair

Rule 155 Water service lines
- Buried portion under positive pressure at all times
- No check valve at pressure tank unless pipe is protected
- Plastic 160 psi minimum
- Approved materials

Rule 141 Connection to casing – above grade
- 12 inches above grade
- Connection may be:
  - Threaded
  - Welded
  - Rubber expansion seal

- Bolted flanges
- Well cap
- Pump base

Rule 142 Connection to casing – below grade
May be:
- Threaded
- Welded
- Approved pitless adapter
- Not submerged during installation

Rule 153 Pumps
- No unprotected openings
- Watertight connection to casing
- Priming not required for ordinary use
- Plastic drop pipe – approved materials, no splices, not used with packer-jet assembly
- Approved lubricants for sub pumps

Rule 154 Water suction lines
- Approved materials
- Protected by one of the following methods:
    - Fully exposed 12 inches above floor of basement, basement offset, pump room
    - Fully exposed 12 inches above ground surface
    - Concentric piping under system pressure
    - Concentric piping drained to basement (20 feet max length, positive drainage, watertight at casing)

Rule 140 Pressure tanks
Bladders, diaphragms, coatings, or lining materials in contact with water must meet the specifications listed.

Rule 156 Pressure tanks
- Shall be in an approved pump room, well house, crawl space, basement offset, or basement
- Buried tanks must be an approved model with proper installation
- If the pump can exceed the working pressure of the tank, a pressure relief valve shall be installed

Rule 158 Sampling faucets
- Down-turned faucet (preferred: unthreaded)
- Not less than 8 inches above floor
- In a convenient location at the pressure tank or as near to the well as possible

Rule 156 Venting of gases
- Toxic or flammable gases shall be vented
- Vent shall discharge to *outside atmosphere*

The Water Well Equipment Approval List is available for download from the EGLE Well Construction Program website at Michigan.gov/WaterWellConstruction.

PUMPS

Centrifugal Pump

A centrifugal pump is of very simple design. The only moving part is an impeller attached to a shaft that is driven by the motor. The two main parts of the pump are the impeller and diffuser. The impeller can be made of bronze, stainless steel, cast iron, polycarbonate, and a variety of other materials. A diffuser or volute houses the impeller and captures the water off the impeller. Water enters the eye of the impeller and is thrown out by centrifugal force. As water leaves the eye of the impeller, a low-pressure area is created causing more liquid to flow toward the inlet because of atmospheric pressure and centrifugal force. Velocity is developed as the liquid flows through the impeller while it is turning at high speeds on the shaft. The liquid velocity is collected by the diffuser or volute and converted to pressure by specially designed passageways that direct the flow to discharge into the piping system; or, on to another impeller stage for further increasing of pressure.

The head or pressure that a pump will develop is in direct relation to the impeller diameter, the number of impellers, the eye or inlet opening size, and how much velocity is developed from the speed of the shaft rotation. Capacity is determined by the exit width of the impeller. All of these factors affect the horsepower size of the motor to be used; the more water to be pumped or pressure to be developed, the more energy is needed.

A centrifugal pump is not positive acting. As the depth to water increases, it pumps less and less water. Also, when it pumps against increasing pressure it pumps less water. For these reasons, it is important to select a centrifugal pump that is designed to do a particular pumping job. For higher pressures or greater lifts, two or more impellers are commonly used; or, a jet ejector is added to assist the impellers in raising the pressure.

Jet Pump

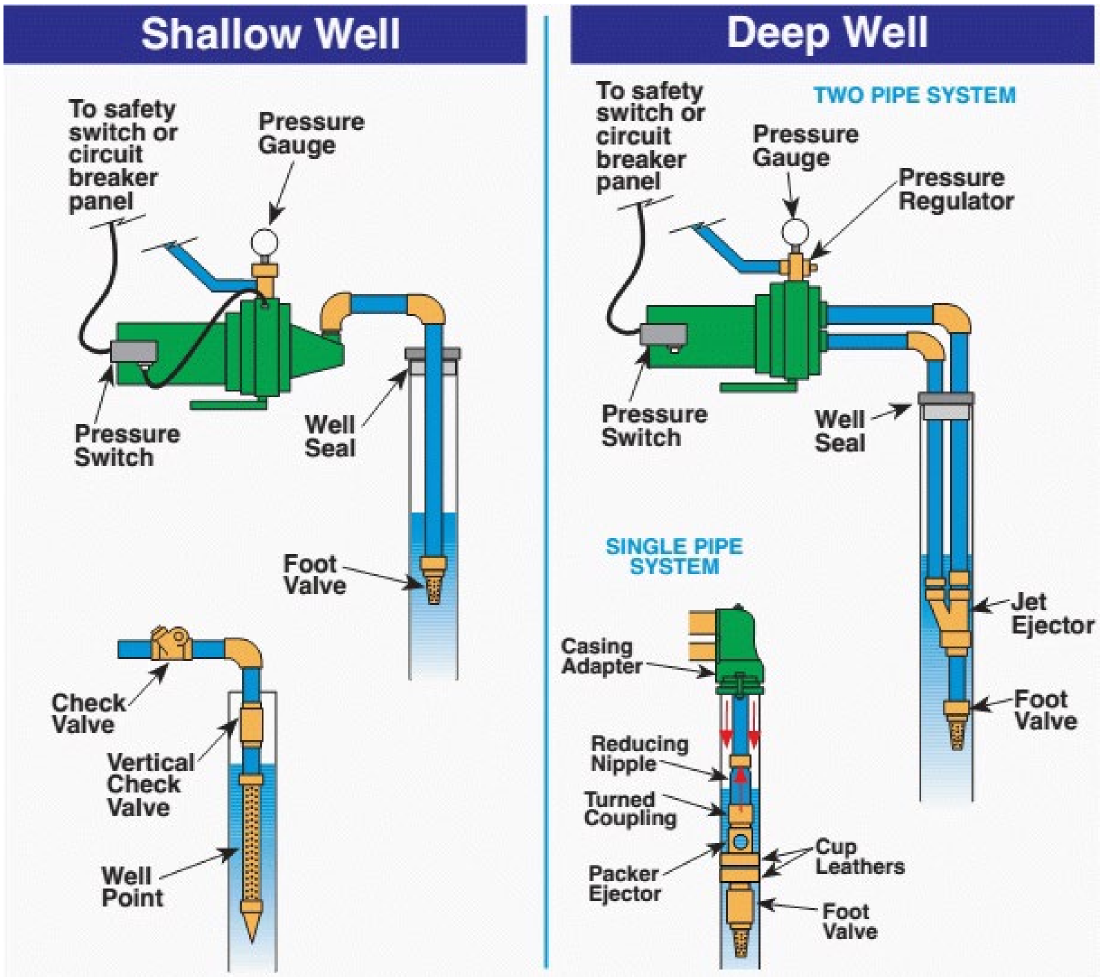
There are two categories of jet pump. A shallow well jet pump can pull water from a maximum of 25-feet depth-to-water. A deep well jet pump can pull water from much deeper (as deep as 80 – 100 feet depending upon model and horsepower).

A shallow well jet pump has the nozzle and venturi of the jet system built into the nose of the pump. In a deep well jet pump setup, the nozzle and venturi are put into an ejector package or “jet kit” that gets placed down in the well. In this type of setup there are two pipes connecting the pump to the ejector package. One pipe pulls the water up (suction) while the other pipe pushes some water down (pressure) to circulate water through the nozzle and venturi. Water moving through that nozzle and venturi makes a pressure differential that helps bring the water up to the pump.

A convertible jet pump allows for shallow-well operation with the ejector mounted on the end of the pump body. This type of pump can be converted to a deep-well jet pump by installing the ejector below the water level. This is of particular value when you have a water level that is gradually lowering. This will probably require a change of venturi to work efficiently. Because jet pumps are centrifugal pumps, the air handling characteristics are such that the pump should be started with the pump and piping connections to the water supply completely filled with water.

With a shallow-well jet pump, the ejector is mounted close to the pump impeller. With a deep well jet pump, the ejector is usually mounted just above the water level in the well, or else submerged below water level.

Centrifugal pumps, both the shallow well and deep well types have little or no ability to pump air. When starting, the pump and suction line needs to have all of the air removed. An air leak in the suction line will cause the pump to quit pumping, sometimes referred to as "losing its prime."



Submersible Pump
The submersible pump is a centrifugal pump. Because all stages of the pump end (wet end) and the motor are joined and submerged in the water, it has a great advantage over other centrifugal pumps. There is no need to recirculate or generate drive water as with jet pumps, therefore, most of its energy goes toward "pushing" the water rather than fighting gravity and atmospheric pressure to draw water.

Virtually all submersibles are "multi-stage" pumps. All of the impellers of the multi-stage submersible pump are mounted on a single shaft, and all rotate at the same speed. Each impeller passes the water to the eye of the next impeller through a diffuser. The diffuser is shaped to slow down the flow of water and convert velocity to pressure. Each impeller and matching diffuser are called a stage. As many stages are used as necessary to push the water out of the well at the required system pressure and capacity. Each time water is pumped from one impeller to the next, its pressure is increased. The pump and motor assembly are lowered into the well by connecting piping to a position below the water level. In this way the pump is always filled with water (primed) and ready to pump. Because the motor and pump are under water they operate more quietly than above ground installations; and, pump freezing is not a concern.

Types and Characteristics of Pumps Used in Private Water Supply Systems

WELL TYPE	PUMP TYPE	NORMAL CAPACITY RANGE (gph)	PRACTICAL SUCTION LIFT (ft.) *	MAX. PRACTICAL PUMPING DEPTH (ft.)	USUAL DISCHARGE PRESSURE RANGE (psi)	REMARKS
SHALLOW WELL	Shallow Well Jet (Jet on pump)	200-1500	20-25	25	20-40 30-50	1. Simple in construction. 2. Easy to service. 3. Can be used with 1-inch and larger wells. 4. Less efficient hydraulics.
	Piston or Reciprocating	200-800	20-25	25	20-40 30-50 40-60	1. Adaptable to low capacity and high head. 2. Handles air without losing prime. 3. No longer widely used. 4. Can be used with 1-inch and larger wells.
	Straight Centrifugal (Single and multi-stage)	500-2000	15-20	20	20-40 30-50	1. Suitable for high capacities. 2. Efficient hydraulics. 3. Can be used with 1-inch and larger wells. 4. Simple and easy to service.
DEEP WELL	Deep Well Jet (single and multi-stage) (Jet in well)	200-600	15-20 (ft. below jet)	200	20-40 30-50 40-60	1. Simple in construction and operation. 2. No moving parts in well. 3. Less efficient hydraulics. 4. Can be installed on 2-inch and 3-inch wells. 5. Can be located away from well.
	Submersible	200-3000	Pump and motor submerged	600	30-50 40-60 50-70	1. Suitable for deep settings. 2. Adaptable to frost proof installations. 3. Efficient hydraulics. 4. Available in wide range of heads and capacities. 5. Only available for 3-inch or larger wells.
	Piston or Reciprocating	200-800	20-25	150	20-40 30-50 40-60	1. Suitable for deep settings. 2. Adaptable to frost proof installations. 3. Efficient hydraulics.

* Practical suction at sea level. Reduce one foot for each 1000 feet above sea level.

PRESSURE TANKS

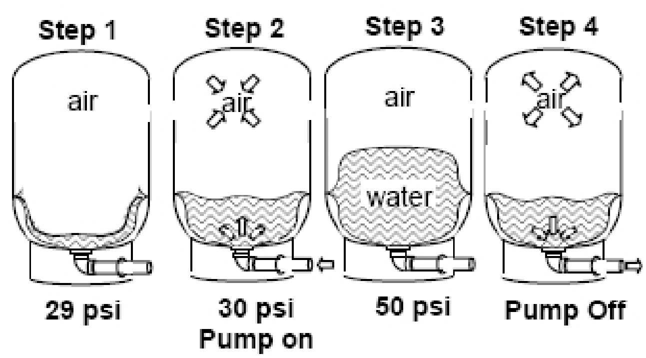
Types of Pressure Tanks

Galvanized Tanks

Galvanized tanks are a single chamber filled with water and pressurized air—nothing separates the two. The pressurized air pushes on the water, providing the necessary pressure for your home's faucets. These tanks are generally larger than most modern models yet have a capacity similar to much smaller tanks. This disparity in size and capacity of the tank may cause the well pump to cycle on and off more frequently, which may lead to premature pump burn-out. The single chamber design of these tanks also makes them prone to becoming water-logged due to air loss through pin-hole corrosion.

Diaphragm and Bladder Tanks

Bladder or diaphragm pressure tanks consist of two separate chambers: one for compressed air and another for water. A diaphragm tank has a rubber diaphragm permanently attached to the sides of the tank to separate water from air. It rises and falls with the water level (see diagram below). As water is pumped into the tank, the diaphragm is pushed up to the compressed air chamber which then triggers a sensor to shut off the pump at a preset level (typically 40 to 60 psi). When someone turns on a faucet, air pressure in the tank forces water throughout the plumbing until the pressure drops to the preset trigger pressure, usually the 20 to 40 psi. That tells the water pump to turn on, and water is then drawn into the house and tank. When the faucet is shut off, pressure builds until it is restored to its default shut-off level. The amount of water delivered by the pressure tank between the time the pump shuts down and the time it starts again is called the drawdown.



Typical Pump Cycle

Step 1. Pump Off: Tank is nearly empty. Air expands to fill tank volume up to the pre-charged pounds per square inch (psi).

Step 2. Pump Starts: Water begins to enter the tank, compressing the air.

Step 3. Pump Stops: The system reaches maximum pressure. Air is compressed to the cut-off setting of the pressure switch.

Step 4. Pump Off: When water is demanded, air pressure forces it into the system, and a new cycle begins.

Common pressure ranges are 30 to 50 or 40 to 60 psi.

Like diaphragm tanks, bladder tanks utilize two separate chambers for compressed air and water. The bladder is a pouch filled with water that expands and contracts, triggering a sensor to activate the pump. Bladders, being self-contained entities, are useful for those worried about a diaphragm dislodging or folding under the pressure of compressed air. A bladder also generally lasts longer than a diaphragm.

What functions do pressure tanks serve?

The functions of a bladder pressure tank are to maintain a desired range of water pressure in the distribution system, minimize pump cycling which prolongs the lifespan of the pump, and protect against water hammer.

Pump and Pressure Tank Terms

Air Volume Control
A device that maintains the air charge in a standard water storage tank. Pre-charged tanks do not require an air volume control.

Capacity
Capacity is the gallons a tank would hold if there were no air or bladder inside.

Cavitation
Cavitation occurs when air gets into the pump chambers or the impellers, parts can overheat, causing mechanical damage to moving parts.

Drawdown
Drawdown is how much water is available in the tank between pump cycles. Measured in gallons, it can vary at different pressure switch settings and pre charge in the same tank.

Friction Loss
Friction loss is the loss of pressure or "head" that occurs in pipe due to the effect of the fluid's viscosity near the surface of the pipe.

Head
Head refers to the gains or losses in pressure caused by gravity and friction as water moves through a system. 1 psi = 2.31 feet head.

Horsepower
Horsepower is a unit of measurement of power, or the rate at which work is done.

Impeller
The impeller is the rotating part of a pump designed to move a fluid by rotation.

Jet Ejector
A jet ejector or jet consists of a nozzle and venturi. The venturi speeds the flow of the fluid, by constricting it in a cone shape tube. The jet is located in the pump housing of a shallow well jet pump. It is located in the well below the water level.

Pre Charge
Pre charge is the air added to the tank. The pressure should be 2 psi less than the cut in pressure for the pump pressure switch. A correct pre charge prevents interruption of water and extends the life of the pump and tank.

Pressure
Pressure is the force exerted on the walls of a container or pipe by the liquid. Measured in pounds per square inch (PSI).

Pressure Relief Valve
A pressure relief valve (PRV) is a type of safety valve used to control or limit the pressure in a system; pressure might otherwise build up and create an equipment failure or injury.

Pressure Switch
A pressure switch automatically turns water on and off, depending on pressure settings. The fluctuating pressure is observed on the pressure gauge.

Pump Cycle
Pump cycle is a measurement of how long it takes for a pump to fill the tank to shutoff. Too short of a pump cycle can create heating issues in submersible motors.

Pump Curve
A pump curve is a curved line drawn over a grid of vertical and horizontal lines. The curved line represents the performance of a given pump. The horizontal and vertical lines represent units of measure to display that performance.

Total Dynamic Head
Total dynamic head is the total equivalent height that a fluid is to be pumped, considering friction losses in the pipe.

Electrical Code Requirements for Well and Pump Installations

The electrical wiring of a water well and pump installation is regulated by the Michigan Electrical Code and the electrical provisions of the Michigan Residential Code rather than the Michigan Water Well Construction and Pump Installation Code (Part 127, 1978 PA 368).

Local and state electrical inspectors have authority for enforcement of electrical code provisions. LHD officials who inspect water wells should refer electrical code violations to the electrical inspector or building official having jurisdiction.

Permits for the electrical circuit for the pump are required to be obtained from the electrical code official. Permits may be obtained by registered well drillers and pump installers.

Electrical hook-ups for water wells serving the public and all other wells that do not serve a single-family dwelling (such as agricultural irrigation wells, fire protection wells, and non-potable industrial wells) must be performed by a licensed electrical contractor.

The Michigan Electrical Administrative Act, 1956 PA 217 and the State Electrical Code are implemented by:

Michigan Department of Licensing and Regulatory Affairs
Bureau of Construction Codes
Electrical Division
611 West Ottawa Street, First Floor
Lansing, Michigan 48933
Phone: 517-241-9320
Fax: 517-241-0130
Email: BCCElec@Michigan.gov

Mailing Address: P.O. Box 30254, Lansing, Michigan 48909

LHD sanitarians conducting final inspections on water wells typically inspect the electrical conduit as part of the wellhead inspection. The types of conduit approved for submersible pump installations are:

a. Rigid Metal Conduit – must be galvanized
b. Rigid Nonmetallic Conduit – must be grey PVC plastic, schedule 40 or 80
c. Intermediate Metal Conduit

Electrical code violations are cited under Rule 112(e) of the State Well Code.

Electrical Troubleshooting for Pumps

The examination to become a Michigan Registered Water Well Drilling Contractor or Pump Installer includes a hands-on submersible pump electrical troubleshooting exercise. The exercise tests whether an applicant can correctly diagnose an electrical problem such as a faulty main motor winding, broken motor lead, or damaged wire insulation.

Pump troubleshooting training materials are also available from pump or motor manufacturers. Some examples are Franklin Electric's "Submersible Pump Motor Application, Installation, Maintenance Manual" or Goulds' "Service Manual for Submersible Pumps and Jet Pumps."

Chapter 10: WATER WELL DISINFECTION

Introduction
Natural groundwater from all but very shallow aquifers is considered free from pathogenic (disease causing) bacteria and viruses. As such, groundwater obtained from properly designed and constructed wells is generally free of disease-causing bacteria, and continuous disinfection is unnecessary. However, disinfection of a new or repaired water supply system is needed to remove contaminants introduced during the construction or repair process. While LHDs may be consulted to help solve a coliform bacteria issue, it is ultimately the contractor's responsibility to determine the course of action and provide coliform free water. Sampling of a new water supply provides a baseline for future sampling.

Existing water supplies require disinfection when routine maintenance of the system takes place, or when the results of water samples show the presence of coliform. The result of effective disinfection is the production of potable, or drinkable, water.

Bacteria is found throughout the environment in air, water, and soil. Some are beneficial, and some can cause illnesses (pathogenic). Bacteria can be classified as follows:

Nonpathogens:
- Nonpathogenic bacteria present no health threat.
- These are common background bacteria that are found in every sample we test.
- Many can be slime formers or iron oxidizers.

Pathogens:
- Pathogens present health dangers to all individuals.
- They must have a warm blooded host to survive.
- E. coli or fecal coliform are the most common found in groundwater.
- Cryptosporidium or Giardia have been the most common in surface water.
- Coliform bacteria are not actually pathogens but non-pathogens. They are used as indicator bacteria that E. coli (fecal coliform) bacteria may be present.

Opportunistic Pathogens
- Opportunistic pathogens present dangers to individuals with weakened health conditions.
- The elderly, young infants, and people with lower immune conditions would be susceptible to problems with these bacteria present.
- A common sub family is Pseudomonas aeruginosa which can cause lower respiratory tract infections.

Pathogenic Bacteria
When E. coli/fecal coliform bacteria are present, disinfection of the well may not be successful in reaching the source. These bacteria need a warm bodied source to survive. Look for the source prior to automatic disinfection:

New wells or new pump installation:
- Bailers with bird nests.
- Pumps, drop pipe, submersible pump cable set on the ground.
- Stepping on drop pipe and cable prior to installation.

Existing wells:

- Loose caps on pitless adapters.
- Location of potential surface contamination e.g., sewage systems, and feed lots.
- Suspect poor grout of casing at surface.

Disinfection Manual

More detailed information can be found in EGLE's Disinfection Manual. It contains detailed information on various disinfection methods, chlorine sources, well preparation, and water sampling for bacteria. To receive a copy of the manual, visit the Well Construction Program website at Michigan.gov/WaterWellConstruction. It is highly recommended that homeowners consult with a registered well driller contractor prior to any treatment attempt.

Principles of Disinfection

When a water well is drilled or an existing water well or household piping is repaired, bacteria can be introduced into the water system. Many state construction codes (for example, Part 127, 1978 PA 368, as amended) requires disinfection of a new or repaired water system before it is placed into service. Disinfecting a water system which includes treatment with chlorine, combined with proper well preparation and flushing, usually eliminates the bacteria if it is associated with well construction activities. Water well drillers and pump installers are responsible for disinfecting the work they perform. Once the properly constructed water well has been disinfected, it should produce safe water consistently without the need for continuous chlorination.

Disinfection does not simply mean treatment of a water supply with chlorine. Disinfection involves a process of:

1. Proper water supply system preparation
2. Flushing of the water supply
3. Treatment with a chlorine solution
4. Water sampling

Factors That Affect the Effectiveness of Chlorine Treatment

There are six factors that influence the effectiveness of chlorine in destroying organisms that may be present in a water supply. The factors are (1) form of chlorine, (2) pH, (3) temperature, (4) interfering substances, (5) chlorine concentration, and (6) chlorine contact time. Following is a brief discussion of these factors and their effect on disinfection.

Form of Chlorine

The form of chlorine that is in a chlorine stock solution is an important factor in how effective the solution is as a disinfectant.

Chlorine dissolved in water, regardless of whether sodium hypochlorite or calcium hypochlorite is used as the source of the chlorine, generally exists in two forms, depending on the pH of the water:

1. HOCl – hypochlorous acid (biocidal)
2. OCl – hypochlorite ion (oxidative)

Hypochlorous acid is 100 times more effective as a disinfectant than the hypochlorite ion. It is generally thought that the death of bacterial cells results from hypochlorous acid oxidizing essential bacterial enzymes, thereby disrupting the metabolism of the organism. In addition, hypochlorous acid has a small molecular size and is electrically neutral, thereby allowing rapid penetration through a cell wall.

The hypochlorite ion is not as strong an oxidizing agent as hypochlorous acid and the negative charge of the ion impedes its ability to penetrate an organisms cell wall. Hence, the hypochlorite ion is not as effective a disinfectant agent as hypochlorous acid.

pH
Chlorine is a more effective disinfectant at pH levels between 6.0 and 7.0, because the presence of the most effective form of chlorine, hypochlorous acid, is maximized at these pH levels. Controlling the pH of a chlorine solution increases the effectiveness of the chlorination process.

The pH determines the biocidal effects of chlorine. By controlling the pH of the solution that the chlorine is in, the form of chlorine (hypochlorous acid or hypochlorite ion) can be controlled. If the amount of hypochlorous acid, the more effective of the two forms of chlorine, can be maximized by controlling the pH, the effectiveness of the chlorine is significantly increased. The following table demonstrates how pH affects the form of chlorine.

EFFECT OF pH ON TYPE OF CHLORINE		
pH	Approximate percentage at 32 to 68 degrees F	
	Hypochlorous Acid	Hypochlorite Ion
5	100	0
6	97-98	2-3
7	75-83	17-25
7.6	42-63	47-58
8	23-32	68-77
9	3-5	95-97
10	0	100

Chlorine will raise the pH when added to water. As noted in the chart above, raising the pH reduces the amount of hypochlorous acid present. By increasing the concentration of chlorine, and subsequently raising the pH, the chlorine solution is actually less efficient as a biocide. At higher pH levels, hypochlorite ion is formed which is the least effective of the two forms of chlorine for treatment.

Controlling the pH of the water in the aquifer is not practical. However buffering or pH-altering agents may be used to control pH in the chlorine solution being placed in the well.

Temperature
As temperatures increase, the metabolism rate of microorganisms increases. With the higher metabolic rate, the chlorine is taken into the microbial cell faster, and its bactericidal effect is significantly increased. Therefore, the higher the temperature, the more likely the chlorination of the water supply will produce the desired results. However, controlling the temperature of the water in the aquifer is not practical.

Interfering Substances
Dirty surfaces and turbid water cannot be effectively treated with chlorine. There may be substances in the water and on surfaces that bind up or use up available chlorine resulting in less chlorine (free chlorine residual) being available to serve as a disinfectant and thereby decreasing the effectiveness of the chlorination process. This binding or using up of chlorine is called chlorine demand. The interfering substances may include:

1. Inorganic matter (sand, silt, clay)
2. Organic matter (synthetic chemicals or biological material)
3. Drilling mud/additives
4. Dissolved iron and other minerals
5. Cuttings

The major chlorine demand in well disinfection is not in the water, but on surfaces of the well. Nuisance organisms (organisms able to reproduce in the environment of the well) may be naturally occurring or introduced during the construction of the well.

Many nuisance organisms are filamentous or slime formers that stick to surfaces such as the well casing, screen or soil particles and produce a biofilm that protects the organism from hazards such as chlorine. Some of these organisms are attached to particles that settle to the bottom of the well, along with soil particles, scale, and other debris. This accumulation of material may be too thick for effective disinfection.

Only clean surfaces in a well render themselves to effective disinfection with chlorine. Proper development of a newly constructed water supply, proper preparation of an existing water supply, and thorough flushing of a water supply can effectively clean exposed surfaces, remove turbid water, and help remove most interfering substances.

Chlorine Concentration

Exposure of an unprotected coliform organism to even very low concentrations of chlorine will kill the microorganism. However, the microorganisms may be protected from exposure to the chlorine by protective slimes, cuttings, drilling fluid, scale, etc. These interfering substances, as discussed earlier, will use up available chlorine as it tries to penetrate to make contact with the microorganism, and thus allows the microbes to survive.

The initial chlorine concentration in the chlorine solution needs to be high enough to assure that there is sufficient chlorine to make up for this “chlorine demand,” and still have a residual of chlorine left to kill the vulnerable microorganisms.

In practice, chlorine concentrations should be kept between 50 and 500 ppm, and the standard recommended concentration is 200 ppm. This allows for enough chlorine to satisfy chlorine demand (interfering substances), and still provide sufficient free available chlorine to disinfect (50 ppm). Exceeding these levels may cause damage to the well or actually reduce the effectiveness of the chlorination process as follows:

1. At higher concentrations of chlorine (in excess of 500 ppm), the corrosivity of the stock solution is significantly increased, creating a potential for damage to metal well components (submersible pumps, check valves, etc.). The use of chlorine solutions with chlorine concentrations in excess of 500 ppm is not recommended.

2. In the presence of higher concentrations of chlorine, the surface of biofilms and mineral scale may be oxidized to form a hard, tight surface. This sealing of the surface layers then reduces the chance that chlorine will penetrate into the material to make contact with the microorganisms that may exist there.

Contact Time
"Contact time" means the amount of time that the chlorine solution is left in the water supply. Adequate time must be provided to allow the residual chlorine to penetrate into the biofilm or other materials that may be present to impact the microorganisms in those areas.

During this period of contact time, it is essential to ensure that a chlorine residual be maintained in the water supply system for 4 to 12 hours, usually overnight.

For an increased contact time to be most effective, the pH of the chlorine solution in the well must be maintained between no lower than 6 and no higher than 7 to keep the chlorine in a nonoxidative state (hypochlorous acid).

Generally speaking, the longer the contact time, the more likely the chlorination procedure will be successful, especially if proper concentrations of chlorine are used at controlled pH conditions.

Commonly Used Chorine Sources
Sodium hypochlorite and calcium hypochlorite are the most common sources of chlorine used for disinfection of onsite water supplies. The following provides information on these two chlorine sources:

Sodium Hypochlorite (common household bleach)

- Clear to slightly yellow colored liquid with a distinct chlorine odor.
- Common laundry bleach – 5.25 to 6.0 percent available chlorine when bottled.
  Use unscented only. Scented bleaches may leave an odor (lemon smell, etc.) for extended periods of time, even after the chlorine has been flushed out of the water supply.
  Do not use bleach products that contain additives such as surfactants, thickeners, stabilizers, and perfumes. These additives may contain hazardous chemicals and may not be used for treatment of water supplies. Always check product labels to verify product content.
- Swimming pool chlorine – 10.0 to 12.0 percent available chlorine. Note that there are types of chlorine other than sodium hypochlorite available for swimming pool use, and these should not be used for treatment of water supplies unless certified as meeting American National Standards Institute (ANSI)/National Sanitation Foundation, Inc. (NSF) Standard 60. Swimming pool chlorine products may also contain UV inhibitors, algaecides, or other additives that should not be added to water supplies. Always check product labels to verify product content.
- Limited shelf life – Sodium hypochlorite solutions are of an unstable nature, due to high rates of available chlorine loss. Over a period of one year or less, the amount of available chlorine in the storage container may be reduced by 50 percent or more. Solutions more than 60 days old should not be counted upon to contain the full amount of original available chlorine. Because light and heat accelerate decomposition of sodium hypochlorite solutions, product degradation is less pronounced when containers are stored in a dry, cool, and darkened area, or in containers protected from light. A chlorine test kit should be used to check the final chlorine residual in a prepared chlorine solution to assure that you have the concentration intended.

As a general rule, **one gallon of 5.25 percent bleach in 100 gallons of water will make a 500-ppm solution**.

Calcium Hypochlorite (pool or spa chlorine)

- Dry white powder, granules, or tablets
- 60-70 percent available chlorine
- 12-month shelf life if kept cool and dry
- If stored wet, loses chlorine rapidly and is corrosive

As a general rule, **3/4 lbs. (1.5 cups) of granular calcium hypochlorite mixed in 100 gallons of water will make a 500-ppm solution**.

A chlorine test kit should be used to check the final chlorine residual in a prepared chlorine solution to assure that you have the concentration intended.

Calcium Hypochlorite Tablets – The use of calcium hypochlorite tablets dropped into the top of a well is ***not*** recommended for the following reasons:

1. Tablets are designed to be slow dissolving. This characteristic is not conducive to getting all the available chlorine into the chlorine solution during the desired chlorination time interval.
2. Conditions in a well are not conducive to dissolving chlorine tablets. The water is cold and there is very little agitation or turbulence in the bottom of a well. Tablets are designed for use in applications where the water is warm, and water is flowing past the tablets such as in a basket in the recirculation line of a swimming pool.
3. It is difficult to get uniform distribution of chlorine if the tablets are dumped into a well. There will be a strong concentration of chlorine around the tablets, but not in other portions of the well.
4. Tablets poured into the top of a well may lodge on the interior of the pitless adapter or on top of the submersible pump causing corrosion. Michigan Well Drilling Contractors have reported cases of severe corrosion of submersible pumps leading to premature failure.
5. The tablets cause high concentrations of chlorine in the bottom of the well, causing chemical interactions with the groundwater leading to excessive scaling.

If tablets are to be used as a source of chlorine for a chlorine solution, they ***must*** first be broken up and dissolved in a 5-gallon pail or bulk tank. Otherwise, they may remain in the bottom of the well for extended time periods and provide poor distribution of chlorine.

Which is Best – Sodium Hypochlorite or Calcium Hypochlorite?

Current experiences by water well drilling contractors and groundwater specialists suggest sodium hypochlorite is more effective. However, this may be associated with the quality of the groundwater in the well being treated rather than with the source of the chlorine itself.

In Michigan there is an abundance of calcium-based materials in both drift and bedrock wells. Calcium hypochlorite already has a high concentration of calcium (the white cloudy appearance). At 180 ppm (or approximately 10 grains of hardness), water is saturated with calcium to the point that it precipitates out of the solution i.e., it changes from the dissolved state to a solid state.

Introducing a calcium hypochlorite solution into a calcium rich aquifer can cause the formation of a calcium carbonate (hardness) precipitate that may partially plug off the aquifer. The plugging can interfere with the effective distribution of the chlorine solution and possibly reduce the production capabilities of the well. Sodium hypochlorite does not have the tendency to create this precipitate, which may be why it appears to be a more effective disinfectant.

If the calcium carbonate concentration in the groundwater is above 100 ppm (mg/l), the use of sodium hypochlorite is recommended instead of calcium hypochlorite.

NSF Certification

Per Rule 140, sodium hypochlorite or calcium hypochlorite that contain other chemicals or additives, such as stabilizers, perfumes, or algaecides, or other chemicals that are used for water supply disinfection purposes **must** be certified that they are in compliance with or surpass ANSI/NSF Standard 60 for Drinking Water Treatment Chemicals – Health Effects, or an equivalent standard.

The following is a description of the disinfection process.

Water Supply Preparation

1. Start with a clean drill site.
2. Minimize contamination of the drilling process (See Preventing Bacterial Contamination section below).
3. Chlorinate filter pack material prior to or during placement.
4. Use approved materials.
5. Replace any defective equipment or materials on an existing system.
6. Well casing of existing wells may need to be scrubbed to loosen and remove rust, scale, and biofilm.

Flushing of the Water Supply

1. Develop well to remove all dirt, drilling mud, cutting and debris from the well and screen area.
2. Air hose, drill rods, or bailer should be run to the bottom to lift and remove any materials that have settled and develop screen area.
3. The development and flushing should include moving water in and out of the screen.
4. The well should be flushed for a period after the water runs clear to help remove bacteria and microorganisms.

Treatment with Chlorine Solution (Chlorination)

Chlorination Methods

Many methods are available for the chlorination of a water well system. Although methods vary, any method employed should expose all components of the well and distribution system to a chlorine solution for an extended period of time. Consideration should be given to the well construction, type of pump and pitless adapter, corrosion of internal pump parts, potential for electric shock, exposure to fumes, and water quality concerns that may complicate the disinfection procedure. Homeowners should especially be made aware of these problems and the need for equipment or expert knowledge of well construction/pump installations which only a well driller or pump installer may possess. Consideration should also be given to possible well construction defects or possible sources of contamination causing the bacterial problems in a well.

Two methods of chlorination are commonly used – Simple Chlorination and Bulk Displacement Chlorination.

Simple Chlorination – is the process of adding a small volume of chlorine solution into the top of the water well and then circulating the chlorine into the water supply's distribution system. Simple chlorination should be used for treating existing water supplies only and should not be used for newly constructed wells unless sampling shows the well is not the source of the bacterial contamination. And when used for treating existing wells, it should be used only for the first treatment. If this first treatment is unsuccessful in disinfecting the existing well, the bulk displacement method of well chlorination should be used for all repeat treatments. Newly constructed wells should be chlorinated using only the bulk displacement method.

Bulk Displacement Chlorination – is the recommended method of introducing a prepared chlorine solution into a well. This method involves preparing a predetermined volume of disinfectant solution, and then pouring or pumping this solution into a well. The chlorine solution displaces water in the casing, screen/borehole, and aquifer, replacing it with the chlorinated solution. This helps assure uniform distribution of chlorine throughout the well and the aquifer immediately around the well. This is the most practical method to assure that chlorine is effectively distributed throughout the well and surrounding aquifer.

Water Sampling

The only way to assure that the disinfection process is complete is to sample the raw water once all treatment residual is flushed out. If the sample still shows the presence of coliform bacteria, review the disinfection process used on the well and determine which steps should be repeated or enhanced.

Preventing Bacterial Contamination

If a water well contractor is encountering a high rate of bacteriological contamination in his well installations, serious consideration should be given to (1) better initial development of the well, (2) better sanitary installation procedures, (3) their source of drilling water and chlorination of it, and (4) their disinfection of filter pack prior to placement.

Sanitary Installation Procedures

The presence of coliform bacteria in a well is not a naturally occurring phenomenon in most Michigan aquifers. Organisms which are present in a well can be introduced during the construction phase. They can be introduced by inserting “dirty” tools, or installation of contaminated pumping equipment or filter pack. The excessive use of grease and pipe dope may also contribute to difficulties by harboring bacteria and rendering them inaccessible to a chlorine solution.

Bacteria which can contaminate a water well are everywhere, and the best approach to avoiding problems is to use common sense. Attempt to keep equipment, tools and pipe as free of debris, dirt and grease as possible. Avoid using excessive amounts of pipe dope and grease on pipe joints. Store casing and screens, pitless adapters, and pumps in clean areas up off the ground. When transporting equipment used in well construction, keep it boxed until you are ready to use it. Avoid transporting casing, pumps, and drop pipe on soiled or greasy truck beds. A clean piece of new sheet plastic can be used as a ground cloth when removing drop pipe, submersible pumps or other parts from the well.

Chlorinating Drilling Water and Sources of Drilling Water

One of the most common means of introducing bacteria into a well is by use of contaminated drilling water. Part 127 of Act 368, Michigan Ground Water Quality Control Act, specifically requires all water used in the drilling process to exhibit a chlorine residual. Chlorination of drilling water as it is introduced into a water tank helps avoid bacterial contamination problems in a well. Maintain a 10 ppm chlorine residual in all drilling waters.

Also note that bleach (sodium hypochlorite) is preferred for the disinfection of drilling water. Sodium hypochlorite will not interfere with the properties of the drilling mud. The use of calcium hypochlorite can cause some undesirable coagulation/flocculation difficulties in drilling mud.

Water used in the drilling of a well is required to be clear, chlorinated water conveyed in clean, sanitary containers. Surface water sources (even when chlorinated) are not to be used. “Clear” surface water can harbor numerous organisms which can result in contamination of a well. Some of these organisms (e.g., giardia) require extensive contact time for inactivation which greatly exceed the practical chlorination requirements of a well. Always obtain drilling waters from a municipal supply or water well known to be free of bacterial contamination.

Disinfection Rules

Rule 139(8)
Drilling water shall have a chlorine residual of not less than 10 ppm at the time of use.

Rule 139(9)
Contractor shall notify well owner or building occupants when chlorine is placed in the water supply system.

Rule 161(1)

- After pumping to waste, a well and pumping equipment shall be disinfected with chlorine to obtain a CT (concentration X time) relationship of 1,000 in all parts of the water supply system before pumping the well to waste and flushing out the chlorine solution.
- A contractor shall be responsible for chlorinating that portion of the water supply system on which work has been performed.

Rule 161(4)
A contractor is not responsible for redisinfecting a well or pump as a result of water samples that are collected from a location other than the sampling faucet.

Adjusting pH with Vinegar

Mixing Chlorinated Water

Checking Chlorine Residual

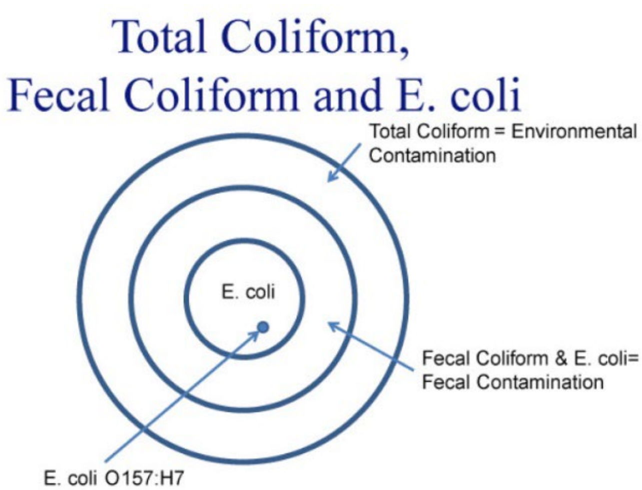
Pumping Chlorinated Water to Bottom of Well

Chapter 11: WATER SAMPLING AND TESTING

Introduction
Michigan's Well Construction Code requires that all new, repaired, or reconditioned wells be disinfected with chlorine to kill bacteria that may have been introduced during construction. Testing is required initially to demonstrate that the water is free of coliform bacteria before the well is put into service. Sample bottles can be obtained from some LHD offices or directly from a Michigan Certified Laboratory.

Coliform Bacteria
Total coliform bacteria are common in the environment (soil or vegetation) and are generally harmless. Coliform bacteria are most commonly associated with sewage or surface waters, they are used as an indicator group to determine the sanitary quality of drinking water. Coliform bacteria distribution in the water supply is not uniform so they may not show up in every sample. If a lab detects only total coliform bacteria in drinking water, the source is probably environmental and fecal contamination is unlikely. However, if environmental contamination can enter the system, pathogens could get in too. Therefore, it is important to find and resolve the source of the contamination.

One particular type of coliform organism, called E. coli, is an indicator of fecal contamination. Most E. coli bacteria are harmless and exist in the intestines of people and warm-blooded animals. However, some strains can cause illness. The presence of E. coli in a drinking water sample usually indicates recent fecal contamination. That means there is a greater risk that pathogens are present. The routine coliform test performed by the EGLE Drinking Water Laboratory detects both fecal and nonfecal coliform bacteria.



The well owner is ultimately responsible for collecting the samples, and the well contractor is responsible for notifying the well owner of their need to collect the samples. Some LHDs may require additional sampling, such as nitrate or arsenic, based on local geological conditions. LHDs may also require special sampling (volatile organic, chloride, etc.) near certain sites of contamination.

Sampling Location
In general, the sampling location selected should reflect the quality of water coming from that portion of the water supply being evaluated. For new installations, the sampling tap at the pressure tank is most commonly used. Samples taken at the sample tap evaluate all components of the well,

including the aquifer. For routine monitoring of both existing and new installations, the sampling tap at the kitchen sink is often used. Samples taken at that location evaluate all components of the well, the aquifer, and the distribution system, including the hot water heater and any treatment equipment. Sampling from the wellhead is the most practical method of determining the quality of water from the well itself. This eliminates the influence from service lines, pressure tanks, valves, etc.

Sampling Procedures

For a recently chlorinated well, sample only after the well water is free of chlorine. Check the water for chlorine residual with test strips or a test kit before collecting samples. Volatile organic compounds (VOC) samples may show disinfection byproducts such as chloroform, bromoform, and other trihalomethanes (THM).

For new wells constructed with PVC plastic casing, be aware that volatile organic analyses may detect by-products of construction such as methyl ethyl ketone (MEK) and tetrahydrofuran (THF). Volatile organic analyses of water from new wells may also detect toluene, which can be a by-product of well construction/development. If toluene is present as a result of construction/development, thorough flushing will gradually diminish its concentration.

The procedure for sampling a well for coliform bacteria is as follows:

1. Flush sampling tap. As a general rule, let the water run at full flow from the sampling point through two pump cycles (or 10 minutes) before collecting the sample. This may not be practical, as it may be difficult to dispose that volume of water in a basement or crawl space. Alternatively, the water may run through another tap, such as an outside or laundry sink tap for two pump cycles, then flush the sampling tap with 10 to 15 gallons of water into a pail before sample collection.
2. Reduce the water flow to provide a stream of water approximately the size of a pencil diameter.
3. Obtain the correct bacteriological (Unit 30) sample container. Do not open sample container until the moment of sample collection. Do not touch the inside of the bottle or cap.
4. Remove seal from sampling container.
5. Carefully remove cap and do not set down.
6. Collect sample (do not fill above designated fill line).
7. Recap bottle immediately.
8. One laboratory sample analysis form must be completed for each bottle submitted.
9. Chill the sample and promptly mail or deliver the sample to a certified laboratory for analysis. Please note the hold time limit is 30 hours, so prompt mailing is important to ensure the sample get to the lab in time for a valid test.

Note: New thermal preservation requirements from the EGLE Drinking Water Laboratory require all water samples to be received within 24 hours of sample collection or be below 6 degrees Celsius (42.8 degrees F).

Coliform Testing Methods
There are several methods for the testing of coliform and E.coli that different laboratories may use. The following tests are the most common methods used.

COMPARISON OF COLIFORM TESTING METHODS		
	Presence/Absence	**Membrane Filtration**
Procedure	Sample collected, reagent added to sample, incubate for 24 hours.	Sample collected, sample run through filter, filter incubated on media for 24 hours.
Results Interpretation	Colorless = negative Yellow = total coliform positive Yellow fluorescent = E. coli positive	Count number of total coliform colonies with green sheen.
Advantages	Results within 24 hours. No need for a confirmation sample if positive.	Can obtain level of concentration of total coliforms.
Disadvantages	No information on level of concentration of total coliforms.	Positive results require a confirmation test, results may take up to 3 days.

Other Common Analyses
Other types of common analyses are explained below with the sample container number in parentheses.

Partial Chemical (32) and Complete Minerals (33)

- Do not touch the inside cap or bottle. Do not rinse the bottle. Fill bottle to bottom of neck.
- Chill sample and transport to the laboratory immediately. The United States Environmental Protection Agency holding time for nitrate (NO_3) and nitrite (NO_2) is 48 hours.

Volatile Organic (36VO)

- Do not collect a sample where chemical odors are detected. Collect the sample in a location free of organic chemical vapors (gasoline, fuel oil, paint, paint thinner, and solvents).
- Do not touch the inside of the cap, septum, or bottle. Do not rinse the bottle or allow the water to overflow. A preservative must be added to the bottles at the time of collection. Do not drop the septum out of the cap. If the septum is dropped or touched, do not use the bottle.
- Fill the bottle so as to exclude all air. Using a low flow, fill bottle halfway then add 4 drops of the included Hydrochloric Acid (HCL), then fill the remainder of the way so water “rounds” above the top of the bottle. Carefully replace and tighten cap. Invert the bottle. If an air bubble appears, remove the cap and carefully add more water to get a rounded top. Repeat until no air remains in the vial.
- Chill the sample and transport to the laboratory immediately.

Nonvolatile Organic (36NV)

- Do not touch the inside of the cap or bottle.
- Do not rinse the bottle or allow water to overflow. Bottles contain a dechlorinating agent. Fill to bottom of bottle neck.

- Chill sample and transport to the laboratory immediately.

Metals (36ME)
- Do not touch the inside of the cap or bottle.
- Do not rinse the bottle.
- Do not filter lead sequential sampling (LSS) samples. The sample will be automatically acidified at the time of sample collection.
- Fill to bottom of bottle neck.
- Transport to the laboratory immediately. Chilling of sample is not required.

Certified Laboratories
The EGLE Drinking Water Laboratory and numerous other private laboratories provide testing services for the evaluation of drinking water. The EGLE lab testing services include physical, chemical and microbiological analyses.

It is recommended that individuals use laboratories certified by the state of Michigan to analyze drinking water samples. A laboratory may be certified, but only for microbiological analysis and perhaps not for VOC, even if the laboratory has the capability to perform that testing. To receive a list of state certified labs, go to Michigan.gov/EGLE and click on "Water," then "Drinking Water," then "Contamination Investigation."

To receive additional information, please visit the EGLE Drinking Water Laboratory website at Michigan.gov/EGLELab.

Water Sampling Rules
Rule 161
(2) Prior to placing well into service:
- ✓ Flush all chlorine (use test kit).
- ✓ Collect 1 or more samples.
- ✓ Coliform shall not be present.

(3) Owner responsible for collection of water sample.
(3) Driller must notify owner of the requirement to sample.
(4) A driller is not required to re-disinfect a well or pump installation if unacceptable results are obtained from a tap other than the sampling faucet.

Rule 158
An approved sampling tap must be installed:
- ✓ At least 8 inches above the floor.
- ✓ In a convenient location.
- ✓ Downturned faucet (preferred non-threaded).

Pressure Relief Valve, Hose Bibb, and Threadless Sample Tap

Chapter 12: ABANDONED WELLS

Introduction
Michigan has approximately 2 million abandoned wells. Abandoned wells, which are often safety or health hazards, can be a tremendous liability for a well owner. There are reports every year of children and pets falling into abandoned wells and of groundwater contamination due to abandoned wells. For this reason, when a well is abandoned for any reason, it should be “plugged” rather than “capped.” This includes "dry holes," wells that are being replaced by a new well, wells that no longer produce water, wells producing water of unsuitable quality, wells in disrepair, or any other case where a well is no longer being used. The term "plugged" means to be filled up with an impervious material. The reason for doing so is to prevent contamination of the fresh water aquifer by foreign material from the surface or by water from other strata which may be of lower quality.

Responsibility for Plugging
The well owner is ultimately responsible to assure that any abandoned well on his/her property is properly plugged. LHDs issuing replacement well permits should include a stipulation on the permit indicating the requirement to plug the existing well. When conducting the final inspection for the replacement well, a field inspection shall also be conducted to assure that the old well has been either properly plugged or repaired and made operational. The well driller is responsible for plugging "dry holes" and other drill holes where a permanent well is not installed.

Locating Abandoned Wells
The following recommendations should be used when trying to locate abandoned wells:

- Look for physical evidence such as casing, well pits, cement slabs, windmills.
- Talk to previous owners, neighbors, contractors, inspectors.
- Search for records such as permits, well logs, bills, receipts, photographs.
- Use equipment and tools such as a metal detector, a detectable tape, or a magnetometer.

For more detailed information on locating abandoned wells, refer to the EGLE Factsheet, “How to Locate Abandoned Wells.”

Permit Requirements
LHDs routinely make plugging of the old well a requirement on the replacement well permits they issue. Contractors and well owners must understand that since it is a permit requirement, any changes to the permit must be discussed with the LHD prior to well construction. For this reason, drillers need to make plugging the old well a part of their bid to drill the new well.

Plugging Materials
The common materials that are now available for plugging abandoned wells are: bentonite grouts/slurries (either powdered or granular), coarse grade bentonite (chips or pellets), neat cement, and concrete grout.

Coated bentonite pellets are **not** recommended for plugging abandoned wells due to the detection of acetone in some pellet coatings.

Bentonite Grouts/Slurries:
This category of well plugging materials includes powdered and granular bentonite slurries. They all consist of bentonite solids placed in water, a mixture that remains pumpable for a short period of time. The plugging of a well is generally done in one continuous operation with placement from the

bottom of the well upward by pumping the material through a tremie pipe. Upon placement, the bentonite particles in the slurry absorb water and swell in place to form a pliable seal of low permeability. Their use in plugging wells in Michigan is restricted generally to drift wells. Mixing directions and yield of product will vary greatly between the different bentonite types and manufacturers. Some products may require considerable caution and/or experience in their use to consistently achieve acceptable results.

Coarse Grade/Pelletized Bentonite:
These plugging materials consist of bentonite in crushed, chipped, granular, or compressed states to achieve particle sizes of 1/4 to 3/4 inch. They are intended for use and placement by pouring through the water column and cannot be pumped. Placement should be performed slowly and accompanied by tamping or measurement to check the level of accumulated bentonite and insure that 'bridging" has not occurred. The bentonite must be prescreened before placement to remove all fine powder that accumulates in the shipping containers (bags). Screening is intended to eliminate the fines that will immediately hydrate upon coming in contact with water and cause “bridging” of the bentonite inside the casing. Bentonite chips shall be poured slowly, with rates not to exceed 50 lbs. in 3-5 minutes. Slower rates of placement are required in smaller diameter wells. Once in place, the bentonite chips swell to form a high solids, low permeability plug.

Neat Cement/Concrete Grouts:
Neat Cement consists of 1 bag (94 lbs.) of Portland or Portland Limestone cement mixed with not more than 6 gallons of water. Neat cement grout is placed from the bottom of the well upward in one continuous operation until the well is filled. This is generally done by pumping the grout through a tremie pipe extended to the bottom of the well. Concrete grout consists of 1 bag of cement, an equal volume of sand, and not more than 6 gallons of water. Concrete grout is difficult to pump using conventional grout pumping equipment. Placement is largely restricted to the dry portion of an abandoned well or dry hole.

Obstruction Removal
Abandoned wells need to be checked for obstructions before they are plugged in order to verify that anything that may interfere with the plugging operations has been removed. Drop pipes, check valves, pumps, drawdown seals, and any accumulated debris, must be removed from the well to enable the well drilling contractor to properly plug the well. In cases where the drilling contractor cannot eliminate an obstruction from an abandoned well, the driller should notify the LHD and indicate the obstruction removal efforts he/she performed under “comments” on the Abandoned Well Plugging Record. Obstruction removal tools are termed “fishing tools” by the well drilling industry. They are specialized in design, require drilling rigs or pump hoist trucks to use, and take experienced workers to operate. Obstruction removal activities should be conducted under the supervision of a registered well drilling contractor. Homeowners are ill equipped to attempt obstruction removal activities.

The depth of the abandoned well should be measured to allow the well drilling contractor to estimate the total volume of plugging material necessary to completely fill the abandoned well casing and/or borehole. Casing size and depth are used to calculate the required volume of plugging material. The tables at the end of this document are useful in estimating volumes of plugging material necessary for typical well plugging jobs.

Wells Terminated in Unconsolidated Formations (Drift Wells)
Screens in small diameter “point” or driven wells and in typical 2-inch to 6-inch drift wells are generally not removed when the well is abandoned. In situations where the casing and screen are to

be removed, the screen should be removed first, then as the casing is being removed, the hole should be kept full of the grouting material, adding more grout from time to time during the process. A few days after the casing is removed, a visit should be made to the site to determine if settling has occurred. If settling of less than 20 feet has occurred, the unfilled portion of the borehole may be refilled with an approved grout by pouring from the surface.

Wells Terminated in Bedrock Formations (Rock Wells)
Where an abandoned well is determined to be terminated in bedrock, the well must be plugged with neat cement or concrete grout. Geologic information documenting the presence of bedrock or drift formations are typically identified on the original well drilling record for the well being abandoned. Alternatively, where no record exists for the abandoned well, records of other nearby wells may be used to establish typical geologic conditions for the area, including the presence and depth of bedrock.

When calculating the amount of plugging material necessary to plug a rock well, the normal procedure is to determine the casing and borehole volume, then add 20 percent for material loss into the rock formation.

In some rock formations, fractures or porous conditions may occur. These conditions are termed “lost circulation zones” and must be addressed in order for the abandoned well to be effectively plugged. Fractured intervals within a rock bore hole may be filled with aggregate (peastone) mixed with neat cement or a commercial plugging additive. The remainder of the well shall be plugged using standard neat cement placement procedures. Where porous conditions are encountered, a commercial plugging additive like cellophane flakes, ground walnut shells, or medium ground bentonite granules, etc. added to the neat cement or concrete grout typically will be employed to reduce loss to the formation and accomplish plugging the well.

When using a neat cement or concrete grout slurry for plugging rock wells, the plugging material shall be pumped from the bottom of the well to the surface using a tremie pipe. If simultaneously placing aggregate to fill fractures, the tremie pipe must be raised as the plugging material is pumped to keep it from becoming stuck in the well by the aggregate.

Flowing Wells
In most cases, neat cement grout pumped directly into the well will stop the flow. However, the plugging of a flowing well can present unusual difficulties and hidden problems which must be handled properly. An inaccurate assessment of the situation can result in water breaking out around the casing or channeling of the water through porous drift formations with subsequent discharge to the surface either at the well or in the vicinity of the well.

It is important to know the depth of the strata from which the flow originated, the discharge rate of the well, and the hydrostatic head characteristics of the well. It is also important to know how (or if) the well was grouted when it was installed. The majority of problems associated with plugging flowing wells result from improper flow control, not stopping the flow before starting the plugging operation, or the grout column weight being inadequate to “hold down” the flow.

Due to their upward, continuously discharging flow, flowing wells often erode void spaces in the formation just below and along the well casing. Because the voids must be filled before the well casing can be plugged effectively, such circumstances frequently require many more times the calculated grout volume than you would expect when calculations are based upon the well casing diameter and casing length alone.

Situations are encountered where the artesian pressure of the formation exceeds the weight of the grout slurry columns. These circumstances require a means of increasing the weight of the grout slurry or provisions for additional flow control. A reliable approach involves (1) stopping or controlling the discharge, and (2) determining the hydrostatic pressure head.

When the head pressure is less than 10 psi, the first option is usually to install a casing seal with a discharge valve on the well head. Once this piping is in place, neat cement is pumped into the well against the pressure head. After delivering the calculated volume of plugging material, the valve is closed, and the slurry is allowed to set. The casing seal and closed valve prevent the grout from washing back out of the abandoned "flowing" well.

Where higher head pressures exist (greater than 10 psi), stopping the flow by installing a casing riser may be more effective. Casing risers may extend 20-25 feet above grade but become less practical at greater lengths. When using a casing riser, the concept is to have the discharge water from the well retained inside a vertical well casing extension that is attached to the existing well casing. The water will rise up inside the casing extension to the point of the well's natural static level, which may be many feet above grade. Once this occurs, the "flow" naturally stops. A tremie pipe can be placed down the casing riser to the bottom of the well. The neat cement grout can be pumped into the well without risking it being expelled because there is no longer any "flowing" discharge.

In some instances, artesian pressures are so great that containing the flow by extending the casing or drive pipe is not possible. The drive pipe can be fitted with valves and connections to allow pumping of neat cement directly into the well and annular space. In these extreme cases, large volumes of plugging material may have to be placed under high pressure. The most reliable means of completing a plugging job of this nature is by the well drilling contractor subcontracting with an oil field cementing firm.

The EGLE Source Water Unit may be contacted for more information concerning this alternative. More detailed information on plugging flowing wells can be found in the EGLE's "Flowing Well Handbook" at Michigan.gov/WaterWellConstruction.

Some older well casings may be deteriorated to the point that placing grout through them under pressure is impractical. There may also be washouts along the outside of the casing where holes in the casing are present and the flow has been discharging. In these cases, an outer drive pipe and the use of a plugging design utilizing a tremie pipe will usually be necessary.

Plugging Records

An Abandoned Well Plugging Record must be filed with EGLE and the LHD. The report must include the type and amount of plugging material used and the method of placement of the plugging material. A Water Well and Pump Record form may also be used for this purpose. Abandoned Well Plugging Records may also be filed electronically using the EGLE Wellogic Program. For more information on using Wellogic, please email the Wellogic staff at Wellogic@Michigan.gov.

Abandoned Well Rules

Rule 101 and 105

- Definitions of an abandoned water well and a temporarily abandoned well.

Rule 106

- Only well drillers can plug wells, not pump installers.

Rule 162

- Abandoned wells shall be plugged by a well drilling contractor or by the well owner.
- Public water supplies shall be plugged by a registered well drilling contractor only.
- Obstructions shall be removed, if possible, before plugging.
- Abandoned wells shall be plugged when public water is installed.

Rule 163

- Wells that terminate in drift materials (sand, gravel, clay, etc.) shall be plugged with neat cement, concrete, or bentonite.
- Wells that terminate in bedrock (shale, sandstone, limestone, etc.) shall be plugged with neat cement or concrete from the bottom up to at least 20 feet above the bedrock.
- Other materials are approved to plug gravel or cavernous, creviced, or fractured bedrock.
- Flowing wells shall be plugged with neat cement or concrete.
- Methane wells shall be plugged with neat cement or concrete.

Rule 164

- Bentonite chips or bentonite pellets shall be poured slowly to prevent bridging and fine particles shall not be used.
- Water shall be put into well to promote expansion of the bentonite chips.
- Plugging slurries shall be placed through a tremie pipe from the bottom of the well to the top.
- Other materials and methods may be used if approved by the LHD.

Rule 165

- Large diameter well shall be plugged by layering bentonite chips and clean soil.
- Granular bentonite may be used in place of bentonite chips.
- Neat cement or concrete may be poured if the well has been dewatered before plugging.
- Remove upper 3 feet of concrete crock or tile.

Rule 167

- Illegally drilled wells shall be plugged.

Rule 168

- The LHD can order an abandoned well or dry hole plugged.

Rule 169

- Well owner is responsible for plugging their well.
- Improperly constructed or located wells shall be plugged by the well drilling contractor.

Rule 170

- A temporarily abandoned well shall meet current code.
- A temporarily abandoned well shall be disconnected from any water distribution piping and shall have the top of the casing securely capped.

Rule 175

- An Abandoned Well Plugging Record shall be submitted within 60 days of plugging an abandoned well or dry hole.

Chapter 13: CROSS CONNECTIONS

Introduction
A cross connection is any actual or physical connection between a potable (drinkable) water supply and any source of non-potable liquid, solid or gas that could contaminate drinking water under certain circumstances. Backflow is the reverse flow of water or other substances through a cross connection into the treated drinking water distribution system. There are two types of backflow: backpressure and back siphonage. Backflow contamination can be prevented by installing proper backflow-prevention devices such as vacuum breakers, air gaps on outlet pipes, anti-siphon devices and backflow preventers.

The most common cross-connection in the home is the garden hose attached to the outside faucet. The outside faucet requires a mechanical protection device such as a hose bibb vacuum breaker to prevent possible contamination of the public water supply. Hardware stores sell the home outside faucet assembly with the built-in vacuum breaker.

A list of approved yard hydrants can be found on the Well Construction Program website at Michigan.gov/WaterWellConstruction.

Cross Connection Rules

Rule 174

- An approved water supply and an unapproved water supply shall not be connected.
- Yard hydrants with buried stop and waste valves shall not be installed.
- Water supply system shall be designed, operated, and maintained to prevent contamination from cross connections.

More detailed information on cross connections can be found in EGLE's Cross Connection Rules Manual. It contains detailed information on the rules, protective devices, hazards, responsibilities, local Cross Connection Control Program, and containment and isolation.

Hose Bibb Vacuum Breaker

Air Gap on Flowing Well

Dual Check Valve

Chapter 14: WATER WELL AND PUMP RECORDS

Introduction
Well records describe the construction details of groundwater wells. Data such as well depths, types, thicknesses of geologic formations penetrated, and groundwater pumping rates are obtained from well records. Contractors are required by state law to file the well records after well completion.

Well record data is commonly used for groundwater mapping and statistical analysis by: the state of Michigan, LHDs, consultants, geologists, and universities. The data is used by many EGLE applications such as the Water Well Viewer, Drinking Water GIS, GeoWebFace, and the Water Withdrawal Assessment Tool. The data is also available for download from Wellogic's website.

Electronic Well Record Submittal (Wellogic)
Wellogic is the internet-based data entry program developed by the state of Michigan to provide an easy method for water well drilling and pump installation contractors to submit well records. Electronic submittal satisfies state and county well record submittal requirements, as required by Part 127, Act 368 of the Public Acts of 1978, as amended and rules. Well records from January 2000 and later are being entered into Wellogic by contractors, LHDs, and EGLE. Both Water Well and Pump Records and Abandoned Well Plugging Records are being entered into the database.

Some of the benefits of using Wellogic are: access to hundreds of thousands of water well and abandoned well records across the state; aids contractors in developing bids; increases efficiency in submitting well records; improves the quality of the data entered; reduces mailing costs and paper file storage; and allows contractors to renew their certificate of registration electronically.

Any questions regarding electronic well record submittal should be emailed to the Wellogic staff at Wellogic@Michigan.gov. Visit the Wellogic website at EGLE.State.MI.US/Wellogic/Login to request a Wellogic account.

Water Well Record Rules
Section 12707 and Rule 175 Well Records

- Water Well and Pump Records and Well Plugging Records shall be submitted within 60 days. The contractor shall retain a copy of the well log and shall provide a copy of the well log to the owner, and two copies to the LHD.
- The LHD shall review and forward one copy to EGLE within 30 days.
- Only those forms approved by EGLE shall be used.
- Electronic submittal of the Water Well and Pump Record via Wellogic is strongly encouraged.
- Drive point wells shall be submitted on a form.
- Contractor shall record the geological thicknesses at the site and it shall be available for inspection.
- The well log shall be signed by the registered contractor only.
- If a contractor fails to submit a well log within 60 days, or fails to maintain a drilling record, the LHD or EGLE may require geophysical logging of the well.

Rule 176 Pump Installation Records

- Pump installation records shall be submitted within 60 days. The contractor shall retain a copy of the well log and shall provide a copy of the well log to the owner, and two copies to the LHD.
- The LHD shall review and forward one copy to EGLE within 30 days.

Rule 268 Dewatering Well Records

- The contractor shall retain a copy of the well log and shall provide one copy of the well log to the person responsible for plugging the dewatering well, and two copies to the LHD.
- Dewatering well drilling data shall be reported on a dewatering well record form.
- Contact EGLE for additional information on dewatering well record submittal.

Well Record Completion

Below is an explanation of how to complete the Water Well and Pump Record (electronic or hard copy). Water well records are required to be accurate. It is strongly recommended that field notes be kept on the job site and later transferred to reconstruct data needed to complete the record. This will avoid having to depend on memory to reconstruct data needed to complete the record.

Location of Well

The location of a well is very important since the formation information is useless without the correct well location. There are several ways to find this location information. In order of increasing difficulty, they are: look for the legal property description on permits for the well, septic system, or building; ask the owner for the legal description from the tax records for the property; look up the property in a commercial plat book; use a county road map to determine the required information.

Latitude and Longitude

The latitude and longitude are obtained by using a global positioning system (GPS) device or mapping website. The GPS device receives information from satellites that orbit the Earth, and it tells you exactly where you are located on Earth. It is important that the GPS device be given plenty of time to obtain an accurate reading, communicating with as many satellites as possible. Prematurely marking the location with the device can lead to a false reading and a location that is not accurate. In lieu of using a GPS device, websites such as Water Well Viewer or Google Maps are excellent tools to obtain the latitude and longitude for a well.

The contractor must make sure that their GPS device is reporting the latitude and longitude in "decimal degrees." The default setting for most GPS devices is "degrees/minutes." In "decimal degree" format, the latitude will look similar to "42.12345" and the longitude will look similar to "-83.12345."

County

If the well is near a county line, be sure that the proper county is listed. Do **not** abbreviate the county name.

Township Name

A county is divided into several townships. Most townships are 6 miles by 6 miles, or 36 square miles. Some townships in Michigan contain more than 36 square miles.

Town and Range Number
These numbers are "grid" numbers used by surveyors to locate a piece of land in the state. For example, a vertical "grid" number, or town number, could be T26N or T8S. Examples of a horizontal "grid" number, or range number, could be R15W or R15E.

Section Number
Most townships are divided into 36 sections. Each section is one mile by one mile and contains 640 acres.

Where there is a lakeshore, the numbering system may be more irregular. The section numbers are the small numbers evenly spaced in one-mile square sections on the map. Each section number has established a range of coordinates that fall within its borders.

Distance and Direction from Road Intersection
Complicated locations should be described as if you were describing where the well is located at the site. It is critical to have an accurate distance and direction when resolving well location issues. Contractors should **never** simply put the well address in this field. Here are some acceptable descriptions:

"220 feet north of Perry Road on US 23, 375 feet west of US 23"
"Farm Lane in Lakeview Subdivision, Lot 18, 35 feet south of Farm Lane"
"On Pleasant Road 1/4 mile east of Maple River, on Shady Lane, 125 feet west of Lane"

Street Address and City/Zip of Well Location
If the owner's address is not the same as the address of the well, this line must be filled out with the address of the well. Be sure to list the street number, street name, closest village, town, or city, and the zip code. If the well is in a new subdivision, obtain the street number if available or a lot number if the street number is not available.

Formation Description
Describe the predominant material penetrated under "Formation" such as clay, silt, sand, gravel, shale, sandstone, or limestone. Each formation drilled should be described. Avoid general terms such as "bedrock" or "drift." Terms such as sandy, silty, or clayey can be used to describe mixed formations. Color is appropriate for more fully describing some formations as well as terms describing texture as soft, hard, coarse, medium fine, fractured, or porous.

Enter the thickness of each formation in feet in the column labeled "Thickness of Stratum." In the column "Depth to Bottom of Stratum" enter the total depth drilled to that point. Electronic submittal of the well record only requires the depth to bottom to be entered. The thickness is calculated automatically.

Owner of Well
The address of the well owner is recorded in this space. Make sure that the street number, street name, city, and zip code are listed. If this address is the same as the well location, check "yes" after the question "Address Same As Well Location?" If this address is not the same as the well location, check "no" and fill out the line to the left asking for "Street Address and City of Well Location."

Well Depth
Record the completed well depth. This may be different from the total depth drilled if the formation was backfilled.

Date of Completion
Record the appropriate date of completion of the well. This may be the date the well was drilled or it may be the date of the pump installation. Refer to Rule 102 of Part 127 of Act 368, P.A. 1978 for clarification.

Well Type
Choose the appropriate well type.

Drilling Method
Choose the drilling method or methods used.

Well Use
Choose the type of well according to the following definitions:

"Household" refers to a private water supply serving one residence only. Wells serving apartments, several houses, gas stations, stores, etc. are not household.

"Irrigation" refers to irrigation wells used for plants, livestock, or other agricultural purposes and not for drinking water.

"Industrial" refers to wells that are used to supply water for industrial processes, fire protection, or similar non-potable uses.

"Test" refers to wells or holes drilled for aquifer testing or other temporary uses.

"Type I Public" refers to wells providing year-round service to a building or community with at least 15 living units or 25 residents. Examples: municipal wells, subdivisions, large apartment buildings, mobile home parks, and nursing homes.

"Type II Public" refers to wells providing water at least 60 days out of the year to at least 15 service connections or 25 individuals. Type II wells are all noncommunity supplies, which means that people are not living permanently at the facility using water. Examples: schools, gas stations, restaurants, and churches.

"Type III Public" refers to wells that supply water to the public, but that do not fall under any other category. Examples: apartments with less than 15 living units and small businesses with less than 25 employees.

"Heat Pump-Supply" – A well that supplies water to an open loop geothermal system. If one well is used for both the household supply and the heat pump supply, choose both well uses.

"Heat Pump-Return" – A well to dispose of water from an open loop geothermal system.

Do not list the well use as "office," "dairy farm," "fire suppression." The correct well use must be chosen from the defined uses listed above.

Casing and Borehole
Indicate the type of casing material, whether it is threaded, glued, etc., the diameter (inches), the length installed (feet), and the SDR number if PVC plastic casing is used. The "Borehole" diameter refers to the size of the hole that the casing is installed in. The "Height Above/Below Surface" refers

to the termination of the casing or pitless adapter above or below the ground surface in feet. Check the appropriate box if any casing fittings are used.

Static Water Level
This is the water surface level measured **before** the well is pumped or bailed, but after completion of well development. Indicate if the well is flowing and provide the **unrestricted** flow rate in gpm.

Well Yield Test
The pumping level is the water level measured **after** the pump is turned on and run until the water level in the well stabilizes. During certain well development procedures, such as air, it is not possible to measure the actual pumping water level. It is acceptable to note the depth at which air development took place. However, the contractor should note "air" on the well record. This will tell anyone interpreting the well record that it is not an actual pumping water level measurement. The development time in hours and the well production in gpm must also be noted.

Screen
"Type" is the screen material (stainless steel wire wrapped, PVC slotted, or other material). "Diameter" is the nominal diameter of the screen in inches. "Slot" is the size of the screen openings (for example, 12 slot). "Length" is the length of the screen in feet. "Set Between" is the depths that the screen is set between in feet. "Fittings" refers to additional fittings on the screen, such as a neoprene packer, Bremer check, or blank. A "Blank" is a piece of pipe or casing set above the screen in a telescoped installation.

Well Grouted
Grouting includes only those materials approved in the well construction regulations such as neat cement, concrete, heavy bentonite slurry, or other bentonite grouts. Note the number of bags of grout used, additives, and grouting method. Do not enter brand names in the grouting materials or additives section.

Wellhead Completion
Mark the type of casing termination. In some cases, more than one box can be checked, such as "pitless adapter" and "12 inches above grade."

Nearest Source of Contamination
Possible contamination sources include: storage tanks or storage areas for chemicals, gasoline or oil storage tanks, buried sewers and sewer connections, septic tanks, drainfields, dry wells, animal yards, and privies. The distance and direction of these contamination sources from the well should be indicated. Do **not** enter vague distances such as "50+."

Abandoned Well Plugged
Complete this section if the abandoned/old well was plugged at a replacement well site. If the abandoned well being plugged is **not** at a replacement well site, a separate Abandoned Well Plugging Record needs to be completed.

WSSN and Source ID/Well Number
Water Supply Serial Number and Source ID/Well Number are fields for public water supplies **only**, specifically Type I and Type II. Those numbers can be obtained from the LHD (Type II) and from EGLE (Type I).

Pump
Check “Not Installed” if no pump is installed in the well. Otherwise, complete all items in this section. If the construction was a “Pump Installation Only” check the box and complete the location, owner of well, well depth and date completed, pump information, and water well contractor’s certification boxes. If a used pump is installed, all of the pump information is still required.

Pressure Tank
Check “Not Installed” if no pressure tank is installed. Otherwise, complete all items in this section.

Remarks
This box can be used to note any unusual characteristics of the well or unusual occurrences during its construction. Examples: lost circulation zones, water quality information, flowing well details, deviation issued, temporary casing.

Drilling Machine Operator and Pump Installer
The name of the person who actually drilled the well and installed the pump should be entered here. Rig operators and pump installers who plan on becoming registered should keep copies of well logs for wells they drill and/or install the pumps so that they can submit them with their application for registration. Do not list multiple names for drilling machine operator or pump installer.

Water Well Construction Certification
Water well records must be signed by the registered contractor of the well firm. An owner-installed well should be indicated by printing “owner” in the space for the registration number. The contractor should keep in mind that all well records are required to be accurate and that the following statement is above the contractor’s signature: “This well and/or pump installation was performed under my registration.” Falsification of water well records is a violation of state law which may result in suspension or revocation of a contractor’s registration certificate.

Chapter 15: INSPECTIONS AND EVALUATIONS

Introduction

A final inspection is an onsite assessment of a newly completed water well/pump system to determine if the water well location and visible components of the well and water supply system comply with the State Well Code and local water well permit conditions and any abandoned wells have been plugged.

LHDs are required as part of EGLE's MPRs for private wells to conduct a final inspection on not less than 10 percent of new well installations. Most LHDs achieve a much higher percentage of final inspections, and some even achieve 100 percent. The state average is approximately 63 percent .

A Predrilling Site Review or RCI (made during well construction) are not Final Inspections because they occur before the water system is completed.

The minimum items checked, and activities performed during a Final Inspection are:

1. Water well location to ensure adequate separation from contamination sources.
2. Casing termination method (pitless adapter, well house, basement offset) and well cap.
3. Visual check of sealing of annular space surrounding the water well casing.
4. Water system component materials (water well casing, water service line, etc.).
5. Pump installation (pump, pressure tank, piping, sample tap, valves, and controls).
6. Collection of bacteriological water sample (by owner or owner's authorized representative) and nitrate/partial chemical analysis is recommended.
7. Plugging abandoned water wells at replacement water well sites.

If code violations are frequently observed while performing final inspections, increasing the rate of final inspections will bring about improved compliance. Sanitarians should use a final inspection checklist for each final inspection.

As part of the final inspection of the water supply, the LHD will typically make an as-built sketch of property which is located either on the well permit or the final inspection form. The LHD will note items such as the correct water well location and measured distances to any sources of contamination (e.g., septic tanks and drain fields, fuel tanks, animal yards, etc.).

Approval

If the well construction meets code, the well record is satisfactory, and the water samples are satisfactory, the LHD will provide the well owner with a written approval. This may be in the form of a letter, inspection tag, finalized permit, or another document. This ensures the well owner that the newly completed water system is suitable for the intended use.

How to Conduct an Investigation on an Existing Water Supply

This outline was prepared to aid the LHD in conducting a complete evaluation of an existing water supply. Properties going through refinancing or wells with water quality issues may prompt the LHD to conduct such an investigation.

Office Investigation

1. Identify exact location of well on county map or plat book.
2. Geological study of the area (well records, groundwater database information, geological maps, hydrogeological studies, etc.).
3. Locate well record for well in question (Wellogic and scanned well records).
4. Review facility file.
5. Review bacteria and partial chemistry history of the water supply.
6. Contact well driller(s) for well construction details for area wells if no well records are available for immediate vicinity.
7. Contact owner to make arrangements for investigation. This may include removal of pump or exposure of pitless adapter (by the owner). If investigation involves temporary shutdown of pumping equipment, owner should be notified so arrangement for an alternate water supply can be made.
8. Prepare materials used for field evaluation such as a grout probe, flashlight, tape measure and evaluation forms.

Field Investigation

1. Determine number of wells located on property. Ask owner if there are any abandoned wells at the site.
2. Review any records the owner may have or record information from the owner regarding the water supply (drilling contractors billing invoice, repair bills, well record, etc.).
3. Survey the well site and prepare a sketch on the survey form, including:
   - Location of potential contamination sources, such as septic systems, sewer lines, fuel tanks, animal feedlots, etc.
   - Location of buildings, roads, and driveways.
   - Location of well(s) and isolation distances from contamination sources.
   - Water service line location.
   - Utility line locations (buried or above grade).
   - Property lines.
   - Surface water (ponds, lakes, rivers, ditches).
   - Prominent topographic features (hills, knolls, gentle sloping, etc.).
4. Pump details
   - Type of pump (submersible, deep well jet, shallow well jet, hand pump).
   - Brand name, model number and horsepower.
   - Rated pumping capacity.
5. Pump installation
   - Location of pump.
   - Pump setting or drop pipe length.
   - Check valve locations.
   - Piping materials (type and specification markings).
   - Protection around buried suction lines.
   - Electrical wiring installation.

6. Pressure tank
   - Number and Type of pressure tank (galvanized steel, bladder, diaphragm).
   - System operating range (from pressure gauge or look at pressure switch for operating range).
   - Brand name and model number.
   - Total tank capacity and tank drawdown (available from manufacturers sizing charts, if brand and model are known).
   - Record measured tank dimensions if brand and model are not available.
   - Note if pressure tank is waterlogged.
   - Location of tank.
   - Piping layout.
   - Pressure switch and pressure gauge (is it functioning?).
   - Pressure relief valve.
   - Sampling tap near tank (high enough to permit sampling?).
7. Distribution system
   - Water service line and distribution piping material (copper, galvanized steel, PVC, PB) – ASTM markings – pressure ratings – NSF-pw (potable water) certification.
   - Check for leaks, corrosion, and other maintenance problems.
   - Cross-connection survey (submerged inlets, unapproved yard hydrants, boiler feed lines, hose bibbs, water closets, etc.).
8. Water treatment devices
   - What type of treatment, if any, is present? (e.g., softening, iron removal, aeration/filtration, reverse osmosis, distillation, chlorination, ultraviolet disinfection, carbon filtration).
   - Are the treatment devices adequately maintained and functioning properly?
   - Were the treatment devices installed to treat aesthetic water quality problems or bacteriological, nitrates, VOC, or other compounds of public health concern?
   - Record the brand and model name of any treatment equipment.
9. Pitless adapter installation
   - Determine type (weld-on adapter, clamp-on adapter, thread-on unit).
   - Determine brand name and model. Since pitless adapters and well caps are sold together, this can usually be determined by checking well cap for manufacturer's name. Becoming familiar with the various makes and models available will help the sanitarian evaluate pitless adapters.
   - If trench is open, inspect the connection to the casing for leaks. For weld-on adapters, carefully check integrity of welds for water tightness.
10. Well caps and seals
    - Is cap or seal intact and free of cracks or severe corrosion?
    - Check well cap for presence of screened vent and proper vent construction, where required.
    - Check to see if vent is unobstructed and functioning. (This can be done by running pump and checking for inward air movement during pumping and outward air movement during well recovery).
    - Check caps and sanitary seals to see if they are securely attached to casing.
    - If vent is unscreened (e.g., old-style overlapping cap), remove cap and check for evidence of insects on underside of cap or in well casing.
    - Check for secure attachment between well cap and protective electrical conduit.

11. Well casing
    - Examine the outside of the casing to determine if there are any cracks, corrosion, etc.
    - Examine interior of casing with flashlight or mirror when well cap is removed.
    - Determine casing material (black steel, galvanized steel, or SDR 21 or SDR 17 PVC).
    - Note any casing markings that may be visible (ASTM specifications, weight per foot wall thickness, manufacturer, or supplier name).
12. Well diameter
    - Measure with tape – common well casing sizes are noted by inside pipe diameter (I.D.). The measurement of outside pipe diameter (O.D.) will be slightly larger – e.g., 4-inch well casing is 4.026 inch I.D. and 4.5 inch O.D.).
    - Upper casing size on thread-on pitless units will be 1-inch larger than nominal casing size (e.g., a 2-inch well will have a 3-inch upper casing.).
13. Well depth
    - Can be measured with weighted drop string or tape after pump and drop pipe have been removed from well.
      WARNING: Do not put anything into well unless all internal components (drop pipe, pump) have been removed.
    - Usually measured only during problem investigations.
    - Downhole cameras can be used to determine well depth and casing depth.
14. Casing depth (bedrock wells only)
    - For steel casing, an electromagnet can be used after pump and drop pipe have been removed from well.
    - Usually measured only during problem investigations.
15. Grouting
    - Grouting is best evaluated during actual grouting operation. This allows the sanitarian to determine if grout is being placed from bottom up to surface and the total depth of grouting. Evaluation after well is complete is best done while the excavation to install the pitless adapter is still open or immediately upon completion of the well. Grout from the surface to 5 feet below grade is usually removed during pitless adapter installation.
    - In high bedrock areas, it may be necessary to have the homeowner excavate to the top of the bedrock to evaluate grouting. This allows evaluation of the seal at the bedrock/overburden interface.
    - Check material around the casing below the pitless unit. If evaluation is done prior to pitless adapter installation, there will often be grouting material visible on the ground surface around the well casing.
        - Neat Cement – If grouting material is neat cement, a shovel may be used to expose a few feet of the grout, but generally the total depth of grouting cannot be determined. Neat cement will appear as a hard, rock-like material, gray to greenish-gray in color.
        - Bentonite grout – An acceptable bentonite grout will appear as a pliable clay with a peanut butter or gelatin consistency, gray to brownish-gray in color. If granular or coarse grade bentonite were used, the individual particle configuration maybe recognized. An unacceptable bentonite drilling mud slurry will appear as a watery clay mixture, tan to gray in color. A shovel or soil probe can be used to evaluate bentonite grouts.
        - Evaluation using soil probe – This process is discussed in the Well Grouting chapter of this manual.
    - For wells in high bedrock areas, where the casing length is relatively short 25-35 feet, or where it is suspected to be less than 25 feet, examination inside the well may determine if there is a leakage problem due to leak of grouting. Look down the casing using a

flashlight or mirror deflecting sunlight to determine if any water is cascading off the end of the well casing. It may be necessary to operate the pump to lower the water level a few feet below the casing. If water is cascading off the end of the casing, grouting is either not present or considered inadequate. This evaluation procedure may not be possible in all wells due to variations in pitless adapter design and casing diameter.

- A tracer dye may be placed in an excavation around a well to detect leakage in the annular space. Place powdered fluorescein dye around the well and flood the excavation. Pump the well for an extended period of time and keep the excavation flooded. The presence of visible dye in the well water indicates a defective seal around the casing. If no dye is visible, a sample should be collected in a partial chemical bottle and submitted to the EGLE lab for fluorescein dye analysis. The inability to detect fluorescein dye does not mean that the annular space is adequately sealed, since many factors (e.g., well depth, pumping length, well efficiency, interactions of dye with solid, etc.) influence the effectiveness of this method.

16. Note any unusual features such as flow of water around casing (loss of confining formation on flowing well), open annulus space or depression around well casing.
17. Disinfect the water supply if pump or drop pipe were removed or if any equipment was placed into the well during the investigation.
18. Collect bacteriological and partial chemical samples where appropriate.

Inspect Pressure Tanks

Evaluate Backflow Prevention

Use Downhole Camera

Inspect Wellhead

Procedures for Field Evaluation of Pump Capacity

Introduction

Simple field procedures may be utilized to estimate well production and evaluate pressure tank function. This information is essential for determining if a water supply will adequately meet demands within the facility. Determination of pump capacity should become a routine part of water supply evaluations, especially for mortgage evaluations and wells serving public facilities where pump capacity is critical.

Pump Capacity Evaluation

1. Open the sampling tap near the pressure tank and drain water from the tank until pressure drops to the pump cut-in pressure. Make sure no other water is being used in the building during the test. On a submersible pump installation, it is often necessary to listen for a "click" in the pressure switch in order to signal the starting of the pump. Observe the pressure gauge and note the pump cut-in and cut-out pressures.

2. When the pump starts, immediately close the sampling tap, and measure the length of time required for the pump to fill the pressure tank and shut off. The length of time between the pump cut-in pressure and cutout pressure is the *pump running time.*

3. After the pump stops, open the sampling tap and using a 5-gallon container measure the volume of water that can be drained from the tank before the pump cut-in pressure is reached. When the pump starts, immediately close the tap and discontinue volume measurement. The volume of water measured is the *usable tank volume.*

4. Divide the usable tank volume by the pump running time to determine pump capacity.

   EXAMPLE
   Pump running time = 30 seconds or 0.5 minutes
   Usable tank capacity = 6.2 gallons
   Pump capacity = 6.2 gallons / 0.5 minutes = 12.4 gpm

Pressure Tank Evaluation

By comparing the observed usable tank volume to the manufacturer's specifications for a particular model pressure tank, one can also determine if the pressure tank is functioning properly.

EXAMPLE
6.2 gallons of water were drawn from a 20-gallon hydropneumatic bladder type tank at an operating pressure of 30-50 psi. (Note: usable tank volume is inversely related to the operating pressure i.e., if the operating pressure of the system is increased from 30-50 psi to 40-60 psi the usable tank volume will decrease.) By checking the manufacturer's data, we find that the total tank volume is 20 gallons and at a 30-50 psi setting, the tank should yield about 0.31 or 31 percent of its total volume as usable tank capacity. 20 gallons x 0.31 = 6.2 gallons. Since 6.2 gallons were withdrawn during the field test, it appears that the pressure tank is functioning in accordance with the manufacturer's specifications.

Chapter 16: PROBLEM WELLS

Flowing Wells

Flowing artesian wells are water wells where the pressure in the aquifer (water-bearing geologic formation) forces groundwater above the ground surface so that the well will flow without a pump. Several methods are used to construct flowing wells and to control the discharge of water from the well. To ensure that the artesian properties of aquifers are preserved, and that environmental and personal property damage do not occur, water well contractors need to be fully prepared when completing wells in areas where flowing wells are encountered. The discharge of water from flowing wells can be stopped in most cases, if proper steps are taken during well construction. The areas of Michigan where flowing wells occur need to be delineated so that county well permit programs become useful tools to regulate flowing well construction practices.

More detailed information on flowing wells can be found in EGLE's Flowing Well Handbook. It contains detailed information on flowing well occurrence, case histories, well construction methods, discharge control, disinfection and plugging of flowing wells.

Flowing Well Rules

Rule 121(c)

Prevent unnecessary discharge of water.

Rule 121(3)(a)

Confining layers must be preserved during well construction and any breaches must be sealed.

Rule 138

Flowing wells shall be grouted:

- To protect the artesian aquifer
- To prevent erosion of the overlying geologic materials
- To confine the flow to within the casing

Rule 163(3)

Flowing wells shall be plugged with neat cement or concrete.

Rule 138(2)

Discharge control shall be provided:

- To conserve groundwater
- To prevent the loss of artesian pressure

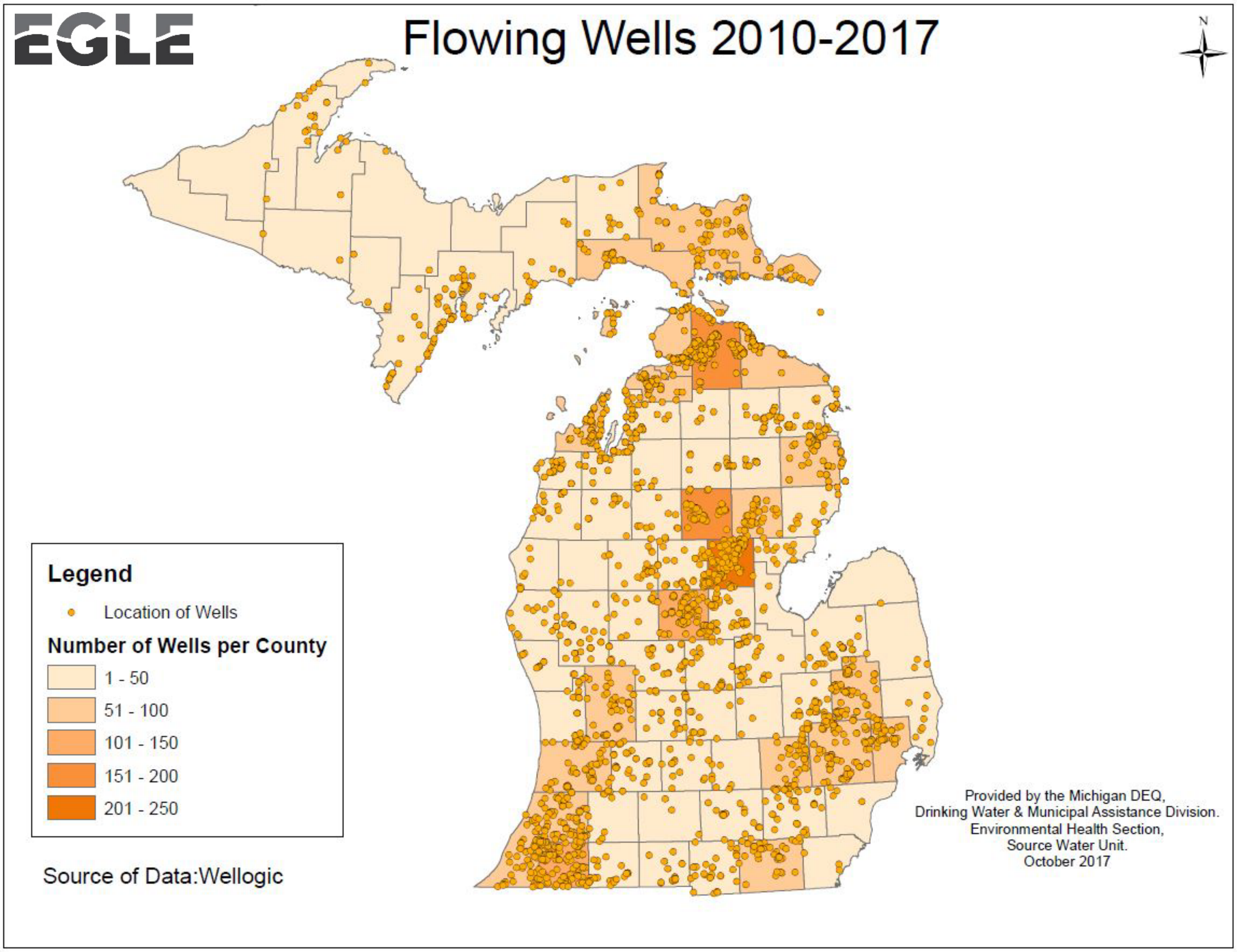
Flow control shall consist of any of the following:

- Valved pipe connections
- Watertight pump connections
- Receiving tank
- Flowing well pitless adapter
- Packer
- Other method approved by the health officer

A flow discharge pipe shall not be directly connected to a sewer or other source of contamination.

Michigan Flowing Well Facts

- There were approximately 3,500 flowing wells drilled between 2010 and 2017.
- Nineteen percent of the 3,500 wells were drilled in just three counties: Gladwin, Cheboygan, and Roscommon.
- The average unrestricted flow rate was 27 gpm.



Deviation to Allow Flowing Well to Discharge

A flowing well that is constructed after April 21, 1994 (effective date of the State Well Code revision) may be permitted to discharge water, **only** if a written deviation is issued by the LHD. If a deviation is issued, EGLE recommends that discharges be reduced to not more than 10 percent of the unrestricted flow rate. Before a deviation can be issued, the well owner or the owner's representative (well driller) must demonstrate any of the following:

1. Control of the flow is not practical – In some rare situations, controlling a flow may not be practical. The degree of difficulty in controlling the flow is increased if site conditions include a high artesian head, a large flow rate, a thin or unstable confining layer, or a shallow depth to the top of the artesian aquifer. This deviation condition also applies to situations where a technically sound but unsuccessful attempt has been made to control the discharge.

2. Control of the flow has resulted in the production of sand or turbidity in the water – While most flowing wells in unconsolidated geologic formations are completed with well screens, there may be cases where the contractor is not able to install one due to excessive uphole pressure. In such cases, the discharge rate should be reduced to the lowest pumping rate that will not result in sand or turbidity. It should be recognized, however, that barometric pressure changes, which affect aquifer head, can occasionally result in turbidity production, regardless of flow control mechanisms. Turbidity production may also be caused by insufficient well development.

3. The discharge is for a beneficial use – such as:
   a. Maintaining water levels in a pond used for irrigation, fire protection, fish rearing, recreation, wildlife enhancement, or other commercial purpose.
   b. Supplying a continuous flow of water for heating, cooling, industrial processes, irrigation, or power generation.

The Flowing Well Discharge Deviation form (see below) may be used by LHDs for issuing deviations to R 325.1638 of the State Well Code.

Since many flowing wells are located near surface waters, the discharge of water from flowing wells frequently involves disposal into a lake, river, or stream. If the buried discharge line or spillway passes through a wetland, a soil erosion/sedimentation permit may be needed. Contact the local soil erosion/zoning office to find out whether a permit will be needed.

Discharge Control

Proper control of discharge water from flowing wells consists of:

(1) Preventing the discharge of water from around the casing by tightly sealing the juncture between the borehole wall and the well casing, and
(2) Stopping or reducing the discharge of water from within the well casing.

Flowing Well Discharge Deviation – EXAMPLE FORM

This is to allow for a deviation of the provisions of R 325.1638 of the Michigan Well Construction and Pump Installation Code (Part 127, 1978 PA 368). This deviation is authorized under R 325.1613.

Well Owner Name	
Well Owner Mailing Address	
Phone	Email
Well Address	
Unrestricted Flow Rate (GPM)	Proposed Discharge Rate (GPM)

Reason for Deviation

☐ Control of Flow Not Practical – Give Reason:	
☐ Flow Control Resulted in Sand/Turbidity	
☐ Discharge is for Beneficial Use – Give Beneficial Use:	
Well Owner Signature	Date
Local Health Department Signature	Date

Methane/Gas Wells
Methane gas can occur naturally in water wells and when it does, it presents unique problems for water well drilling contractors. The major concern relates to flammable and explosive hazards when water is used in small unvented or poorly vented rooms such as laundry rooms or showers. Methane should be suspected whenever the well water appears milky and effervescent. Problems such as “air-locking” of the pump or sputtering of water at the faucets may also indicate the presence of methane or other gases.

Methane (CH_4) is the first member of the paraffin series of saturated hydrocarbons. Methane is a colorless, odorless gas and has an explosive limit between 5 to 15 percent by volume in air. Since it is lighter than air it rises: in a fire, it will be at the ceiling. Methane stays in solution below 42˚F and evolves out of the water between 42 to 58˚F. Above 58˚F methane is a gas and will not stay in solution. Methane can be generated by the decomposition of carbonaceous matter in swampy or marshy areas and is often called “marsh gas.”

The gas that causes problems in water wells can occur in either bedrock or overburden wells. Methane is generated in source rock, then “stored” in a reservoir with some type of cap rock or impervious layer to contain the gas underground. In Michigan, these wells generally occur in areas underlain with Antrim or Coldwater shale formations of the late Devonian or early Mississippian period. These two shales are carbonaceous in nature and serve as the source rock. Gas from these sources may contain methane or may be nearly all nitrogen. A high nitrogen content gas can cause problems in pump operations, but it is not an explosive hazard.

Production type natural gas may also be occasionally encountered in water wells. This higher British Thermal Unit (BTU) gas may escape from an oil/gas well blowout or from a failure at an underground gas storage field.

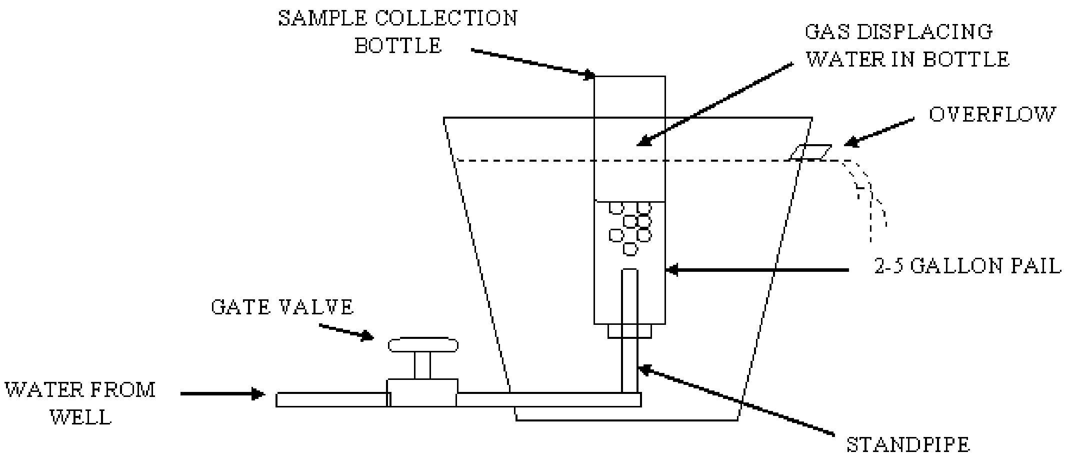
Gas Venting and Plugging Rules
Rule 156a
Gases shall be vented.
- Vented to the outside atmosphere.
- Consultation for identification and treatment of gases.

Rule 163(4)
Abandoned wells discharging gases shall be plugged with neat cement or concrete.

Sampling procedures
A simple qualitative test for methane can be done with the use of a plastic, narrow-mouthed milk carton and a book of matches. Use the following procedure:
1. Fill the gallon container up to the bottom of the narrow neck. Place hand over the mouth of the bottle. If methane is present, it will collect in the upper portion of the neck.
2. Bring a lighted match to the mouth of the bottle and quickly move hand away. The presence of methane will result in a brief wisp of blue or yellow flame. NOTE: It is important that a plastic container be used rather than glass because of possible breakage. This test should be performed outdoors and away from flammable materials.

EGLE uses the bubbler pail method for collecting gas samples from water supplies. The bubbler pail method can be constructed easily from a small pail (see figure below). Water enters the pail through an inlet near the bottom of the pail and rises up through a standpipe. The pail is filled with water during the sample collection. A sample collection bottle is filled with water and inverted over the standpipe and gas will accumulate by displacing the water in the sample bottle.

The flow rate and length of test should be recorded and submitted with the sample to the laboratory. Laboratory analysis of the gas is performed to determine the presence of methane and the percentage of methane in water. Portable combustible gas meters can also be used for field determinations of methane levels.



BUBBLER PAIL METHOD FOR COLLECTING GAS SAMPLES FROM WATER SUPPLIES

EGLE considers less than 1 percent methane-in-water (by volume) as being safe from explosion hazards. If levels are above 1 percent, it is usually recommended that a methane removal system be installed on the water supply.

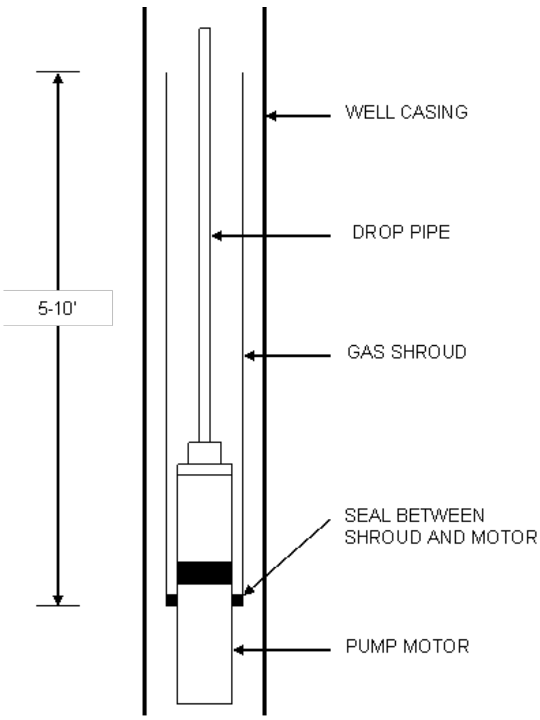
Well Venting
Proper venting at the wellhead is essential. Methane gas is lighter than air and will exit through a vented well cap. The upward movement of water in the casing when the well is recovering after pumping will push the accumulated methane gas out the top of the well. If large amounts of combustible gasses (methane, ethane, butane, etc.) are present, the well vent should terminate above a person’s head level to avoid ignition of the gases by lawnmowers, barbeque grills, cigarettes, etc.

Gas Shrouds
One method that has been successful in several gaseous water wells involves the installation of a gas shroud on the submersible pump (see figure below). The shroud will usually eliminate substantial amounts of gas and help prevent air locking of the pump, which is a common problem in gas producing wells. In some cases, the installation of a shroud on the pump has reduced the gas levels enough so that further treatment was not necessary.

The shroud seals to the top of the submersible pump motor, below the intake, and extends 5 to 10 feet above the top of the pump. The water must then travel upward and over the top of the shroud and downward to the pump intake. The dissolved gases will have a tendency to continue upward rather than follow the water to the intake, allowing gases to escape from the well vent.

If casing is 5 inches or larger with a 4-inch submersible pump, a gas shroud can be easily fabricated from 4-inch thin wall plastic pipe. A few submersible pump manufacturers have shrouds available for

4-inch wells. A 3-inch submersible pump with a thin-wall plastic shroud can also be used in a 4-inch well. It is important that a tight seal be made between the pump motor and the bottom of the shroud, since leakage will cause gaseous water to enter the pump intake. The bottom of the shroud must seal at the top of the motor to allow for proper motor cooling. Drillers have sealed the shroud to the motor by wrapping tape around the shroud or by slitting the thin-wall plastic near the bottom and clamping the shroud to the motor.



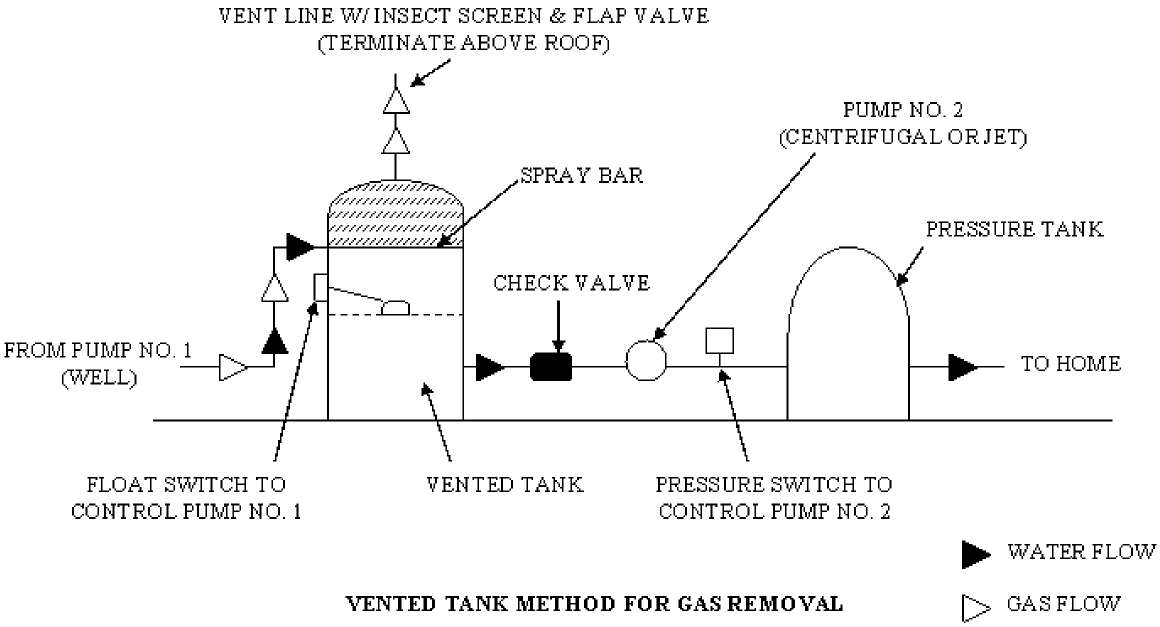
GAS SHROUD ON SUBMERSIBLE PUMP

Vented Tank Method

A gas removal system that has worked effectively on several installations in Michigan uses a vented storage tank with a spray bar mechanism (see figure below). The spray bar is a length of pipe with small holes drilled in it to disperse the water. Agricultural spray nozzles may also be used for this purpose.

Water from the well is sprayed upward through the spray bar into the vented tank and gas is liberated and exits through a vent pipe at the top of the tank. A float switch is used in the vented tank to control the well pump. A shallow well jet or centrifugal pump is then used to pump water from the vented tank into a pre-charged pressure tank to provide pressure for the distribution system.

If methane or other combustible gases (e.g., ethane, butane, pentane, hexane) are present, the vent line that eliminates gas from the system should terminate above the roof line of the building. The vent should be screened and turned down to prevent insects and debris from entering. It is recommended that a flap-type check valve be installed on the vent line to allow the tank to vent to the outside only. This will minimize the intake of airborne bacteria, spores, pollen, etc., into the vent line. In addition, the check valve will place the tank under negative pressure when the second pump is operating, further increasing the liberation of gas from the water.



VENTED TANK METHOD FOR GAS REMOVAL

Water retention time in the vented tank is critical. The tank should be adequately sized to allow the water to remain in the tank for several minutes to optimize gas liberation. Also, the location of the tank inlet and outlet should prevent short circuiting of water flow through the tank.

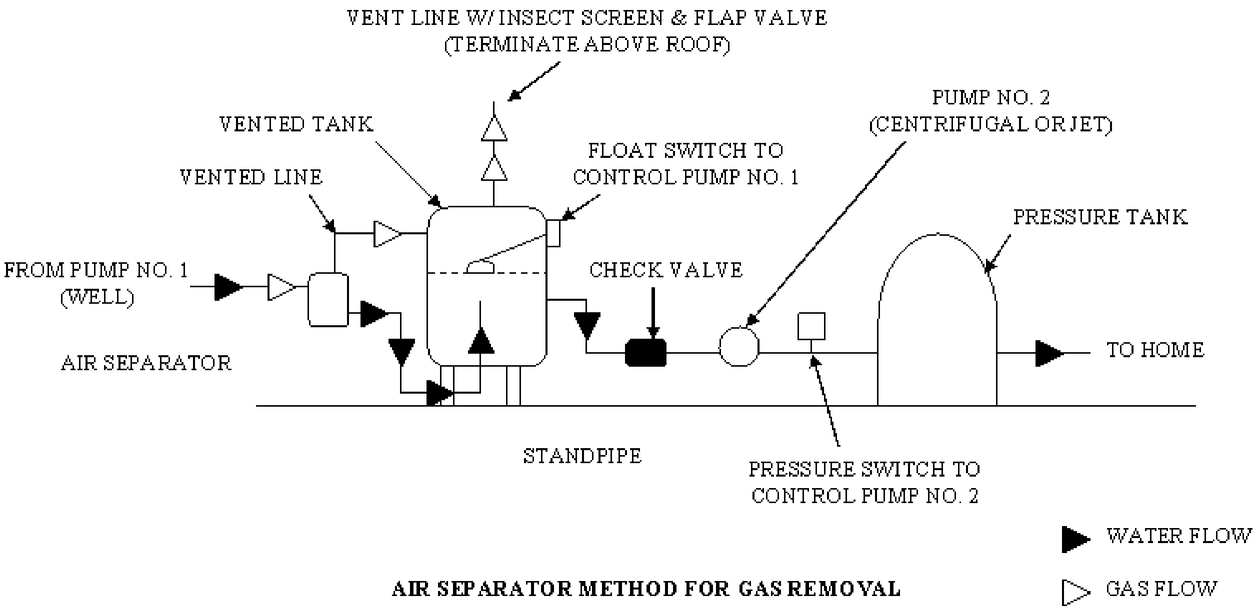
Air Release Valve Method

Another system involves the use of an air release valve on a galvanized storage tank. Gas is released from the air release valve when the liquid level is lowered to a predetermined point due to the accumulation of gas in the upper part of the tank. The vent line from the air release valve is terminated above the roof line of the building.

Since the tank remains pressurized, gas liberation does not occur as readily as in those systems using a vented tank. Several systems using air release valves tested by EGLE have not been effective in removing large amounts of gas.

Air Separator Method

The air separator is a cylindrical device with an inlet near the top, outlet near the bottom, and air vent on top. Water flowing through the unit creates a centrifugal force that causes heavier, gas-free water to move toward the outside. Lighter gas-entrained water moves toward the center due to a low velocity vortex being created within the air separator. The gas rises and exits through a vent line into the top of a vented tank. A vent from the tank terminates about a foot above the roof line of the building.



AIR SEPARATOR METHOD FOR GAS REMOVAL

Water from the air separator enters the bottom center of the vented tank through a smaller diameter standpipe. The smaller diameter of the standpipe lowers the pressure and increases water velocity and turbulence in the tank, which induces further gas-water separation.

A centrifugal pump was used to pump water from the vented tank into the school's pressure tanks. A float control on the vented tank controls the submersible pump in the well, and a standard pressure switch located downstream from the centrifugal pump controls the repumping operation.

Conclusion

Methane and other dissolved gases can be removed from water supplies, however, the additional equipment and space necessary may be prohibitive for small domestic systems. Whenever vented tanks are used, oxidation can cause turbidity problems in certain groundwaters, which may make further treatment necessary. Additional field research is needed in the area of methane removal so that low-cost treatment methods can be developed.

Water well drilling contractors, engineering firms, or other regulatory agencies that have had experience with other methane removal systems are encouraged to share their experiences.

Sand and Turbidity in Wells

New wells occasionally pump a small amount of sand or turbidity initially. Well drilling contractors should not place a well into service that is producing sand or turbidity. Once a well is put into routine service, the intake area generally stabilizes. Sand grains bridge on the outside of the well screen and sand production ceases. Existing wells can occasionally develop sand/turbidity (ST) problems after several years of service. Over time, corrosion of metallic casing or screens can allow sand or sediment to enter a well. Erosion in the production zone, loss of a drive-shoe seal, and overpumping can cause ST problems. Persistent ST problems can be challenging to correct.

No single approach will solve all ST problems. Some are easily cured while others can be stubborn. It is important to determine whether the ST problem is an isolated case or if it is surrounded by other wells with the same problem. Most often, an ST problem is an isolated case and can be corrected.

Sand and Turbidity Rules

Rule 139(1)
Well shall be fitted with a screen that is properly sized to produce sand-free water.

Rule 139(5)
Well shall be developed and pumped to waste until the water is clear.

Rule 121(2)
Well shall be adequate in size, design, and development for the intended use.

Problems Associated with Sand and Turbidity Production

While ingestion of small amounts of sand or sediment from a water well is not a health concern, their presence can be aggravating and troublesome. Excessive sand and other sediment can damage and decrease service life of the following: pump impellers or bearings, which can decrease pump efficiency, pressure tanks, valves, geothermal heat pumps, water treatment devices, water heaters, aerators, plumbing fixtures, dishwashers, clothes washers, and dryers, clothing and linens, finishes of appliances, automobiles, countertops, sinks, utensils, showers, and glass. Severe ST problems can cause reduction of septic system capacity, and plugging of lawn irrigation systems, showerheads, water softener resin tanks, and water lines.

Complaint Evaluation and Problem Diagnosis

Investigation of a ST complaint should involve first and foremost, a confirmation the ST problem exists. A site visit to check the severity of the ST problem and determine the nature and source of the particulate matter is crucial. Is it sand, silt, clay, scale, drilling fluid, or something else that needs to be identified in a laboratory? Sand has a distinctive, hard, gritty texture, while silt feels slippery and claylike. Precipitated iron scale can also cause turbidity. This reddish/brown/orange scale usually rubs away between the fingers, leaving a colored residue. A black scale that leaves a residue with a rotten egg or sewage odor when smeared between the fingers, may be attributed to sulfate-reducing bacteria.

Sometimes turbidity is the result of biofilm formation due to microbial growth in the well. Turbidity can also be due to residual bentonite drilling fluid used in rotary drilling operations or bentonite grout that may have infiltrated the filter-pack or native permeable formation surrounding the well screen.

Well construction details on the well record should be analyzed, and the depth and geologic formation sequence of the problem well to other wells in the vicinity should be compared. Surrounding wells that produce clear water may have been completed in a different aquifer or at a different zone within the same aquifer.

If a replacement well was drilled, it is good to ask the owner if the old well produced sand. If the replacement well is free of sand, the observed sand residual may be coming from the pressure tank or distribution system. If so, correction will involve a thorough flushing of the plumbing system.

It is important to determine when the problem began and how often it occurs. Some questions to ask the well owner are:

1. Was the ST problem present as soon as the well was placed into service?
2. If the ST problem started after the well was placed into service, how long afterward did it appear?
3. Was the casing hit by a vehicle or did a lightning strike occur just before the ST problem started? If so, the casing could have been damaged, allowing sand to enter.
4. Is the ST production continuous or sporadic?
5. Does the ST problem clear up with extended pumping or does it worsen?
6. Were there any major increases in water demand (e.g., installation of a lawn irrigation system, pump replaced with higher capacity pump, etc.)? Increased pump capacity will increase water entrance velocity into the well, enabling the water to carry sand into the well.
7. Does the problem exist at particular faucets, out buildings, or individual pipelines?

Sample Collection

An investigator should collect a sample of the sand or sediment. They can do this by running water into a clean, white 5-gallon pail from the sample tap or outside faucet that bypasses the water softener. To determine the ST problem's source, it is best to isolate the well from the pressure tank and piping. Before collecting a well sample for sand verification, be sure that the pump is running. This will ensure that the sample represents new water and not water stored in the well. Distribution system samples can be obtained from toilet tanks (if no filter is present) or from filter housing, if a sediment filter is present. Allow sand to settle.

To help diagnose the source of the sand, inspect the sand and compare grain size to well screen slot size shown on the well record. For example, if the well record shows a 20 slot (0.020-inch opening) and the sand sample is about 0.010 inches., the contractor may have selected an improper well screen. Portable sieves and gauges can be used to identify particle sizes.

If the screen slot is smaller than the sand sample (e.g., screen slot is 0.010 inches and the sand is in the 0.020 – 0.030-inch range), improper well screen selection is not the problem. The following causes are possible: (1) the screen may have been damaged during installation, (2) the casing may have been damaged, or (3) the neoprene packer between the screen and casing may be faulty.

In filter-packed wells, sand problems may result from improper filter-pack sand selection, bridging of filter-pack above screen, non-uniform or incomplete placement of filter-pack, non-centered screen, or insufficient development.

Common Correction Methods

No single approach will solve all ST problems. Some are easily cured while others can be stubborn. It is important to determine whether the problem is an isolated case or if it is surrounded by other wells with the same problem. Most often, an ST problem is an isolated case and can be corrected.

An important factor to consider is the type of well development method and extent of development used by the well driller. Premature termination of the well development stage by the contractor is a common cause of ST problems in new wells. Further development or using alternate development methods may resolve the problem. Ask the driller to explain how the well was developed and the proposed corrective action. One of the following methods may be applicable:

1. Replace the well screen with one having smaller slot openings.
2. Use a portable air compressor or drilling rig compressor to redevelop the screen until the well is sand-free at a pumping rate at least twice that of the permanent pump. A well will generally remain sand free if the permanent pumping rate is lower than the discharge rate used during final development.
3. Switch to a different development method than that used initially. For example, if the well was developed with air, redevelopment with a plunger may be successful. Another technique is to water jet within the well screen. A high pressure, high velocity water stream is injected through a pipe placed within the screen. Jets or nozzles near the end of the pipe, or on a special jetting tool, force water horizontally through the screen openings. Sand-laden water is then air lifted out of the well.
4. Resetting the screen at a different elevation may solve the problem. Sometimes, deepening the well a few feet will move the screen into a zone with different sand gradation.
5. If redevelopment is unsuccessful, or if screen replacement is not possible, replacement of the well with a filter-packed well (also known as “gravel-packed”) may be necessary. This involves placing specially selected filter sand outside the well screen. Filter-packing technology has reduced sand production problems throughout Michigan.
6. Reduction of the pumping rate may alleviate ST production. Decreasing the pumping rate lowers the water entrance velocity. Therefore, the energy of the water to carry suspended solids is reduced. Installation of a flow-restricting valve on the pump drop pipe may provide relief.
7. The installation of an additional well screen (if sufficient formation is present) is a common correction method. The added intake area lowers the water entrance velocity.
8. While performing corrections to remedy a ST problem, the well depth should be checked and compared to the depth reported on the well record. Sediment that has accumulated in the bottom of the borehole should be flushed out.

   Sand and turbidity problems in existing wells can result from mineral incrustation or biofilm formation. Partial screen plugging increases water entrance velocity and energy. The faster-moving water is able to carry particulate matter more readily. Rehabilitation of a well to restore well yield can correct the problem.

Other Causes

Some additional causes of ST problems are:

- An unsealed annular space – sediment can move downward from the annulus into the well intake during pumping. A complaint that a well becomes cloudy after a rainfall, or subsidence around the casing are likely signs of an ungrouted annulus.
- Placement of bentonite grout adjacent to the well screen.
- A failing check valve above a submersible pump can also cause a ST problem because of the surging action of water exiting the drop pipe.
- In bedrock wells, sand or turbidity may be the result of inadequate sealing between the casing and the bedrock, or leakage around the drive shoe. Sediment can enter from a sand-bearing formation above the bedrock. Sometimes, reseating the drive-shoe will resolve the problem.

- Sloughing shale formations or friable sandstone zones can cause ST problems. Surficial cracks in the bedrock may trend deeper than the casing depth. Correction can often be achieved by installing a liner pipe with packers to isolate the problem strata.
- Some flowing wells may produce slight turbidity when the flow is restricted or upon severe changes in barometric pressure.

Filters and Separators

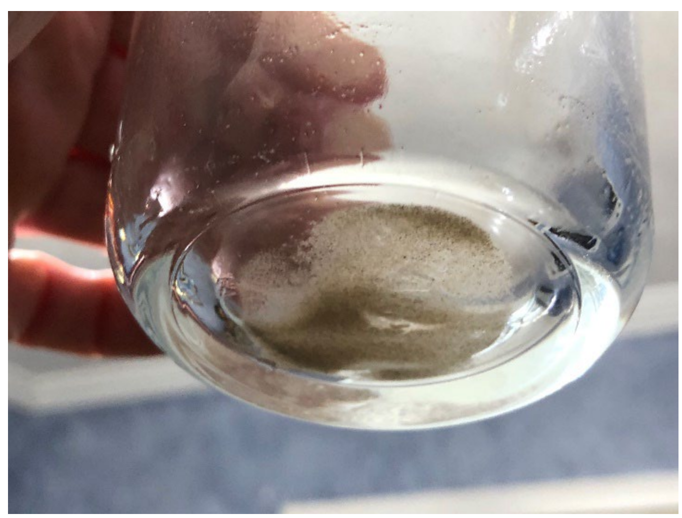
If the ST problem is present because of geological limitations and the well has been properly designed, correction options may be limited. Sediment filters and sand separators do not correct the source of the problem but can be effective at preventing particles from reaching the water distribution system. Their use should be considered **only** if the ST problem is geologically controlled. Devices such as filters or separators should be used **only** as a last resort and not as a substitute for proper well design or development. Always address ST problems at their source.

Clean-up of Water System

After the source of the ST problem has been corrected, sediment should be flushed from the water distribution system. Failure to do so will result in residual sand or sediment continuing to show up at sinks, showers, and toilets. To the well owner, it will appear as though the problem has not been corrected.

Once clear water is being produced from the well, all distribution system piping should be flushed. Hook a garden hose to a tap at the end of the building opposite from the pressure tank. Do not discharge the hose into the septic system. Turn on the tap and flush at full force. Gently tap exposed plumbing lines to loosen sediment. Remove and clean showerheads and aerator screens from faucets. Drain water heater and pressure tank (several flushing's may be needed). Be sure to turn off power to hot water tank before draining. Clean any sand filters and filter housings that may be present. Contact a water treatment dealer to flush sediment that has accumulated in the water softener resin tank. Injecting compressed air into pipelines also helps eliminate sand or other sediment.

Sand in Filter Housing



Sand in House Plumbing

Low Capacity Wells
What is a low capacity well? Generally, it is considered one with a production rate of less than 5 gpm. Most areas of Michigan provide well owners with more than enough well water to meet their needs. However, there are a few areas (e.g., the "Thumb," far southeast Michigan, certain areas of the Upper Peninsula, etc.) that produce less than 5 gpm. Since some areas in Michigan only produce 2-3 gpm, a minimum well capacity is not listed in the Well Construction Code. In addition, local groundwater conditions are taken into consideration when evaluating low capacity wells. Some LHDs notify the applicant of this concern within the permit language.

Well Owner Conservation Efforts
Simple changes in water use habits may be enough to meet peak water demands where water shortages occur infrequently. Peak water demands on the well can be reduced by changing the timing of water-using activities or by reducing the amount of water used. Examples of changing the timing of water use include: spreading laundry loads throughout the week instead of doing all loads in one day and having some family members shower at night rather than all showering in the morning.

Reducing the amount of water used involves water conservation. This might include changes in water use behaviors such as taking shorter showers or not washing the car. Changing water use behavior to spread out peak water use may be inconvenient at times but there is no added cost involved. A more permanent but costly water-conservation solution is to install water-saving devices like front-loading clothes washers or low-flush toilets.

Well Construction Considerations
Changes to well construction practices can sometimes overcome the obstacles associated with low capacity wells. These changes should be discussed with the well owner prior to well installation. Some considerations when constructing wells in low production areas are:

- Use a different formation, if possible.
- Practice longer or more rigorous initial development. Rigorous development (mechanical surging, high velocity jetting, air burst development) can remove drilling fluid damage done to the formation by the drilling operation. It also alters the basic physical characteristics of the aquifer 1-2 feet around the screen allowing water to flow more freely into the well.
- Screen considerations:
    - Install a greater length of screen
    - Use larger screen openings
        - Continuous slot wire wound screen …. 20-40 percent openings
        - Saw Cut Plastic Screen ……………..... 10-12 percent openings
        - Slotted Casing …………………………. 2-5 percent openings
    - Change the shape of the screen openings
        - V-shaped (widest to outside) – no clogging
        - Straight cut – clogs easily, increases drawdown
        - Perforations – creates turbulence and encrustation
    - Use filter pack
    - Install multiple screens – together or spaced
- Install drawdown seals.
- Restrict pump capacity by a flow control valve.
- Increase pressure tank storage capacity. This may require modifying the pressure settings to increase available storage.

- Install a storage reservoir/re-pump system, which must be approved by the LHD prior to installation.
- Submit a hydrofracturing request to EGLE for review to try to increase the flow rate in dense crystalline bedrock.

Drawdown Sal

Storage Tank Re-Pump System

Flow Control Valve

MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY
DRINKING WATER AND ENVIRONMENTAL HEALTH DIVISION

WATER WELL AND PUMP RECORD

Completion is required under authority of Part 127 of 1978 PA 368, as amended.

TAX NUMBER	Failure to comply is a misdemeanor.	PERMIT NUMBER

LATITUDE	LONGITUDE	COUNTY	TOWNSHIP

DISTANCE & DIRECTION FROM ROAD INTERSECTION	WELL STREET ADDRESS, CITY/ZIP	WSSN	SOURCE ID/ WELL NO.	SECTION	TOWN NO.	RANGE NO.

WELL OWNER NAME

ADDRESS

CITY/ZIP

Owner Address Same As Well Address? ☐ Yes ☐ No

DRILLING METHOD ☐ Rotary ☐ Cable Tool ☐ Hollow Rod ☐ Jetted ☐ Auger/Bored ☐ Other ______ ☐ Rotary w/Casing Hammer ☐ Cable Tool w/Casing Hammer

WELL DEPTH ______ ft.

WELL USE ☐ Household ☐ Type I Public ☐ Heat Pump-Supply ☐ Irrigation ☐ Type II Public ☐ Heat Pump-Return ☐ Industrial ☐ Type III Public ☐ Other ______ ☐ Test Well

DATE COMPLETED

WELL TYPE ☐ New ☐ Replacement ☐ Dry Hole ☐ Boring (Uncased) ☐ Deepening

CASING Type ☐ Plastic ☐ Steel-Black ☐ Steel-Galvanized ☐ Other ______

Joint ☐ Glued ☐ Spline ☐ Welded ☐ Threaded

Diameter ______ in. to ______ ft. depth ______ SDR

______ in. to ______ ft. depth ______ SDR

Height Above Grade ______ ft. Fittings ☐ Drive Shoe ☐ Shale Packer

BOREHOLE Diameter ______ in. to ______ ft. depth

______ in. to ______ ft. depth

STATIC WATER LEVEL ______ ft. Below Grade ☐ Flowing Flow Rate Before Control ______ G.P.M.

WELL YIELD TEST

Pumping Level ______ ft. after ______ hrs. pumping at ______ G.P.M.

☐ Air ☐ Bailer ☐ Plunger ☐ Test Pump

SCREEN ☐ Not Installed ☐ Filter-Packed Diameter ______ in.

MATERIAL ☐ Stainless Steel ☐ Plastic ☐ Other

Slot ______ Length ______ ft. From ______ ft. To ______ ft.

Slot ______ Length ______ ft. From ______ ft. To ______ ft.

INSTALLATION ☐ Telescoped ☐ Attached

FITTINGS ☐ Neoprene Packer ☐ Bremer Check

BLANK ☐ Above ______ ft. Other ______

WELL GROUTED From ______ ft. To ______ ft.

☐ Bentonite Slurry ☐ Bentonite Dry Granular ☐ Neat Cement

☐ Neat Cement with Bentonite ☐ Concrete No. of Bags ______

ADDITIVE ☐ Lost Circulation Material ☐ Accelerator ☐ Retarder

METHOD ☐ Grout pipe outside casing ☐ Driven dry grout ☐ Grout pipe inside casing ☐ Displacement plug

WELLHEAD COMPLETION ☐ Pitless Adapter ☐ 12 in. Above Grade ☐ Basement Offset ☐ Well House

NEAREST SOURCE OF POSSIBLE CONTAMINATION

Type ______ Distance ______ ft. Direction ______

Type ______ Distance ______ ft. Direction ______

ABANDONED WELL PLUGGED ☐ Yes ☐ No

Latitude ______ Longitude ______

Casing Diameter ______ in. Depth ______ ft.

PLUGGING MATERIAL ☐ Neat Cement ☐ Bentonite Slurry ☐ Cement/ Bentonite Slurry ☐ Concrete Grout ☐ Bentonite Chips

No. of Bags ______ Casing Removed? ☐ Yes ☐ No

REMARKS

ATTENTION WELL OWNER: FILE WITH DEED

PUMP ☐ Not Installed ☐ Pump Installation Only

Manufacturer ______

Pump Type ☐ Submersible ☐ Jet ☐ Other ______

Model Number ______ HP ______ Volts ______

Pump Capacity ______ G.P.M. ☐ Drawdown Seal Installed

Length of Drop Pipe ______ ft. Diameter of Drop Pipe ______ in.

PRESSURE TANK ☐ Not Installed ☐ Buried

Type ☐ Diaphragm/Bladder ☐ Galvanized

Manufacturer ______ Model ______

Total Tank Capacity ______ gal. ☐ Pressure Relief Valve Installed

Formation Description	Thickness of Stratum	Depth to Bottom of Stratum
USE SECOND SHEET IF NECESSARY		

DRILLING MACHINE OPERATOR ☐ Employee ☐ Subcontractor

Name ______

PUMP INSTALLER (If different from drilling machine operator.)

Name ______

WATER WELL CONTRACTOR'S CERTIFICATION:

This well and/or pump installation was performed under my registration.

Registered Business Name ______ Registration No. ______

Address ______

City/State/Zip ______

Signature of Registered Contractor ______ Date ______

MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY
DRINKING WATER AND ENVIRONMENTAL HEALTH DIVISION

ABANDONED WELL PLUGGING RECORD

Completion is required under authority of Part 127, 1978 PA 368, as amended.

Tax No.	*Failure to comply is a misdemeanor.*			**Permit No.**		
Latitude	**Longitude**	**County**		**Township**		
Distance and Direction from Road Intersection	**Well Street Address, City/Zip**	**WSSN**	**Source ID/Well No.**	**Section**	**Town No.**	**Range No.**
		Well Owner Name **Address** **City/State/Zip** Owner Address Same as Well Address? ☐ Yes ☐ No				

Drilling Method ☐ Unknown ☐ Rotary ☐ Cable Tool ☐ Other ______________________________

Date of Well Plugging / /

Measured Well Depth _______ ft.

Well Use ☐ Household ☐ Type I Public ☐ Type II Public ☐ Type III Public ☐ Industrial ☐ Irrigation ☐ Test Well ☐ Heat Pump ☐ Other ______________________

Date Well Constructed / / ☐ Unknown

Well Construction Type ☐ Drift Well ☐ Rock Well ☐ Dry Hole ☐ Unknown ☐ Other ______________________

Flowing Well ☐ Yes ☐ No

Casing ☐ Steel-black ☐ Steel-galvanized ☐ Plastic ☐ Clay Tile Crock ☐ Other ______________________

Diameter ________________ in. to ________________ ft. depth

Diameter ________________ in. to ________________ ft. depth

Casing Status After Plugging _________ ft. ☐ Below Grade ☐ Above Grade ☐ Casing Pulled

Note: Cutting casing off 4 feet below grade is recommended.

Reason for Abandoning Well ☐ Public Water Connection ☐ Well In Disrepair ☐ Well No Longer Needed ☐ Dry Hole ☐ Uncompleted Well ☐ Other ______________________

Abandonment Method ☐ Pumped Through Grout Pipe ☐ Poured From Surface ☐ Poured Through Grout Pipe ☐ Other ______________________

Pumping Equipment Removed ☐ Yes ☐ No

Equipment Removed ☐ Bremer Check Valve ☐ Drawdown Seal ☐ Drop Pipe ☐ Electrical Wiring ☐ Packer ☐ Pitless Adapter Spool ☐ Check Valve ☐ Pump Cylinder ☐ Pump Rods ☐ Stones/Debris ☐ Submersible Pump ☐ Turbine Pump Bowls ☐ Unknown Obstruction ☐ Obstruction Driven to Bottom ☐ Other ______________________

Note: Plugging well from bottom up to ground surface is required.

Plugging Material *(Enter the layers from top to bottom.)*	**From**	**To**	**Quantity**	**Units**
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________
☐ Bentonite Chips/Pellets ☐ Bentonite Slurry ☐ Clean Soil Fill ☐ Concrete ☐ Neat Cement ☐ Other ____________	______ ft.	______ ft.	________	☐ Bags ☐ Yards ☐ Other ____________

General Remarks

ATTENTION WELL OWNER: FILE WITH DEED

Water Well Contractor's Certification ☐ Well Owner Plugged the Well

This well plugging was performed under my registration.

______________________________ ______________________
Registered Business Name Registration No.

Address ____

City/State/Zip ____

______________________________ ______________________
Signature of Registered Contractor Date

If you need this information in an alternate format, contact EGLE-Accessibility@Michigan.gov or call 800-662-9278.

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This form and its contents are subject to the Freedom of Information Act and may be released to the public.

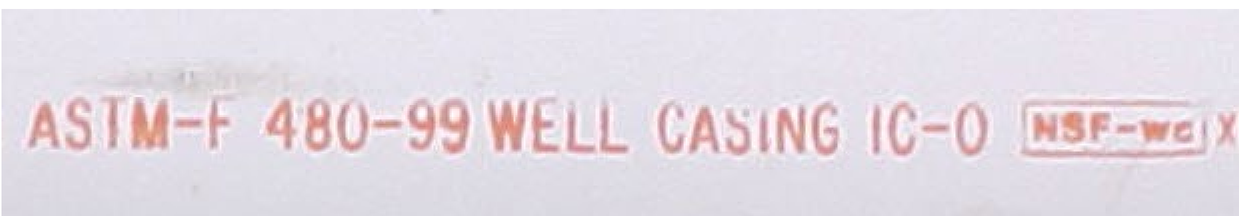
WATER WELL CASING STANDARDS AND MARKING REQUIREMENTS

Standards for Water Well Casing (Rule 110)

PVC Plastic	ASTM F 480
PVC Plastic	NSF 14
Black and Galvanized Steel (seamless)	ASTM A 53
Carbon Steel (seamless)	ASTM A 106
Carbon Steel (threaded and coupled)	ASTM A 589
Steel Line Pipe (seamless)	API 5L-90
Steel casing coating	NSF 61

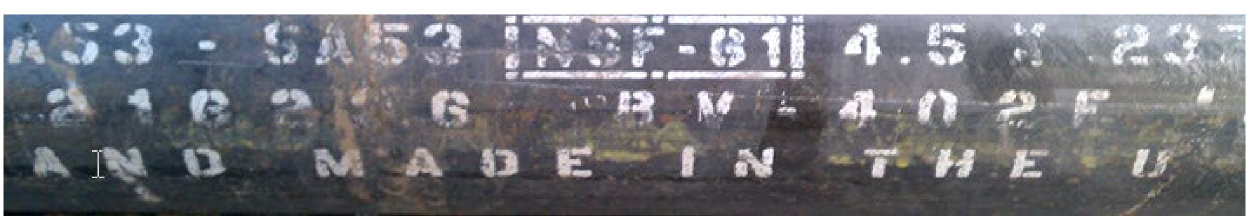
PVC Plastic Well Casing Markings (Rule 126)

1. Manufacturer's Name and Resin Manufacturer
2. Size and SDR
3. ASTM Number
4. NSF Marking
5. Impact Classification
6. Lot Number and Date Manufactured
7. Designated as Well Casing
8. Type of Plastic

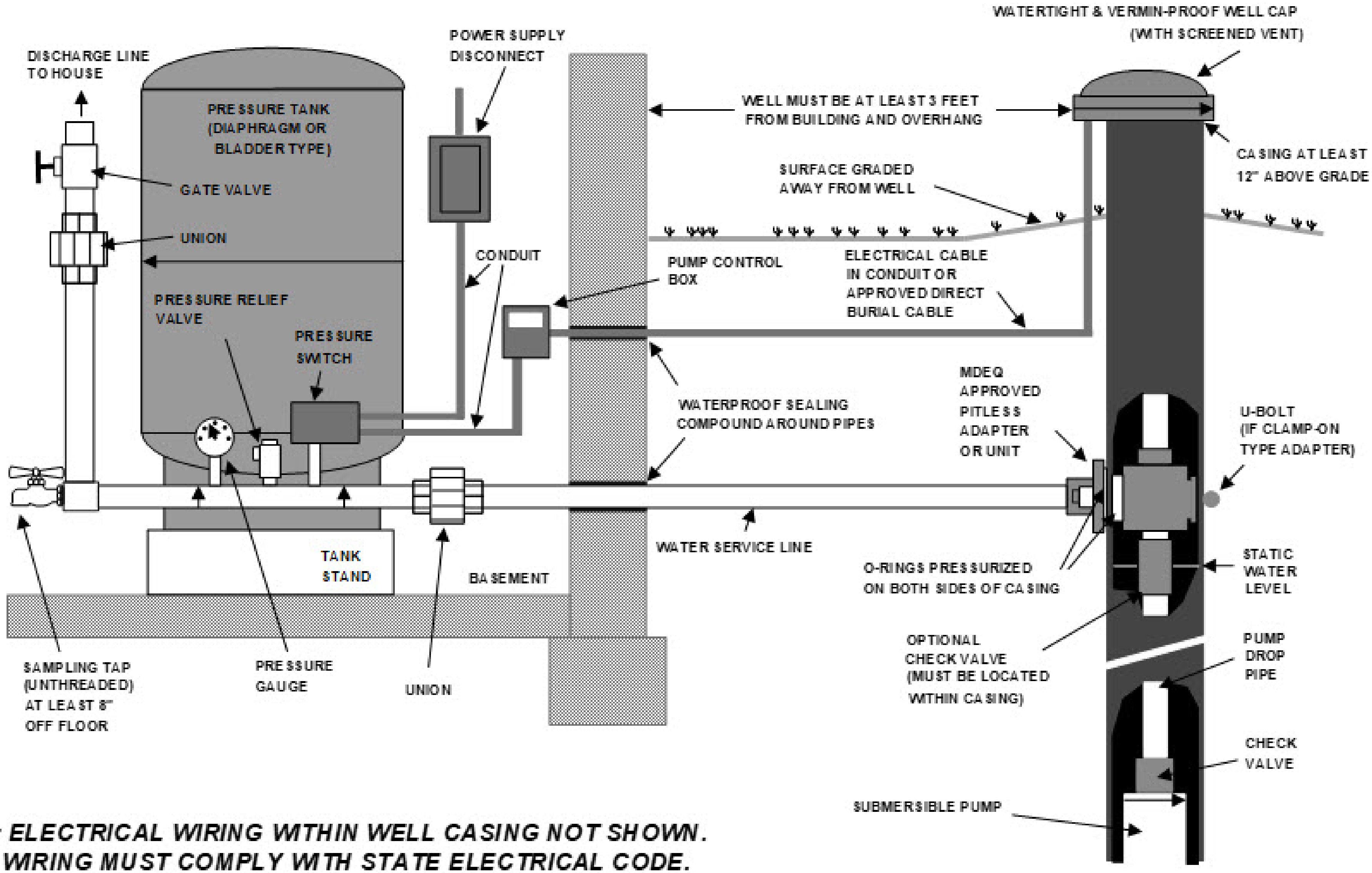


Steel Well Casing Markings (Rule 126)

1. Manufacturer's Name
2. Weight or Schedule
3. Specification Number
4. Kind of Pipe (Continuous Welded, Electric Resistance Welded, or Seamless)
5. Nominal or Outside Diameter
6. Length
7. Heat Number or Lot Number



Water System with Submersible Pump – Typical Household System



NOTE: ELECTRICAL WIRING WITHIN WELL CASING NOT SHOWN. WIRING MUST COMPLY WITH STATE ELECTRICAL CODE.

EGLE

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Michigan.gov/WaterWellConstruction
(https://www.michigan.gov/EGLE/About/Organization/Drinking-Water-and-Environmental-Health/Water-Well-Construction)

The following information can be found on our website:

- ✓ Water Well Equipment Approved List
- ✓ Directory of Registered Contractors
- ✓ Geothermal Heat Pumps
- ✓ Registered Contractor Application and Exam Dates
- ✓ Flowing Well, Disinfection, and Abandoned Well Manuals
- ✓ Laws and Rules
- ✓ Administrative Enforcement Actions
- ✓ Guide to LHDs
- ✓ Fact Sheets
- ✓ Directory of Advisories, Policies, and Educational Material
- ✓ Helpful Links