WATER WELL MANUAL

Michigan Department of Environmental quality
Office of Drinking Water & Municipal Assistance
Environmental Health Section

October 2013
# TABLE OF CONTENTS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction, Water Well &amp; Pump Code, Safe Drinking Water Act</td>
</tr>
<tr>
<td>2</td>
<td>Hydrogeology</td>
</tr>
<tr>
<td>3</td>
<td>Pre-Drilling Site Review, Permitting &amp; Isolation Distances</td>
</tr>
<tr>
<td>4</td>
<td>Water System Sizing</td>
</tr>
<tr>
<td>5</td>
<td>Drilling Methods &amp; Types of Wells</td>
</tr>
<tr>
<td>6</td>
<td>Drilling Site Evaluation</td>
</tr>
<tr>
<td>7</td>
<td>Grouting</td>
</tr>
<tr>
<td>8</td>
<td>Screen Installation &amp; Well Development</td>
</tr>
<tr>
<td>9</td>
<td>Wellhead Completion &amp; Pump Equipment</td>
</tr>
<tr>
<td>10</td>
<td>Well Disinfection</td>
</tr>
<tr>
<td>11</td>
<td>Sampling &amp; Testing</td>
</tr>
<tr>
<td>12</td>
<td>Abandoned Wells</td>
</tr>
<tr>
<td>13</td>
<td>Cross Connections</td>
</tr>
<tr>
<td>14</td>
<td>Water Well Records</td>
</tr>
<tr>
<td>15</td>
<td>Inspections &amp; Evaluations</td>
</tr>
<tr>
<td>16</td>
<td>Problem Wells</td>
</tr>
<tr>
<td>17</td>
<td>Appendices, Contacts</td>
</tr>
</tbody>
</table>
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.

For further information, contact:
Michigan Department of Environmental Quality
Office of Drinking Water & Municipal Assistance
Environmental Health Section
P.O. Box 30241
Lansing, Michigan 48909-7741
Phone: 517-284-6542
Fax: 517-241-1328

This manual can be found at: [www.michigan.gov/deqwaterwellconstruction](http://www.michigan.gov/deqwaterwellconstruction)
The first well code became effective on February 14, 1967, when the Michigan Department of Public Health promulgated the administrative rules authorized by passage of the Ground Water Quality Control (GWQC) Act (1965 PA 294). The most recent revisions to the well code went into effect on April 21, 1994. The statute authorizing the well code is now Part 127 of the Michigan Public Health Code, 1978 PA 368, as amended.

Michigan’s water well construction and pump installation code (water well code) contains minimum specifications for the location and construction of water wells and associated pumping equipment. The 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 code booklet can be ordered from:
Michigan Department of Environmental Quality
Office of Drinking Water & Municipal Assistance
Environmental Health Section
P.O. Box 30241
Lansing, Michigan 48909-7741

The well code and statute can also be downloaded from the DEQ website at:

www.michigan.gov/deqwaterwellconstruction

The well code and statute are found under the “Laws & Rules” section.
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 Michigan Department of Public Health*
- Adopted: November 23, 1966
- Effective: February 14, 1967 to April 20, 1994

**Safe Drinking Water Act**
Act 399 PA 1976
- Based on federal Safe Drinking Water Act
- Act Effective: January 4, 1977
- Rules Effective: January 11, 1978

**Act 294, PA 1965 (GWQCA)**
- amended in 1972 to include Dewatering Well Standards

**Part 127, Act 368**
- revision project 1990 to 1993
- Minimum Program Requirements (MPRs) were established for each core program

**Sections 12701 to 12715 of Michigan Public Health Code**
- Section 12701 – **Definitions**
  - Person
  - Pump
  - Pump Installer
  - Well
  - Well Drilling Contractor

- **12703(1) – Applicability**
  Sec 12701 to 12715 do not apply to:
  - Dewatering well 2 inch or less and 25 feet or less in depth
  - Artesian pressure relief wells at hydroelectric projects
  - Wells used with drilling of oil/gas wells
  - Brine, test, storage, or disposal wells
**12703(2) – Criteria for persons drilling wells on their own property**
- Single-family dwelling on owned/leased property
- Permanent residence of owner
- Not intended for public use
- Not intended for another residence
- Well record must be submitted
- Must comply with water well code

**12704 – Requires Registration**
**Well Drilling Activities:**
- Construct/reconstruct/repair well
- Operate well drilling machine
- Install/remove well casing or screen
- Grouting/plugging abandoned wells
- Well development
- Hydrofracturing
- Chemical treatment/rehabilitation

**Pump Installation Activities:**
- Selection/placement of pump
- Making entrance to well
- Installing any of the following:
  - Pitless adapter
  - Suction line
  - Well cap
  - Discharge line
  - Pump drop pipe
  - Pressure tank

**12704(3) – Registration Fees (initial and annual renewal)**
- $40 well drilling contractor
- $25 pump installer
- $10 additional well drilling machine

**12705 – Registration Certificate**
- Nontransferable
- Expires April 30 each year
- 50 percent penalty after July 1

**12706 – Drilling Machine Identification**
- Registration number (issued by DEQ)
- Rig decals
  - Both sides of rig
  - Minimum 2 inches high
  - Contrasting colors
* 12707 – **Water Well and Pump Records**
  o Filed within 60 days of well completion
  o Copy to owner, local health department (LHD), and DEQ
  o Complete on DEQ form

* 12708 – **Inspection Authority for DEQ or LHD**
  o Permits entry onto property during reasonable hours

* 12709 – **Requires DEQ and LHDs to:**
  o Investigate suspected statute/rule violations
  o Order responsible person to correct violation

* 12709(2) – **Authorizes DEQ to:**
  o Suspend registration of person who violates statute or rules

* 12715(1) – **A person is guilty of a misdemeanor if they violate:**
  o The statute
  o The rules and water well code
  o A correction order

* 12715(3) – **Attorney General or local prosecuting attorney are responsible for:**
  o Prosecuting persons who violate Sec. 12701-12715 of GWQC Act
LOCAL HEALTH DEPARTMENT’S ROLE IN GROUNDWATER PROTECTION

Introduction
Michigan incorporates a preventive public health strategy to ensure that newly installed water well systems are safe and reliable. Drinking water program is administered as a joint effort between Michigan’s local health departments (LHD) and the DEQ. The Well Construction Code allows the state of Michigan to delegate well permitting duties to the LHDs.

Funding
LHDs receive state funding from an annual appropriation by the state legislature to Department of Community Health. There is a contract between the state and LHDs for delivery of services such as: well and sewage system permitting and food service inspections.

Minimum Program Requirements
The LHD’s must comply with the 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

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

LOCAL SANITARY CODES
LHDs each have their own local sanitary code that covers water supplies. Water wells constructed in Michigan must comply with local code requirements. Fail 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 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.
Public water supplies (Type I, Type II, Type III) are regulated under Act 399 PA 1976 (Safe Drinking Water Act). Examples of public water supplies include: municipal water supplies, apartment complexes, schools, restaurants, campgrounds & parks, retail stores, and two private homes sharing one well. The construction regulations of public water supplies are in conjunction with Part 127 Act 368 PA 1978. Local health departments regulate Type II and Type III supplies. The DEQ regulates Type I supplies.

### Summary of Selected Public Water Supply Rules
(refer to Act 399 for complete requirements)

<table>
<thead>
<tr>
<th><strong>ISOLATION</strong></th>
<th>Type I and IIa – Standard isolation area 200 feet – no sewer lines, septic systems, etc., in isolation area.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rules 808 and 812, Pages 32 and 33</td>
<td>Major isolation area 2000 feet – No lagoons, landfills, groundwater contamination sites, chemical storage in isolation area.</td>
</tr>
<tr>
<td></td>
<td>Type II and III – Standard isolation area 75 feet – no buried sewer lines, septic systems, etc., in isolation area unless written deviation. Major isolation area 800 feet – no lagoons, landfills, groundwater contaminations sites, chemical storage in major isolation area unless under written deviation. Also see chemical storage areas.</td>
</tr>
</tbody>
</table>

| **CHEMICAL STORAGE AREA**                    | Type I and IIa/IIb and III – Wells shall not be located within 2,000 / 800 feet respectively of chemical storage areas (including fuels, oils, degreasers, etc.) unless a written deviation has been issued. Chemical type, volume, containment, well capacity, hydrogeologic conditions, etc., are to be considered in the approval of deviations. |
| Rule 812, Page 33                            |                                                                                                          |

| **CASING TERMINATION**                       | Type I and IIa – Casing must be minimum of 12 inches above ground surface.                                  |
| Rules 817, Page 35                           | Type IIb and III – In addition to 12 inches above grade, casing may be 12 inches above floor of approved basement offset. |

| **PUMPING EQUIPMENT**                        | Type I and IIa – Must be located above established ground surface.                                        |
| Rule 826, Page 37                            | Type IIb and III – May be in approved basement offset. Pressure tanks may be buried if approved by the MDEQ. |

| **DEVIATIONS**                               | Shall be approved by the department in writing and based on information showing that public health will not be adversely affected. |
| Rule 802, Page 31                            |                                                                                                          |

| **GROUTING**                                 | Well grouting shall be in accordance with permit specifications.                                         |
| Rule 822, page 36                            |                                                                                                          |

<p>| <strong>CLASSIFICATIONS</strong>                          | Public Water Supply – Any water supply serving drinking water to other than a single family residence.   |
| Rule 107(h), Page 5                          |                                                                                                          |
| Rule 107 (f), Page 3                         | Type I or community – Year-round water service to 25 or more residents or 15 or more service connections. Permit required from DEQ. Examples are municipal systems, apartments, |
| Rule 502 (a), Page 17                        |                                                                                                          |</p>
<table>
<thead>
<tr>
<th>Rule 106 (c), Page 5</th>
<th>mobile home parks with greater than 15 lots.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 502 (2a), Page 17</td>
<td>Type II or noncommunity – Nonresidential water supplies that serve water for drinking or “household” purposes to at least 25 persons per day at least 60 days per year or have at least 15 service connections. Permits are required statewide prior to construction.</td>
</tr>
<tr>
<td>Act 399, Part 325.1004</td>
<td></td>
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<tr>
<td></td>
<td>Type IIa – Average daily water production for the maximum month greater than or equal to 20,000 gallons per day. Examples are industries, large seasonal resorts.</td>
</tr>
<tr>
<td></td>
<td>Type IIb – All other Type II supplies. Examples are food service establishments, campgrounds, schools, rest areas.</td>
</tr>
<tr>
<td></td>
<td>Type II nontransient – A Type II water supply that routinely serves the same 25 or more individuals on a daily basis at least 6 months per year. Examples are schools, daycare centers, factories, offices and other work sites.</td>
</tr>
<tr>
<td></td>
<td>Type II transient – Any Type II (noncommunity) water supply that does not meet the definition for a Type II nontransient water supply. Examples are motels, restaurants with less than 25 employees, medical offices, parks, campgrounds, churches, and marinas.</td>
</tr>
<tr>
<td>Rule 502 (c), Page 17</td>
<td>Type III – All public water supplies that are not Type I or Type II. Examples are small businesses, some gas stations, Grade A dairies.</td>
</tr>
</tbody>
</table>
A “public water supply” means a waterworks system that provides water for drinking or household purposes to persons other than the supplier of the water, except those systems that supply water to only one living unit. Public water supplies are classified into three types.

<table>
<thead>
<tr>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
</tr>
</thead>
<tbody>
<tr>
<td>A community water supply provides year-round service to not less than 15 living units or serving not less than 25 residents. 1) Permits are required from the Michigan Department of Environmental Quality (MDEQ) in Lansing or Gwynn. 2) Engineering plans are required. 3) Examples—municipal water supplies, condominiums, apartment complexes, and subdivision water supplies.</td>
<td>A noncommunity water supply which has not less than 15 service connections or which serves not less than 25 individuals on an average daily basis not less than 60 days out of the year. 1) Permits are required and are issued by the MDEQ or an MDEQ designated local health department. 2) Construction details and sketch of well site are required. 3) Examples—schools, restaurants, industries, campgrounds, parks, motels. 4) See back of this sheet for a breakdown of the different Type II water supplies.</td>
<td>All public water supplies which are not Type I or Type II public water supplies. 1) No MDEQ statewide permit required. Most local health departments require permits under local ordinances. 2) Examples—small apartment complex, small grocery store, small retail store.</td>
</tr>
</tbody>
</table>

A living unit is a house, apartment, or other domicile occupied or intended to be occupied on a day-to-day basis by an individual, family group, or equivalent.

A service connection is a direct connection from a distribution water main to a living unit or other facility for the purposes of providing water for drinking or household purposes.
**TYPE II**

A noncommunity water supply which has not less than 15 service connections or which serves not less than 25 individuals on an average daily basis not less than 60 days out of the year. 1) Permits are required and are issued by the MDEQ or an MDEQ designated local health department. 2) Construction details and sketch of well site are required. 3) Examples—schools, restaurants, industries, campgrounds, parks, motels.

**Customer Type**

**TYPE II NONTRANSIENT**

A Type II water supply that routinely serves the same 25 or more individuals on a daily basis at least 6 months per year. (Examples—schools, daycare centers, factories, offices and other work sites)

**TYPE II TRANSIENT**

Any Type II (noncommunity) water supply that does not meet the definition for a type II nontransient water supply. Examples include motels and restaurants with less than 25 employees, medical offices, parks, campgrounds, churches, and marinas.

**Average daily water production**

**TYPE IIa**

Type II supplies with an average daily water production for the maximum month equal to or greater than 20,000 gallons per day.

**TYPE IIb**

Type II supplies with an average daily water production for the maximum month of less than 20,000 gallons per day.

**TYPE IIa**

Type II supplies with an average daily water production for the maximum month equal to or greater than 20,000 gallons per day.

**TYPE IIb**

Type II supplies with an average daily water production for the maximum month of less than 20,000 gallons per day.
Hydrology

Introduction
Hydrology, by definition, is the science dealing with the waters of the Earth, their distribution on the surface and underground, and the cycle involving evaporation, precipitation, etc.

While the enclosed document, Agriculture’s Role in Protecting Groundwater, Conservation GEM Program Manual, December 1991, is not the best quality due to scanning, the hydrology information contained in it is excellent.

Other Resources

Additional information regarding groundwater in Michigan can be found at the Groundwater Mapping Project website at http://gwmap.rsgis.msu.edu/. It contains an interactive map viewer, a groundwater information database, project reports, web resources, and a lot of supporting hydrology and hydrogeology documents.
Agriculture's Role in Protecting Groundwater

CONSERVATION GEM PROGRAM MANUAL

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Charles P. Rader

December 1991

USDA - Soil Conservation Service
and
Michigan Association of Conservation Districts
I. INTRODUCTION

Ground water is the water below the land surface that completely fills (saturates) the pore spaces in the subsurface materials. Ground water is a vital part of rural life. Nearly 95 percent of rural families in the United States rely on ground water as their source of drinking water. In addition, there are many agricultural uses for ground water such as irrigation and livestock watering. Also, it is a critical component of our natural resource base. The quality of life in the rural community depends on an abundant and dependable supply of potable ground water (i.e. suitable for drinking).

The ground water system is poorly understood by most people. Misconceptions are common. For instance, the perception of ground water occurring as underground lakes and streams is not accurate in most circumstances. Misconceptions like this stem largely from our inability to visualize the water held beneath the surface. Other misunderstandings, particularly those related to the effects of our surface activities on ground-water quality, often lead to unintentional serious threats to our ground water resources.

Anyone who has ever seen photographs of the earth taken from space can appreciate why some call our world the water planet. About 70 percent of its surface is covered by water. But more than 97 out of every 100 drops of water on earth are saline and, therefore, not potable (Table 1). The largest storehouses of fresh water on earth are the ice caps and glaciers. But they are not easily accessible sources of drinking water. Ground water is the premier source of readily available fresh water for human consumption. Compared to other fresh water sources, ground water is 25 times more abundant than all the lakes, reservoirs and rivers of the world combined.

The current quality of our ground water resources is generally very good in most locales. In many rural areas it is used and consumed with little or no treatment. Ground water quality is at risk though. Many common urban, industrial, and farm practices are a potential threat to the quality of our ground water.

Given the economic and life-sustaining importance of ground water to rural residents, we must collectively ensure the conservation of its quality and quantity through education and prudent land practices. An appreciation of the benefits of ground water, coupled with an understanding of the basic concepts of water movement throughout the farm environment, will help us realize the link between our actions at the land surface and how they affect our ground water resources.
Table 1. Estimated Distribution of the World's Water Supply

<table>
<thead>
<tr>
<th>Total saline waters</th>
<th>97.2079 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>97.2</td>
</tr>
<tr>
<td>Saline lakes</td>
<td>0.0079</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total fresh waters</th>
<th>2.7921 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of total fresh water</td>
<td></td>
</tr>
<tr>
<td>Ice caps and glaciers</td>
<td>2.158</td>
</tr>
<tr>
<td>Ground water</td>
<td>0.61</td>
</tr>
<tr>
<td>Lakes and reservoirs</td>
<td>0.015</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>0.008</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>0.001</td>
</tr>
<tr>
<td>Rivers</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

* to a depth of 13,000 feet

[modified from Heath, 1987 and Fetter, 1988]
II. BASIC HYDROLOGY & GROUND WATER FLOW

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 ground water 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 cycle (Figure 1).

The Hydrologic Cycle

Within the hydrologic cycle, water moves into 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 Table 2.

Energy

The driving force behind all 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. As an example, Figure 2 shows vapor being added to the atmosphere by the evaporation of pond water. 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 and from a higher elevation to a lower one.
Table 2. 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 Ground Water
  - ground-surface infiltration and downward movement
  - infiltration and downward water movement from loosing streams or ponds

* Ground Water to Surface
  - upward ground-water movement into gaining streams or ponds
  - root uptake
  - artesian water movement producing a flow at the surface from a confined aquifer release point

* Ground Water to Ground Water
  - down slope ground water flow within and between aquifers
Energy Sources for Water Movement

Evaporation

Radiant energy

Warm dry wind

Moist wind

Pond

Agriculture's Role in Protecting Ground Water

Figure - 2
The Farm-scale Hydrologic System

Introduction

For the hydrologic discussions throughout this manual the size of land area to be considered will be the farm site and the immediate vicinity around it. This will be considered the farm-scale hydrologic system. We will discuss water movement in terms of inputs and outputs through the different areas of water storage in the hydrologic system.

Water Pathways

The farm-scale hydrologic cycle is a description of the cyclical movement of water on and around the farm. Water travels through the cycle by various pathways (Figure 3). The time to completely travel through the hydrologic cycle can vary greatly. Beginning as a raindrop, water can move vertically downward through the soil surface and unsaturated areas as soil moisture and further into saturated areas as ground water. Ground water moves very slowly through the subsurface material. It can creep along, almost horizontally, on a slight grade for years and possibly centuries until it reaches a distant discharge site (Figure 4). On the distant surface, the water can evaporate and finally fall as precipitation again. A much shorter cycle would be precipitation falling onto the ground surface and immediately evaporating. That water could, but usually doesn’t, return as precipitation in a few hours.

Water Inputs

Inputs to the farm-scale hydrologic system include all precipitation and irrigation. Rain, dew, snow, sleet, and hail are all forms of precipitation. Irrigation water is applied to the farm-scale hydrologic system from above surface, at the surface and by subsurface methods.

Water Outputs

Outputs from the farm-scale hydrologic system include water movement by surface flow, evaporation from soil and plant surfaces, and infiltration into the subsurface. Surface flow occurs as runoff from snow melt, excess rains or over-irrigation. Evapotranspiration is a combination of two water movement pathways, evaporation and transpiration.
Water Pathways

Evaporation and Transpiration

Cover crops

Confined feeding

Infiltration

Water table

Ground water

Perennial stream

Orchard

Surface runoff

Row crops

Local ground water flow system

Regional ground water flow

Agriculture's Role in Protecting Ground Water

Figure - 3

Center for Remote Sensing, Michigan State University, East Lansing, Michigan 48824
Hydraulic Conductivity of Selected Geologic Materials

- **Igneous and Metamorphic Rocks**
  - Unfractured
  - Fractured
  - Basalt
  - Sandstone
  - Shale
  - Carbonate Rocks
  - Clay
  - Silty loess
  - Silty sand
  - Clean sand
  - Glacial till
  - Gravel

<table>
<thead>
<tr>
<th>cm/sec</th>
<th>$10^{-10}$</th>
<th>$10^{-9}$</th>
<th>$10^{-8}$</th>
<th>$10^{-7}$</th>
<th>$10^{-6}$</th>
<th>$10^{-5}$</th>
<th>$10^{-4}$</th>
<th>$10^{-3}$</th>
<th>$10^{-2}$</th>
<th>$10^{-1}$</th>
<th>1</th>
<th>10</th>
</tr>
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<tbody>
<tr>
<td>m d⁻¹</td>
<td>$10^{-8}$</td>
<td>$10^{-7}$</td>
<td>$10^{-6}$</td>
<td>$10^{-5}$</td>
<td>$10^{-4}$</td>
<td>$10^{-3}$</td>
<td>$10^{-2}$</td>
<td>$10^{-1}$</td>
<td>$10^{0}$</td>
<td>$10^{1}$</td>
<td>$10^{2}$</td>
<td>$10^{3}$</td>
</tr>
<tr>
<td>ft d⁻¹</td>
<td>$10^{-7}$</td>
<td>$10^{-6}$</td>
<td>$10^{-5}$</td>
<td>$10^{-4}$</td>
<td>$10^{-3}$</td>
<td>$10^{-2}$</td>
<td>$10^{-1}$</td>
<td>$10^{0}$</td>
<td>$10^{1}$</td>
<td>$10^{2}$</td>
<td>$10^{3}$</td>
<td>$10^{4}$</td>
</tr>
<tr>
<td>gal d⁻¹ ft⁻²</td>
<td>$10^{-7}$</td>
<td>$10^{-6}$</td>
<td>$10^{-5}$</td>
<td>$10^{-4}$</td>
<td>$10^{-3}$</td>
<td>$10^{-2}$</td>
<td>$10^{-1}$</td>
<td>$10^{0}$</td>
<td>$10^{1}$</td>
<td>$10^{2}$</td>
<td>$10^{3}$</td>
<td>$10^{4}$</td>
</tr>
</tbody>
</table>

Prepared by David P. Lusch, PhD * Center For Remote Sensing * Michigan State University
Evaporation is a change of liquid water, from land and water surfaces, to water vapor by energy from the sun and wind. Transpiration is the release of water vapor by plants through their leaves. Infiltration is the seepage of water into the ground and percolation is the subsequent downward movement of the water, through cracks and pore spaces, into the subsurface.

An additional output is subsurface drainage systems such as tile fields which move water from the subsurface directly to a ditch. Ground water may eventually flow out of the saturated zone directly into a surface water feature such as a stream. This input to perennial streams is called base flow. Thus the hydrologic cycle links ground water to surface water, and back again.

The Subsurface

Introduction

We have discussed the major components of the entire farm-scale hydrologic system. Now let's focus on the components of the subsurface and the water movement through this portion of the hydrologic system. The subsurface is divided into two principle regions, the unsaturated zone and the saturated zone (Figure 5). 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 soil 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
Subsurface Hydrologic Zones

Infiltration

Unsaturated zone

Water table

Saturated zone

Root zone

Soil moisture

Air spaces

Soil particles

Ground water

Soil particles

Agriculture's Role in Protecting Ground Water

Figure - 5
capacity. Before water can infiltrate out of the unsaturated zone into the saturated zone, the water storage capacity (i.e. 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 to 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 ground water. 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 ground water 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 per minute to a many feet per second. In comparison, ground water moves very slowly. In a coarse sand aquifer, ground-water flow velocities may be as fast as 1 foot per day. A clay layer, on the other hand, may allow ground-water flow at a rate of only 0.3 inches per year!

**Unconfined Aquifers**

The saturated zone can have two types of productive aquifers within it, unconfined aquifers and confined aquifers (Figure 6). 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.
Aquifer Types

- Perennial stream
- Line of springs
- Water table
- Perched aquifer
- Unconfined aquifer
- Confined aquifer
- Confining layers
- Leakage through cracks and breaks in confining layer

Agriculture's Role in Protecting Ground Water
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 ground water relative to the adjacent aquifer. Water pressure in a confined aquifer is always greater than the atmospheric pressure. 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 layers. 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 confined aquifer in it, but only one unconfined aquifer as shown in Figure 6.

Perched Aquifers

Figure 6 also shows perched aquifers. These are areas above the water table that can collect a small amount 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.

Ground Water Flow

Ground water 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 ground water 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 to the water-height contours (Figure 7). Determining the direction of ground water flow can help in the resolution of existing pollution problems and aid in identifying vulnerable areas within a region.

Wells

Introduction

A well is a 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 ground water 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 (Figure 8). Wells drilled into completely consolidated bedrock have no need for a well screen. Typically, well depths in Michigan range from 15 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 (Figure 9, Well "a") 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 (Figure 9, Well "b") will rise above the aquifer to an equilibrium elevation which is proportional to the pressure within the confined aquifer.
Water Well Design

- Pump
- Well head
- Top soil
- Unconsolidated sand and gravel
- Water table
- Protective casing
- Grout seal
- Screen
- Uncased hole
- Unconsolidated Formation
- Consolidated Formation
- Top soil
- Unconsolidated sand and gravel
- Water table
- Static equilibrium water level
- Confining layer
- Water-bearing rock

Agriculture's Role in Protecting Ground Water

Figure - 8
Wells in the Saturated Zone

- Well a
- Well b
- Water levels in wells
- Water table
- Unconfined aquifer
- Confined aquifer
- Confining layer
- Static equilibrium water level

Agriculture's Role in Protecting Ground Water

Figure - 9
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 (Figure 10). 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 ground water. Below the sloping surface of the water table, ground water 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 unpumped well. Ground water will move toward the pumped well from outside areas, but the entire confined aquifer remains saturated (Figure 11). 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 & gravel) are subject to more compaction than consolidated materials (i.e. bedrock) because the cemented rock layers usually have a greater inherent strength.

Having completed our discussion of the farm-scale hydrologic cycle, and specifically subsurface water movement, we will now examine the effect of human activities on ground water within the farm-scale hydrologic cycle. We will look at how chemicals enter into and move within the farm-scale hydrologic cycle.
Pumping an Unconfined Aquifer

Natural Conditions
- Unconfined aquifer
- Confined aquifer
- Saturated zone
- Water table
- Screen

Pumping Conditions
- Unconfined aquifer
- Confined aquifer
- Saturated zone
- Cone of depression
- Unsaturated zone

Figure 10
Pumping a Confined Aquifer

Natural Conditions

- Unsaturated zone
- Water table
- Static equilibrium water level
- Saturated zone
- Confined aquifer
- Confining layer

Pumping Conditions

- Unsaturated zone
- Water table
- Equilibrium water level during pumping
- Saturated zone
- Confined aquifer

Agriculture's Role in Protecting Ground Water

Figure - 11
Agriculture's Role in Protecting Ground Water
SUPPLEMENT

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Bedrock Geology

Structure

North America, like all of the Earth's continents, is composed of three components: a shield, a stable platform, and folded mountain belts. The core of the continent is the craton which encompasses both the shield and the stable platform. The Canadian Shield is an area of highly deformed, metamorphic rocks and granitic intrusions of Precambrian age (see Table 5) which are exposed in the region between Hudson Bay and the upper Great Lakes. These are some of the oldest rocks in North America. To the south and southeast of the Superior province of the Canadian Shield, including all of Michigan, the igneous and metamorphic rocks of the basement complex change in composition and are progressively younger, although still Precambrian, in age. Beginning in the eastern Upper Peninsula and continuing southward, the basement complex is covered with a sequence of Paleozoic and younger sedimentary rocks. Although originally deposited nearly horizontally, in the Central Lowlands region these lithified sediments have been warped into broad, shallow domes and basins.

In the Great Lakes Region, there are several broad uplifts where Precambrian basement rocks occur at or near the surface (Figure 18). To the south of Michigan, there is the generally north-trending Cincinnati arch. Midway between the Ohio River and southernmost Michigan, this arch splits into two prongs along the Indiana-Ohio border. The northeastward trend, called the Findlay arch, continues through the western end of Lake Erie to eventually join the Canadian Shield in Ontario. The other prong of the Cincinnati arch, commonly known as the Kankakee arch, trends northwestward to join the north-trending Wisconsin arch in south-central Wisconsin. The Wisconsin arch merges with the Wisconsin dome which occupies the majority of the northern third of Wisconsin. The western half of the Upper Peninsula continues this positive trend in the form of the Superior Upland, an extension of the Canadian Shield.
Table 5. Geologic Time Scale.

<table>
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<th>Millions of Years Before Present</th>
<th>Duration in Millions of Years</th>
<th>Epoch</th>
<th>Period</th>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Precambrian</td>
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</tbody>
</table>
The Michigan Basin is the central negative structure in the Great Lakes Region. It is bounded on the north by the Canadian Shield, on the east by the Algonquin arch, on the south by the Kankakee and Findlay prongs, and on the west by the Wisconsin arch/dome and the Superior Upland. Two other structural basins also occur in this region of the continent. East of the Findlay arch is the Allegheny Basin. The Illinois Basin lies southwest of the Kankakee arch.

The Michigan Basin encompasses about 122,000 square miles and contains about 108,000 cubic miles of sedimentary rocks which filled a depression in the Precambrian basement complex. The vast majority of these sedimentary rocks are Paleozoic age although patches of late Jurassic rocks subcrop beneath the glacial drift in the west-central portion of the Lower Peninsula (Figure 19). The oldest sedimentary rock unit in Michigan is the Jacobsville Sandstone of late Precambrian age which is found along much of the north shore of the Upper Peninsula (Figure 20). The oldest Paleozoic sedimentary rocks (Cambrian) are found at or near the surface along the northern fringe of the eastern Upper Peninsula and arcing southward to the big bend in the Menominee River in southern Menominee County. The oldest sedimentary rocks in the Lower Peninsula, found in southeastern Monroe County, are Silurian in age.

The thickness of the sedimentary rocks increases from the margins toward the center of the basin which is located near the middle of the Lower Peninsula. A hydrocarbon exploration well drilled in North Star Township, Gratiot County penetrated more than two miles of sedimentary materials before entering the Precambrian basement complex. The concentric, ovoid pattern of the sedimentary rocks in Michigan, illustrated in Figure 19, is an indication of the basin's saucer-like structure.

An example of the margin of the sedimentary basin is shown in Figure 20. The Ordovician and Cambrian units of the sedimentary sequence can be seen to thin as they reach the erosional limits of the basin. The underlying Precambrian rocks which slope down into the basin can also be observed in this cross section. Figure 21 presents a section across the Lower Peninsula which passes near the center of the structural basin. The inclinations of the various sedimentary units on this graphic have been greatly exaggerated for clarity. Basin-wide, the average dip of the beds is less than one degree — about 45-60 feet per mile. Such a declivity would appear to be horizontal if viewed in an outcrop. Given the size of the basin, however, this slight inclination is sufficient to account for the rocks that form the coastline of the eastern Upper Peninsula being found over 10,000 feet below the surface of the central portion of the Lower Peninsula.
Geologic Cross Section of the Upper Peninsula

Series
- Mississippian
- Devonian
- Silurian
- Ordovician
- Cambrian
- Precambrian
- Precambrian - Jacobsville
- Sandstone

Sources: Bedrock Geology of Michigan, Small Scale Map 2, 1977 and Bedrock Geology of Michigan, 1987; State of Michigan, Department of Natural Resources, Division of Geology.

Agriculture's Role in Protecting Ground Water

Figure - 20
Geologic Cross Section of the Lower Peninsula

Sources: Bedrock Geology of Michigan, Small Scale Map 2, 1977 and Bedrock Geology of Michigan, 1987, State of Michigan, Department of Natural Resources, Division of Geology.

Series
- Jurassic
- Pennsylvanian
- Mississippian
- Devonian
- Silurian
- Ordovician
- Cambrian
- Precambrian

Agriculture's Role in Protecting Ground Water

Figure - 21

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Lithology

As mentioned previously, the majority of the Precambrian basement complex is composed of crystalline rocks (i.e. igneous and metamorphic). An exception to this is the Precambrian Jacobsville sandstone, shown in part in Figure 20. Of the Paleozoic and Jurassic sedimentary rocks which fill the basin, about 47 percent of them are carbonates (i.e. limestone or dolostone), 23 percent are sandstones, 18 percent are shales, and roughly 12 percent are evaporites (i.e. salt, anhydrite, and gypsum).

Most of the sedimentary rocks in the Michigan Basin originated as marine deposits. Near-shore areas in these ancient seas received sandy sediments which became sandstone when lithified. In somewhat deeper waters, fine-grained muds were deposited -- the source for our shales. In the deepest parts of these oceans, calcareous-rich sediments were deposited which through geologic time became limestone or dolostone. Special lagoonal environments under conditions of high evaporation rates account for the salt, anhydrite and gypsum deposits.

Most of the Ordovician, Silurian and Devonian Periods in Michigan's stratigraphic record are dominated by the carbonate rock types. Various grades of sandstone dominate much of the Cambrian Period and smaller portions of the Middle Ordovician, Late Silurian, Early Devonian, Early Mississippian and Late Pennsylvanian Epochs. Shales dominate much of the Mississippian Period and short intervals of the Late Ordovician, Early and Late Silurian, Late Devonian, and Early Pennsylvanian Epochs. The evaporites are confined largely to the Middle and Late Silurian and Middle Devonian Epochs.

Bedrock Aquifers

The availability of potable ground water in bedrock units 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. Figure 22 illustrates the pattern and extent of the major bedrock aquifers of Michigan.
Bedrock Aquifers


Aquifer status
- Good aquifer
- Marginal aquifer 1
- Marginal aquifer 2
- Not an aquifer

Note: Marginal aquifer 1 consists of water bearing sedimentary rocks; marginal aquifer 2 consists of igneous and metamorphic rocks containing water in fracture zones.
Figure 23 shows the accessibility of the bedrock aquifers in terms of the thickness of the glacial materials which bury them in most places. The good aquifers shown on this map routinely provide potable ground water 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, ground water 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 of the eastern Upper Peninsula, the vicinity of Presque Isle County in the northeastern 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 ground water 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 county-wide zone that traverses the southeastern sector of the state.
Accessibility of Bedrock Aquifers

Sources: Hydrogeologic Atlas of Michigan, Department of Geology, Western Michigan University, Kalamazoo, Michigan, 1981; Plates 6, 7, and 15 and Bedrock Geology of Michigan, Michigan Department of Natural Resources, Geologic Survey Division, Lansing, Michigan, 1997.

Map depicting the accessibility of bedrock aquifers in Michigan, with different symbols indicating various aquifer statuses and drift thickness. The map includes a scale for miles and kilometers.

Aquifer status:
- Good aquifer
- Marginal aquifer 1
- Marginal aquifer 2
- Not an aquifer

Drift thickness (ft):
- 0 - 100
- 101 - 400
- Over 400
- No data

Note: Marginal aquifer 1 consists of water-bearing sedimentary rocks; marginal aquifer 2 consists of igneous and metamorphic rocks containing water in fracture zones.

Agriculture's Role in Protecting Ground Water

Figure - 23

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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 ground-water 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 ground water 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 particularly vulnerable to potential contamination from human activities at or near the surface.

The darkest pattern in Figure 24 depicts the known or suspected areas of karst in Michigan. The lighter-gray 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.
Karst Areas in Michigan

Key
- Known or suspected karst areas
- Easily soluble rock
- Non-soluble rock

Source: Hydrogeologic Atlas of Michigan, Department of Geology, Western Michigan University, Kalamazoo, Michigan, 1981, Plate 18.

Agriculture's Role in Protecting Ground Water

Figure - 24
KARST

* TERRAIN WITH DISTINCTIVE HYDROLOGY AND LANDFORMS ARISING FROM A COMBINATION OF HIGH ROCK SOLUBILITY AND WELL-DEVELOPED SECONDARY POROSITY

* Karst is the German form of the Slovene word Kras which means "crag or stony ground" especially the bare rock surfaces of northern and coastal Yugoslavia.

* The best-formed karst occurs in limestone and to a lesser degree in dolostone terranes, but it also forms in regions underlain by gypsum or rock salt. Although gypsum (CaSO₄) and rock salt (halite, NaCl) are more soluble than limestone, they occur much less frequently than limestone and then only in areas of limited areal extent
POST-GLACIAL SINKHOLES

POST-GLACIAL SOLUTION FEATURES IN 30 TO 80 FEET OF DRIFT

Prepared by David P. Lusch, PhD * Center For Remote Sensing * Michigan State University
Figure 15.11
The evolution of a cave system is shown schematically in these diagrams.
Glacial Geology

Introduction

During the last ice age, all of Michigan and the bordering Great Lakes basins were engulfed by the Laurentide ice sheet. This continental glacier advanced into an area that had been glaciated at least three times previously in the recent geologic past. The initial invasion of Pleistocene glaciers probably encountered a rolling countryside that had been maturely dissected by flowing streams. This landscape was underlain by nearly horizontal sedimentary rock layers which possess varying resistances to erosion. The downcutting of streams is more successful in the weaker rock units and less successful in the more resistant strata. As a result of this differential erosion, geomorphologists envision that the pre-glacial Great Lakes Region contained several master streams which flowed, primarily to the east and north, across the terrain now occupied by the lake basins.

The advancing ice was capable of enhanced flow in these pre-existing valleys compared to the interfluvies. As a result, the ice front was dissected into a number of individual lobes with adjoining interlobate areas. Each of the lobes followed the local path of least resistance. The Superior Lobe flowed southwest in the western Lake Superior basin past Duluth. The Chippewa Lobe moved southwestward out of Keweenaw Bay across the lowland between the Keweenaw-Ontonagon ridges on the west and the Huron Mountains on the east. The Green Bay Lobe, which advanced toward the south-southwest, was separated from the neighboring Michigan Lobe by the resistant backbone of Wisconsin's Door Peninsula. The Michigan Lobe, the most robust of the seven discussed here, expanded primarily to the south. The Huron Lobe, flowing southeastward and then southward, was separated from the Saginaw Lobe by the low, resistant bedrock cuesta that forms the axis of Michigan's thumb. Entering the state from the east-northeast, the Erie Lobe merged with the Huron Lobe in the vicinity of Detroit and advanced as far as southeastern Branch County.

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 ground water in bedrock aquifers. Also, the thicker the glacial materials are, the more likely it is that multiple drift aquifers will occur at depth. Figure 25 depicts the drift thicknesses in the Upper Peninsula. Large areas of "no data" are shown due to the small number of water wells in this part of Michigan. Where data are available, drift thicknesses less than 100 feet are common.
The picture is very different in the Lower Peninsula (Figure 26). 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 thin (less than ten 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 (200-400 feet) in the interlobate regions which trend from Cass County to northern Kent County in the southwest and, in the southeast, from Hillsdale County to southern Lapeer 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, ground water in drift aquifers is a plentiful resource as indicated by Figure 27. Most of the state is covered with glacial deposits which store and transmit ground water 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 on Figure 27 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 on Figure 27 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.
Drift Thickness for Lower Michigan


Note: No data for islands.

Agriculture's Role in Protecting Ground Water

Figure - 26
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 ground water) is most often found in the drift. The vulnerability of ground water 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 ground water. The elevation of the water table is a function of surface topography and the altitude of the local ground-water 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, coarse-drift terrains, shown in Figure 28, 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 ground-water flow regime very complicated. This combination of inherent vulnerability coupled with subsurface, three-dimensional complexity produces landscapes which are particularly challenging in terms of ground-water protection strategies.
Ice-Contact Coarse Drift

Key
- Ice-contact coarse drift


Agriculture's Role in Protecting Ground Water

Figure - 28
Naturally "Protected" Drift Aquifers

It is a well known fact that fine-textured earth materials transmit water very slowly compared to coarse soils. In Michigan, this concept is codified in the Rules of the Solid Waste Management Act (Act 641, P.A. 1978, as amended). As a means of safeguarding ground-water quality, these rules specify that a Type II sanitary landfill on a natural soil site should optimally be underlain by materials having a hydraulic conductivity no greater than $10^{-7}$ cm/sec. If the soil is thick enough, a hydraulic conductivity up to $10^{-6}$ cm/sec may be sufficient. These very low hydraulic conductivities are associated with clay soils.

Lakes and other still-water bodies are the environments in which clays can be deposited. Most lakes in Michigan are kettle lakes — they occupy depressions which were formed when blocks of glacier ice finally melted after being partly or wholly covered by outwash sediments. Although some of these kettle depressions are very large, most are relatively small in size. In addition, since the littoral zone near the shore of a lake is the depositional site of coarse-textured material, it is only in the central portions of the lake that conditions are right for the deposition of clay. These facts suggest that most clay deposits will be local rather than regional in size. An inspection of the soil surveys of counties where clay-rich parent materials occur in abundance bears this conclusion out. Most soil map units that represent clay materials are 300 acres or less in size. Some larger areas of clay, up to 2,000 or 3,000 acres, do occur, but these are rare.

As depicted in Figure 29, the most common occurrence of clay materials in the drift of Michigan will be as discontinuous masses of relatively local extent, usually much less than 640 acres. As a result, the common assumption that extensive layers of clayey drift exist and provide natural protection to the confined aquifers at depth is largely incorrect. The infiltration pathway in the local area on the front left of Figure 29 is much slower than the pathway on the far right. However, recharge water (and any contaminants it carries) will infiltrate to the ground water system everywhere in the diagram. From this perspective, what some would call protection is really only an impediment to contaminant movement, not a barrier.
Agriculture's Role in Protecting Ground Water

Figure - 29
Aquifer Vulnerability to Surface Contamination in Michigan

David P. Lusch, Charles P. Rader, Linda R. Barrett, and Nancy K. Rader.
Center for Remote Sensing and Department of Geography, Michigan State University, East Lansing, Michigan, 1992

Notes: Map generalized from 1:1,500,000 map. Polygons smaller than 40 km$^2$ were eliminated to simplify this representation. Areas over unknown drift lithology (3 classes on the original map) were grouped with the moderately vulnerable class.

Map produced from digital files at the Center for Remote Sensing, Michigan State University, 302 Berkey Hall, East Lansing, Michigan 48824-1111.

Lambert Conformal Conic Projection, standard parallels at 33° and 45° north.
HYDROGEOLOGIC DEFINITIONS

Artesian Aquifer
An aquifer where ground water is 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 ground water 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 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/foot 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 gallons per minute (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 a zone of saturation.
PUMPING WELL DIAGRAM

- Static level
- Drawdown
- Radius of influence
- Cone of depression
- Pumping level
- High capacity well
- Low capacity well
PREDRILLING SITE REVIEWS AND WELL PERMITTING

Introduction
Local health departments (LHD) 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 pre-drilling site review.
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 may or may not conduct 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 not based on the well record, water sample results, and a final inspection, if applicable.

Pre-Drilling Site Review
A Predrilling Site Review (PDSR) 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 ground water 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 (NREPA), 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).
An **Office Predrilling Site Review** consists of, but is not limited to, a review of the following factors:

1. A detailed site plan 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 Websites for Contamination Information” in this chapter).
6. Hydrogeological studies (if submitted by the permit applicant).

A **Field Predrilling Site Review** consists of the same components as an **Office Predrilling Site Review**, except that an on-site assessment of the proposed water well site is made to verify the site plan details. Checklists for performing Office and Field PDSRs can be found in this chapter.
Water Withdrawal and Contamination Investigation Unit:
www.michigan.gov/deq
Click on “Water”, then “Drinking Water”, then “Contamination Investigation”. Users can retrieve “Replacement Well Construction and Well Abandonment Specifications”, and “Water Quality (arsenic, nitrate, VOC) Maps by County”.

Environmental Mapper:
www.mcgi.state.mi.us/EnvironmentalMapper/

Part 201 Contamination Sites:
www.michigan.gov/deq
Click on “Land”, then “Part 201 Site Search”.

Part 213 Leaking Underground Storage Tanks:
www.michigan.gov/deq
Click on “Land”, then “Leaking Underground Storage Tank Sites”.

Part 211 Underground Storage Tanks:
www.michigan.gov/deq
Click on “Land”, then “Underground Storage Tank List”.

Part 117 Septage Application Sites:
www.mcgi.state.mi.us/miswims

Part 615 Oil & Gas Wells:
www.michigan.gov/deq
Click on “Land”, then “Gas, Oil, and Minerals”, then “Oil & Gas”, then “Maps of Oil and Gas Wells”.

Part 111 Hazardous Waste Sites:
www.deq.state.mi.us/tsd

Part 115 Landfills:
www.michigan.gov/deq
Click on “Waste”, then “Solid Waste”, then “Solid Waste Facilities”.

Part 31 Groundwater Discharge Sites:
www.mcgi.state.mi.us/miswims
OFFICE PREDRILLING SITE REVIEW CHECKLIST

Owner __________________________________ Site Address ____________________________________________

Permit/Application Number ______________________________________________________________

A. Application Review

1. Site sketch - Required information provided? (Checklist)

   Proposed well location _____ Existing wells _____ Existing/proposed building ______
   Roads and driveways ______ Existing/ proposed septic tank/drainfield _________
   North arrow shown _____ Fuel storage tanks _____ Sewer lines (sanitary/storm) _______
   Surface water (lakes, ditches, etc.) _____ Septic tank, drainfield, fuel tanks on adjacent
   property _______ Property lines _________

2. Fee paid? □ YES □ NO

3. Application signed and dated? □ YES □ NO

B. Proposed water well location acceptable? □ YES □ NO

C. Any deviations requested? □ YES □ NO
   If yes, specify on permit.

D. Existing wells on site? □ YES □ NO

   If yes, will water wells continue in use after construction of new well? □ YES □ NO

   (If existing well(s) meet definition of an abandoned well, it must be plugged.
   Plugging must be a permit condition.)

E. Is proposed well in a subdivision? □ YES □ NO

   If yes, any subdivision/deed restrictions relating to well construction? □ YES □ NO

   List subdivision/deed restrictions on permit.

F. Has available ground water data (water well records, computerized data bases, etc.) been reviewed? □ YES □ NO

1. Any of the following contamination sources or aquifer concerns exist? □ YES □ NO

   Salt Water ___ Hydrogen Sulfide ___ Methane ___ High Iron ___ Arsenic ___ Nitrates
   Other ____________________________________________

   Known ground water contamination site ______ Act 451, Part 201 site
   L.U.S.T. ______ Other ____________________________________________

   Flowing Well Area ___ Unprotected aquifer ___ Fractured (Karst) Limestone ___ Bacteriological ___
   Bedrock within 25 ft of surface _____ Low Production/dry hole area _____
   Other ____________________________________________
2. Are special well construction requirements necessary?  □ YES □ NO

Type of special construction requirements ________________________________

3. Special sampling necessary?  □ YES □ NO

Type of sampling ________________________________
Sampling frequency: Initial sample only _____ Monthly _____ Quarterly _____ Annual _____
Other ________________________________

Evaluated By: ________________________________    Date: __________________
FIELD PREDRILLING SITE REVIEW CHECKLIST

Owner___________________________________________ Site Address___________________________________________
Permit Number ____________________________________________________________________________________________

A. Is water well site location information provided on application accurate? □ YES □ NO

B. Is site sketch accurate? □ YES □ NO

Check site for:
  Proposed well location _____ Existing wells _____ Existing/proposed building _____
  Roads and driveways _____ Existing/ proposed septic tank/drainfield _____ North arrow shown _____
  Fuel storage tanks _____ Sewer lines (sanitary/storm) _____ Surface water (lakes, ditches, etc.) _____
  Septic tank, drainfield, fuel tanks on adjacent property _____ Property lines _____

C. Are overhead or buried utility lines near proposed water well? □ YES □ NO

D. Will trees or other obstructions interfere with water well drilling rig setup? □ YES □ NO

E. Does the site topography allow access for water well drilling rig? □ YES □ NO

F. Will water well be accessible for maintenance after site development is completed? □ YES □ NO

G. Proposed water well location approved? □ YES □ NO

  If proposed well location is not approved, is there an acceptable location? □ YES □ NO
  If yes, mark location on site sketch.

Comments______________________________________________________________________________________________
______________________________________________________________________________________________
______________________________________________________________________________________________

Evaluated By _____________________________ Date _____________________________
ISOLATION DISTANCES

Introduction
Michigan law 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 your well will often be determined by factors other than sources of contamination or geologic conditions. 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. In some cases, for example a well installation near a groundwater contamination site, the isolation distance should be maximized to provide the well owner with the best possible chance of maintaining a safe water supply.

Local Health Department Authority
Local health departments (LHD) 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 through the use of deviations. Deviations are issued 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.

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

Act 399 PA 1976 (Safe Drinking Water Act) contains minimum isolation distances for public water supplies (Type I, Type II, and Type III).
The following lists sources of contamination and the well isolation distances required from those sources by state codes. The DEQ and local health departments 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 (example - 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 DNRE 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.

<table>
<thead>
<tr>
<th>Contamination Source</th>
<th>Part 127, Act 368 PA 1978</th>
<th>Act 399, PA 1976</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IIb and III</td>
<td>I and IIa</td>
</tr>
<tr>
<td>Agricultural chemical/ fertilizer storage or preparation area</td>
<td>150</td>
<td>800</td>
</tr>
<tr>
<td>Animal/poultry yard</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Brine wells/injection wells</td>
<td>**150</td>
<td>**800</td>
</tr>
<tr>
<td>Building or projection thereof</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cemetery/graves</td>
<td>**50</td>
<td>*75</td>
</tr>
<tr>
<td>Cesspool</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Chemical Storage</td>
<td>150</td>
<td>800</td>
</tr>
<tr>
<td>Contaminant plumes, known (Part 201, LUST sites, etc.)</td>
<td>**150</td>
<td>**800</td>
</tr>
<tr>
<td>Description</td>
<td>Value 1</td>
<td>Value 2</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
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<td>---------</td>
</tr>
<tr>
<td>Drainfield</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Drywell</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Footing Drains</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Fuel/chemical storage tanks – Underground or abovegrade and associated piping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>depot/tank farm</td>
<td>300</td>
<td>800</td>
</tr>
<tr>
<td>1,100 gal. or larger, without secondary containment</td>
<td>300</td>
<td>800</td>
</tr>
<tr>
<td>1,100 gal. or larger with secondary containment</td>
<td>50</td>
<td>800</td>
</tr>
<tr>
<td>less than 1,100 gal. which store motor or heating fuel for noncommercial purpose or consumptive use on premises where fuel is stored</td>
<td>50</td>
<td>800</td>
</tr>
<tr>
<td>less than 1,100 gal. which store motor fuel for commercial purpose</td>
<td>*50</td>
<td>800</td>
</tr>
<tr>
<td>located in a basement, regardless of size</td>
<td>*50</td>
<td>800</td>
</tr>
<tr>
<td>Grease trap</td>
<td>50</td>
<td>*75</td>
</tr>
<tr>
<td>Kennels</td>
<td>50</td>
<td>*75</td>
</tr>
<tr>
<td>Landfill or dump sites (Active or inactive)</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Liquid Petroleum (LP) Tanks (See comments on last page)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid waste draining into the soil</td>
<td>50</td>
<td>*75</td>
</tr>
<tr>
<td>Metering station for pipelines</td>
<td>*300</td>
<td>*300</td>
</tr>
<tr>
<td>Municipal wastewater effluent or sludge disposal area (land surface application or subsurface injection)</td>
<td>300</td>
<td>800</td>
</tr>
<tr>
<td>Oil or gas wells</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Other wastewater handling or disposal unit</td>
<td>50</td>
<td>*75</td>
</tr>
<tr>
<td>Description</td>
<td>Width</td>
<td>Length</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>Petroleum product processing or bulk storage</td>
<td>300</td>
<td>800</td>
</tr>
<tr>
<td>Pipelines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gas, oil, etc.</td>
<td>*300</td>
<td>*300</td>
</tr>
<tr>
<td>natural gas (See comments on last page)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Privy/Outhouse</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Seepage pit</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Septic tank</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Septage waste (land application area)</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Sewage holding tank</td>
<td>50</td>
<td>*75</td>
</tr>
<tr>
<td>Sewage lagoon serving a single family dwelling</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Sewage lagoon effluent – land application area</td>
<td>50</td>
<td>800</td>
</tr>
<tr>
<td>Sewage or liquid waste draining into soil</td>
<td>50</td>
<td>*75</td>
</tr>
<tr>
<td>Sewage pump chamber, transfer station, or lift station</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Sewers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buried gravity sewer (sanitary or storm) - Service weight or heavier ductile-iron or cast iron, or schedule 40 PVC, all with watertight joints</td>
<td>10</td>
<td>75</td>
</tr>
<tr>
<td>Buried pressure sewer (sanitary or storm) - Watertight joints (pressure tested after installation to 100 psi), equivalent to Schedule 40 or SDR 21, and meets or exceeds ASTM Specifications D1785-91 or D2241-89</td>
<td>10 (by written deviation only)</td>
<td>75</td>
</tr>
<tr>
<td>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</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Sump pit</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Source of Groundwater Contamination</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Receiving household waste (laundry, softener backwash, sink waste, etc.)</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Surface water (lake, river, stream, pond, ditch, etc.)</td>
<td>10</td>
<td>75</td>
</tr>
<tr>
<td>Unfilled space below ground surface (except an approved basement, basement offset, or crawl space beneath single family dwelling)</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

**Comments:** Natural gas and liquid petroleum (LP) are not considered sources of groundwater contamination because of the volatile gas nature of the fuels. If leaks occur, the gases escape into the atmosphere. Leaked gases do not migrate downward into the soil. Wells should be sufficiently isolated from natural gas lines or LP tanks to minimize the potential for damage to the lines or tanks during well construction or repair, trenching of water lines, etc., and to allow accessibility to the well.
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 drilling. Types of documentation submitted to the LHD for a deviation approval include: location and sources of contamination, detailed site plan, neighboring well details, and proposed well construction details. Depending on the situation, a hydrogeological study and test wells may also be required.

Criteria for issuance of deviations are set forth in R325.1613 and are listed below:

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

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.

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.

10 feet to a pressurized sewer that meets all of the following requirements:
- pressure tested, not less than 100 pounds per square inch 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 subrule.

3 feet to a building if all of the following conditions exist:
- well is a replacement well
- can not meet minimum distance
- access for maintenance

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 are identified as not being suitable for human consumption
- water supply system are 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 exists:
  • isolation distance is increased
  • a confining layer is present above the aquifer.

Length of casing to be grouted for rotary-bored or augered wells to be decreased if the well is more than 100 feet deep and if a confining layer is not penetrated.

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

Flowing well discharge:
  • Control of the flow is not practical.
  • Control of the flow will likely result in the production of sand or turbidity in the water.
  • The discharge is for a beneficial use.

Deviations from the rules shall be made, 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
WATER SYSTEM SIZING

Introduction
It is crucial that water supply systems are properly sized. Well owners are often concerned about whether or not 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 gallons per minute 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 gallons per minute. However, the well code does have a provision that requires the well be “adequate in size, design, and development for the intended use.” 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.

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 2 bathrooms (each with a water closet, tub/shower, and lavatory), kitchen sink, garbage disposal, dishwasher, washing machine, laundry sink, and 3 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 seven (7) minutes. The seven minute peak demand and minimum pump size for modern residences may be obtained from Table 1.

<table>
<thead>
<tr>
<th>No. of Bathrooms</th>
<th>7 Minute Peak Demand (GAL)*</th>
<th>Minimum Pump Size to Meet PD (GPM)**</th>
</tr>
</thead>
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<tr>
<td>1</td>
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</tr>
<tr>
<td>1.5</td>
<td>70</td>
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<td>98</td>
<td>14</td>
</tr>
<tr>
<td>3 to 4</td>
<td>122</td>
<td>17</td>
</tr>
</tbody>
</table>

* 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.

** Minimum pump size to meet peak demands without supplemental storage.

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 one to two 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 2-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 one 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 two 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-off (available water volume) of 28 gallons.

The additional volume required can also be provided by precharging the pressure tank and adjusting the pressure switch settings. Precharging is the addition of air to the pressure tank. If the precharge 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 precharge, 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 precharging 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 precharge 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 Black residence has a 7 minute peak demand of 70 gallons. The Blacks 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 precharge 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, precharged 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

The total dynamic head 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. Total dynamic head = 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 Table I (Friction Loss Charts) and Table 2 (Resistance of Valves and Fittings to Flow of Fluids) 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:
1psi = 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
**TOTAL DYNAMIC HEAD CALCULATION**

**EXAMPLE**

**Elevation head**
Elevation difference between pumping level and pressure tank  
\[= 85.00'\]

**Friction head loss**
- Fittings (Refer to Table 2)
  - 3 \(1\frac{1}{4}''\) 90° elbows = 3.75 ft/elbow  
  \[x 3 \text{ elbows} = 11.2'\]
  - 1 \(1\frac{1}{4}''\) gate valve  
  \[= 0.8'\]
  Equivalent length of straight pipe due to fittings  
\[= 12.0'\]
- Pipe (Refer to Table 1)
  - 110' of \(1\frac{1}{4}''\) steel pipe @ 25 gpm flow.
  \[\frac{16.8'}{100'} \times 110' = 18.48'\]
  - 120' of \(1\frac{1}{4}''\) plastic pipe @ 25 gpm flow.
  Equivalent length of pipe due to fittings must be added to the plastic pipe length.
  \[120' + 12' = 132'\]
  \[\frac{9.06'}{100'} \times 132' = 11.95'\]
Friction head loss:  
\[18.48' + 11.95' = 30.43'\]

**Pressure head**
30-50 psi pressure switch setting. Maximum discharge pressure = 50 psi.
\[50 \text{ psi} \times 2.31 \text{ ft/psi} = 115.50'\]

**Total dynamic head**
\[85.00' + 30.43' + 115.50' = 231'\]
# FRICTION LOSS CHART

1 1/2 inch to 2 1/2 inch pipe and under 300 GPM

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

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<th>2 INCH</th>
<th>2 1/2 INCH</th>
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Note: The area above the heavy line is recommended for normal operation based on a maximum flow velocity of 5 ft./sec.
# Friction Losses Through Pipe Fittings in Terms of Equivalent Lengths of Standard Pipe

<table>
<thead>
<tr>
<th>Size of Pipe (Small Dia.)</th>
<th>Standard Elbow</th>
<th>Medium Radius Elbow</th>
<th>Long Radius Elbow</th>
<th>45° Elbow</th>
<th>Tee</th>
<th>Return Bend</th>
<th>Gate Valve Open</th>
<th>Globe Valve Open</th>
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<td>1200</td>
<td>600</td>
</tr>
<tr>
<td>48&quot;</td>
<td>135.</td>
<td>110.</td>
<td>82.</td>
<td>58.</td>
<td>275.</td>
<td>300.</td>
<td>26.</td>
<td>1400</td>
<td>680</td>
</tr>
</tbody>
</table>

From "Engineering Data On Flow Of Fluids In Pipes." - Crane Co.
PUMP SELECTION USING A PUMP CURVE

In order 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 upon request from either the pump manufacturer or supplier.) 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.
TOTAL DYNAMIC HEAD PROBLEM #1

- 100 ft.
- 55 ft.
- 50 ft.
- 20 GPM Pump
- Pumping Water Level
- 1.25 in. Plastic Pipe
- 5 ft.
- Pressure Tank 30-50 psi
- 55 ft.
- 100 ft.
TOTAL DYNAMIC HEAD WORKSHEET

Determine Total Elevation Head
1. How many vertical feet is it from the pumping water level to the pressure tank? _____ ft.

Determine Friction Head
2. What is the pump capacity flow rate through pipe? _____ gpm

3. What is the diameter and material type of the water service line from the well to the pressure tank? Diameter _____ in. Material _____________

4. Apply the answers to questions 2 and 3 to a friction loss chart to find the friction head per 100 feet of water service line. _____ ft./100 ft.

5. What is the length of the water service line? _____ ft.

6. What is the friction head for the water service line (multiply the answers for questions 4 and 5). _____ ft.

Example: Friction loss chart shows that 1 inch diameter plastic pipe at 10 gpm flow rate has a friction head loss of 6.3 ft. per 100 ft. 6.3 ft. x pipe length = friction head 100 ft.

Water service line is 200 ft. in length.

\[ \frac{6.3 \text{ ft}}{100 \text{ ft}} \times 200 \text{ ft} = 12.6 \text{ ft. friction head} \]

7. What is the diameter and material type of the drop pipe from the pump to the pitless adapter? Diameter _____ in. Material _____________

8. Apply the answers to questions 2 and 7 to a friction loss chart to find the friction head per 100 feet of pump drop pipe. _____ ft./100 ft.

9. What is the length of the pump drop pipe? _____ ft.

10. What is the friction head for the water service line? (multiply the answers for questions 8 and 9 – see example in #6 above). _____ ft.

11. What is the total friction head? _____ ft.

Determine Pressure Head
12. What is the pressure switch pump cut-out setting? _____ psi

Example: The pump cut-out setting is the pressure at which the pump will shut off at the end of the pump operating cycle. If the pressure switch setting is 30-50 psi, the pump cut-out setting is 50 psi.

13. Determine the pressure head by converting the answer from question 12 from pound per square inch to feet of head by multiplying it by 2.31 ft./psi. _____ ft.

Example: 50 psi x 2.31 ft./psi = 115.5 ft.

Determine Total Dynamic Head

\[ \text{Total dynamic head} = _____ \text{ ft} \]
Determine Total Elevation Head
1. How many vertical feet is it from the pumping water level to the pressure tank? 50 ft.

Determine Friction Head
2. What is the pump capacity flow rate through pipe? 20 gpm
3. What is the diameter and material type of the water service line from the well to the pressure tank? Diameter 1.25 in. Material plastic
4. Apply the answers to questions 2 and 3 to a friction loss chart to find the friction head per 100 feet of water service line. 6 ft./100 ft.
5. What is the length of the water service line? 50 ft.
6. What is the friction head for the water service line (multiply the answers for questions 4 and 5). 3 ft.
   Example: Friction loss chart shows that 1 inch diameter plastic pipe at 10 gpm flow rate has a friction head loss of 6.3 ft. per 100 ft. 6.3 ft. x pipe length = friction head 100 ft.
   Water service line is 200 ft. in length.
   6.3 ft. x 200 ft. = 12.6 ft. friction head 100 ft.
7. What is the diameter and material type of the drop pipe from the pump to the pitless adapter? Diameter 1.25 in. Material plastic
8. Apply the answers to questions 2 and 7 to a friction loss chart to find the friction head per 100 feet of pump drop pipe. 6 ft./100 ft.
9. What is the length of the pump drop pipe? 100 ft.
10. What is the friction head for the water service line? (multiply the answers for questions 8 and 9 – see example in #6 above). 6 ft.
11. What is the total friction head? 9 ft.

Determine Pressure Head
12. What is the pressure switch pump cut-out setting? 50 psi
   Example: The pump cut-out setting is the pressure at which the pump will shut off at the end of the pump operating cycle. If the pressure switch setting is 30-50 psi, the pump cut-out setting is 50 psi.
13. Determine the pressure head by converting the answer from question 12 from pound per square inch to feet of head by multiplying it by 2.31 ft./psi. 115 ft.
   Example: 50 psi x 2.31 ft./psi = 115.5 ft.

Determine Total Dynamic Head

Total dynamic head = 174 ft.
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, Table 1 may be used as a guide:

<table>
<thead>
<tr>
<th>Gallons per Minute</th>
<th>Pump Running Time (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 20</td>
<td>1</td>
</tr>
<tr>
<td>21 - 50</td>
<td>2</td>
</tr>
<tr>
<td>51 - 75</td>
<td>3</td>
</tr>
<tr>
<td>76 - 100</td>
<td>4</td>
</tr>
<tr>
<td>&gt;100</td>
<td>Consult DEQ</td>
</tr>
</tbody>
</table>

**Bladder or Diaphragm Type Tank with Precharge**

The available water capacity in gallons (drawdown) should equal or exceed the pump capacity times minimum pump running time. The available water in a precharge 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**

\[
25 \text{ gpm} \times 2 \text{ min. running time} = 50 \text{ gallons of available water}
\]
\[
\text{Total volume} (T) \times 25\% = 50 \text{ gallons. Therefore}
\]
\[
T \times .25 = 50 \text{ gallons} \quad T = 50 \quad T = 200 \text{ gallons}
\]

Total volume of bladder or diaphragm tank with precharge = 200 gallons

**CONVENTIONAL STEEL TANK (no bladder or diaphragm) WITH PRECHARGE**

Available draw-off down 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**

\[
25 \text{ gpm} \times 2 \text{ min. running time} = 50 \text{ gallons of available water}
\]
\[
\text{Total volume} (T) \times 20\% = 50 \text{ gallons. Therefore .}
\]
\[
T \times .20 = 50 - 50 \text{ gallons} \quad T = 50 \quad T = 250 \text{ gallons}
\]

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 precharge with a 30-50 psi setting is about 10 percent of the total tank volume.

EXAMPLE

\[
25 \text{ gpm} \times 2 \text{ min. running time} = 50 \text{ gallons of available water} \\
\text{Total volume (T) } \times 10\% = 50 \text{ gallons. Therefore.} \\
T \times .10 = 50 \text{ gallons} \quad \quad T = \frac{50}{.10} \quad \quad T = 500 \text{ gallons} \\
\]

Total volume of conventional steel tank without pre-charge = 500 gallons

The examples given use 30-50 psi as the assumed pressure switch setting, since 30-50 psi is now becoming more common to the water well industry than the 20-40 psi setting. Variations in system operating pressure and pre-charging of pressure tanks will alter the amount of available water (draw-off-\text{down}) from the pressure tank, Table 2 shows that precharging of the tank increases the draw-off, and increasing the operating pressure of the system decreases the tank draw-off. Operating pressure and tank precharge pressure must be taken into consideration when evaluating proposed storage facilities.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
 & 42 gal & 82 gal & 120 gal \\
\hline
20-40 psi & no precharge & 6.5 & 12.8 & 18.6 \\
\hline
system pressure & 10 psi precharge & 10.8 & 21.3 & 31.0 \\
\hline
 & 15 psi precharge & 13.0 & 25.6 & 37.4 \\
\hline
30-50 psi & no precharge & 4.3 & 8.4 & 12.3 \\
\hline
system pressure & 15 psi precharge & 8.6 & 16.8 & 24.6 \\
\hline
 & 20 psi precharge & 10.0 & 19.6 & 28.7 \\
\hline
 & 25 psi precharge & 11.5 & 22.4 & 32.8 \\
\hline
\end{tabular}
\caption{Gallons Drawdown per Pump Cycle}
\end{table}

For details on water storage facilities for flowing wells consult DEQ.
CONSTANT PRESSURE SYSTEMS

Constant pressure (CP) technology for water well systems has become increasingly popular. Pump manufacturers are marketing the new technology as the biggest advancement since the development of the submersible pump. Sanitarians should become familiar with CP systems and the differences between conventional pump/pressure tank system and CP system design and operation.

Two methods are used to control the water pressure in CP systems: variable frequency drives (VFDs), also known as variable speed pumps, and pressure control valves (PCVs). 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. Therefore, the traditional pressure tank sizing criteria found in MDEQ, Water Division and Noncommunity Manuals should not be applied to VFD systems. To determine appropriate pressure tank sizes for VFD systems follow the manufacturer’s installation specifications.

More and more well drillers and facility owners are expected to request approval to install VFD systems. Sanitarians can approve the installation of these systems with the appropriate reduction in pressure tank sizing for VFD systems. 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.
WATER WELL DRILLING METHODS

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

Rotary Drilling

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 drillhole, (2) prevent collapse of the drillhole 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 Drilling**

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 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 drillhole. 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 loosens 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 drillhole roundness.

The portion of the drillhole above the bedrock must be cased to prevent caving. Casing is driven into the drillhole with the use of heavy drive clamps bolted onto the drill stem. 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 drillhole. 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 Drilling**

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.

**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 an 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 sledge hammer 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 pitcher 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 gallons per minute [gpm]), since they can be pumped only with a shallow well jet pump or hand pump.

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 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 Drilling

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 a 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.
OTHER DRILLING METHODS

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
inches 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: 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 drillhead 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 bolders 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 Drilling
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.
### COMPARISON OF WATER WELL DRILLING METHODS

<table>
<thead>
<tr>
<th>Other names</th>
<th>Cable Tool</th>
<th>Rotary</th>
<th>Auger</th>
<th>Hollow Rod</th>
<th>Jetting</th>
<th>Driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percussion Spudding Churn Drill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Driven well point, stab well</td>
</tr>
<tr>
<td></td>
<td>Raising-dropping of drill stem and bit</td>
<td>Rotating drill string and bit</td>
<td>Rotating of augers and bit</td>
<td>Raising-dropping of drill rods and bit</td>
<td>Jetting action of water exiting bit</td>
<td>Well point and casing driven into ground to displace soil material</td>
</tr>
<tr>
<td></td>
<td>Cable with suspended drill string (rope socket, drill stem, bit)</td>
<td>Swivel-kelly drill rods-stabilizer-bit (top head or table drive)</td>
<td>Top head drive-auger flights-bit</td>
<td>Swivel-drive block drill rods-bit</td>
<td>Swivel-drive block drill rods-bit</td>
<td>Drive cap-5 foot casing lengths drive point</td>
</tr>
<tr>
<td></td>
<td>As drilling proceeds</td>
<td>After drillhole is complete</td>
<td>After drillhole is complete</td>
<td>As drilling proceeds</td>
<td>As drilling proceeds</td>
<td>As drilling proceeds</td>
</tr>
<tr>
<td></td>
<td>Driven</td>
<td>Gravity (some driving)</td>
<td>Gravity (some driving)</td>
<td>Driven</td>
<td>Driven</td>
<td>Driven</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>Bentonite water (mud rotary), air (air rotary or down hole hammer), water (rev. rotary)</td>
<td>Down annulus-up drill rods</td>
<td>Down annulus-up annulus</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stationary</td>
<td>Down drill rods-up annulus (opposite in rev. rotary)</td>
<td>Down annulus-up drill rods</td>
<td>Down drill rods-up annulus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bailer</td>
<td>Flow into mud pit with drilling fluid</td>
<td>Deposited on ground surface</td>
<td>Flow into mud pit with drilling fluid</td>
<td>Flow into mud pit with drilling fluid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Drilling motion:**
- **Cable Tool:** Raising-dropping of drill stem and bit
- **Rotary:** Rotating drill string and bit
- **Auger:** Rotating of augers and bit
- **Hollow Rod:** Raising-dropping of drill rods and bit
- **Jetting:** Jetting action of water exiting bit
- **Driving:** Well point and casing driven into ground to displace soil material

**Drill string:**
- **Cable Tool:** Swivel-kelly drill rods-stabilizer-bit (top head or table drive)
- **Auger:** Top head drive-auger flights-bit
- **Hollow Rod:** Swivel-drive block drill rods-bit
- **Jetting:** Swivel-drive block drill rods-bit
- **Driving:** Drive cap-5 foot casing lengths drive point

**Casing installation method:**
- **As drilling proceeds**: Driven
- **Gravity (some driving)**: Gravity (some driving)
- **Deposited on ground surface**: Flow into mud pit with drilling fluid

**Drilling fluid type:**
- **Cable Tool**: Water
- **Rotary**: Bentonite water (mud rotary), air (air rotary or down hole hammer), water (rev. rotary)
- **Auger**: Down annulus-up drill rods
- **Hollow Rod**: Down annulus-up drill rods
- **Jetting**: Down annulus-up drill rods
- **Driving**: Down drill rods-up annulus

**Direction of fluid flow:**
- **Stationary**: Down drill rods-up annulus (opposite in rev. rotary)

**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**: Flow into mud pit with drilling fluid
## ADVANTAGES & DISADVANTAGES OF COMMON DRILLING METHODS

<table>
<thead>
<tr>
<th>Drilling Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable Tool</strong></td>
<td>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. <strong>Less Material Removed During Drilling:</strong> Generally no oversized borehole, material removed from casing inside diameter, lighter soils can be bailed from casing. <strong>Repair Work:</strong> Cable tool rigs ideal for casing reaming, screen replacement, and development.</td>
<td><strong>Slow Drilling Speed:</strong> Bedrock drilling – 1/7 as fast as rotary drilling, Glacial drift drilling – 1/5 as fast as rotary drilling <strong>Depth Limitations with Single Casing String:</strong> Driving generally difficult in caving formations, ability to drive casing is limited by tool weight and ground friction. <strong>Outer Casing Needed for Gravel Packing or Full Length Grouting:</strong> 3 to 4 inch larger casing needed to maintain annulus and must be extracated during grouting. <strong>Steel Casing Material Only:</strong> PVC casing cannot be used unless installed in an oversized borehole without driving.</td>
</tr>
<tr>
<td><strong>Jetting and Hollow Rod</strong></td>
<td>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. <strong>Less Material Removed During Drilling:</strong> Generally no oversized borehole, material removed from casing inside diameter. <strong>Repair Work:</strong> Jetting rigs ideal screen replacement and development.</td>
<td><strong>Slow Drilling Speed:</strong> 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. <strong>Depth Limitations with Single Casing String:</strong> Driving generally difficult in caving formations, ability to drive casing is limited by tool weight and ground friction. <strong>Outer Casing Needed for Gravel Packing or Full Length Grouting:</strong> 3 to 4 inch larger casing needed to maintain annulus and must be extracated during grouting. <strong>Steel Casing Material Only:</strong> PVC casing cannot be used unless installed in an oversized borehole without driving.</td>
</tr>
<tr>
<td>Rotary</td>
<td>Speed of Drilling:</td>
<td>Cost of Equipment:</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>5 to 7 times faster than cable tool, capable of several hundred feet per day (dependent on geologic material).</td>
<td>5 times as costly as a cable tool or jetting rig, bit cost and tooling more expensive.</td>
</tr>
<tr>
<td>Options of Well Design:</td>
<td>Screen can be telescoped or attached, separate screens can be installed, filter packing to enhance formation production, downholle casing hammer method.</td>
<td>Maintenance &amp; Support:</td>
</tr>
<tr>
<td></td>
<td>Grouting: Oversized borehole requires grouting of annular space surrounding casing, most adaptable to various grout placement methods, practical for grout placement thru casing.</td>
<td>Much more extensive and costly than cable tool, higher fuel consumption, water truck needed.</td>
</tr>
<tr>
<td></td>
<td>Limited Equipment: Less expensive than rotary, minimal amount of equipment needed.</td>
<td></td>
</tr>
<tr>
<td>Auger (Solid Stem and Hollow Stem)</td>
<td>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</td>
<td>Limited Depth: Poor results in caving formations, gravel, or high water table, less than 100 feet.</td>
</tr>
<tr>
<td></td>
<td>Limited Equipment: Less expensive than rotary, minimal amount of equipment needed.</td>
<td></td>
</tr>
</tbody>
</table>
WATER WELL COMPONENTS

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

**Borehole**
Borehole is a vertical boring to reach 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**
Well seal is a mechanical device to prevent contamination from entering 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:

<table>
<thead>
<tr>
<th>PVC</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncorroding</td>
<td>Corrodes</td>
</tr>
<tr>
<td>Lower strength</td>
<td>Higher strength</td>
</tr>
<tr>
<td>Fewer water quality complaints</td>
<td>Rusty water</td>
</tr>
<tr>
<td>Rotary construction only</td>
<td>Suitable for any drilling method</td>
</tr>
</tbody>
</table>

**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, it also stabilizes the borehole.

The benefits of filter packing are:
- Greater porosity
- Higher hydraulic conductivity
- Reduced drawdown
- Higher yield
- Reduced entrance velocity
- Faster development
- Easier grouting
- Longer well life
- Improved well rehabilitation
- Reduced sand pumping
Packer
A neoprene packer (often called a K packer) is a device that seals space between casing and telescoped screen to keep sand out of 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 semiconsolidated 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. Slot size may also be expressed in metric units; for example, 0.010 inch equals 0.25 millimeter (mm). For small-diameter screens covered with wire mesh, the number of openings in the mesh per inch are designated by gauze numbers.

<table>
<thead>
<tr>
<th>Geological Material</th>
<th>Slot Size</th>
<th>Opening (inches)</th>
<th>Opening (mm)</th>
<th>Gauze Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay &amp; Silt</td>
<td>-</td>
<td>0.003</td>
<td>0.10</td>
<td>-</td>
</tr>
<tr>
<td>Fine sand</td>
<td>6</td>
<td>0.006</td>
<td>0.15</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.007</td>
<td>0.18</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.008</td>
<td>0.20</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.010</td>
<td>0.25</td>
<td>60</td>
</tr>
<tr>
<td>Medium sand</td>
<td>12</td>
<td>0.012</td>
<td>0.30</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.015</td>
<td>0.40</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0.018</td>
<td>0.45</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.020</td>
<td>0.50</td>
<td>-</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>25</td>
<td>0.025</td>
<td>0.65</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>0.035</td>
<td>0.90</td>
<td>20</td>
</tr>
<tr>
<td>Very coarse sand</td>
<td>50</td>
<td>0.050</td>
<td>1.27</td>
<td>-</td>
</tr>
<tr>
<td>Very fine gravel</td>
<td>90</td>
<td>0.090</td>
<td>2.29</td>
<td>-</td>
</tr>
<tr>
<td>Fine gravel</td>
<td>150</td>
<td>0.150</td>
<td>3.81</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>0.250</td>
<td>6.35</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>375</td>
<td>0.375</td>
<td>9.52</td>
<td>-</td>
</tr>
</tbody>
</table>

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 .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.
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 Wells
- Terminate in glacial drift (sand, gravel) or bedrock.
- Constructed using rotary, cable tool, jetting, hollow rod, or auger rigs.
- 2 inches or larger casing (domestic wells 4-5 inch).
- Casing material can be steel or PVC plastic.
- Installed by well drilling contractors.
- More common than driven or dug wells.
- Most are greater than 50 feet deep.
- Most sanitary type.

Driven Wells
- Installed in glacial drift only.
- Cannot be driven into bedrock.
- Well point driven into ground with post driver, tripod with weight or sledge hammer.
- 1.25-2 inches diameter.
- Most installed by owner.
- Common around lakes and high water table areas.
- Most are less than 35 feet deep and have a limited yield (less than 7gpm).
- More susceptible to contamination than drilled wells.
Dug Wells
- Historical type of wells, originally drilled in Michigan
- Larger diameter (18-48 inch).
- Curbing material is usually concrete crocks with loose joints.
- Water enters well through loose casing joints.
- Older dug wells were hand-dug.
- Some were installed with bucket augers.
- Low well yield, but casing stores 100’s of gallons.
- Highly vulnerable to contamination (85 percent positive for coliform based on 1994 CDC study).

Large Diameter Low Yield Wells
- Installed in low yield areas (“Thumb” and SE Michigan)
- Casing material is slotted fiberglass (National Sanitation Foundation certified).
- Upper 25 feet of casing is grouted.
- More sanitary than old dug wells
- Requires unique pitless adapter (due to corrugated casing wall).
- Only allowed under a deviation where conventional wells can not be drilled.
DRILLING SITE EVALUATION OUTLINE

This outline was developed to aid the local health department sanitarian in conducting an evaluation during the construction of a water well. These are typically called Random Construction Inspections (RCI). Also attached is a checklist the sanitarian can use while conducting an 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 MDEQ directory.
      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 (buried and overhead)? Was MISS DIG contacted prior to drilling?

4. Drilling Method
   a. What type of drilling method is being used? (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 as well casing? (steel or PVC plastic)
   2. Check casing markings - (ASTM spec., weight/ft., 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?

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?
A. PERMITS
1. Was permit issued? YES  NO
2. Were there any permit restrictions or conditions? YES  NO
3. Is the water well drilling contractor aware of the permit conditions? YES  NO

B. CONTRACTOR REGISTRATION
1. Is the water well drilling contractor registered? YES  NO
2. Is the drilling rig properly registered and identified with DEQ decals, registration number, business name, and address on both sides of the rig, in letters at least 2 inches high? YES  NO

C. DRILLING SITE LOCATION
1. Is the water well location adequately isolated from sources of contamination. YES  NO
2. Does the location comply with permit conditions? YES  NO
3. Will the water well be accessible for maintenance? YES  NO
4. Is the water well in a nonflooding location? YES  NO

D. DRILLING METHOD
1. What type of drilling method is being used?
   Rotary       Cable Tool       Auger       Hollow Rod       Jetting       Driving
   Combination                                            Other

E. WATER WELL RECORDS
1. Is the water well driller routinely checking cuttings samples and recording geologic information? YES  NO

F. WATER WELL CONSTRUCTION DETAILS
1. Well Type: Sand or Gravel (unconsolidated) _______ Bedrock (consolidated) _________
2. Grouting:
   a. Type_________________Manufacturer_________________Product Name_________________
b. Is the mud scale used to weigh grout?  □ YES  □ NO

c. What grouting method will be used?

Grout pipe in annulus ______ Grout pipe inside casing ______ Displacement method _________
Other _________________________________

d. Does the water well drilling contractor have necessary grouting equipment (mixer, pump, grout pipe, hoses) and materials at the drilling site?  □ YES  □ NO

e. Did grout appear at the wellhead after pumping?  □ YES  □ NO

Weight of grout at surface: ______ lbs./gal  Weight of grout before pumping: ______ lbs./gal.

f. If the water well casing is driven (cable tool, jetting, hollow rod), is dry granular bentonite placed around the casing during driving?  □ YES  □ NO

3. Water Well Casing

a. Type of well casing: PVC ___ Galvanized steel ___ Black steel ___ Other _________________

b. Casing material approved?  □ YES  □ NO

4. Water Well Screen

a. Type of screen: PVC_____ Stainless steel___ Other____________________________

b. Installation method: telescoped ______ attached to casing _________________________

c. Filter-pack installed?  □ YES  □ NO

d. Filter-pack chlorinated?  □ YES  □ NO

5. Drilling Water

a. Source approved?  □ YES  □ NO

b. Drilling water chlorinated to at least 10 ppm residual?  □ YES  □ NO

6. Water Well Development

a. Development method used: air _____ surge block _____ bailer _____________________________
   plunger _____ water jetting _____ overpumping ___________

b. Approximate water well capacity (use 5 gallon pail): ______ gallons per minute

c. Water free of sand or other turbidity upon completion of the development?  □ YES  □ NO
   (Check with clean white pail or clear jar)

7. Water Well Disinfection
a. Water well disinfected upon completion? □ YES □ NO

b. Method and amount of disinfectant adequate? □ YES □ NO

c. Final chlorine residual in well ______ ppm (Check w/chlorine test strips)

8. Approved temporary cap? □ YES □ NO

Comments:______________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Evaluated by ______________________ Date: ___________ Reinspektion Date: __________
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 ground water quality. The DNRE 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.

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 contaminated by sewage systems that are installed in the thin glacial drift. Proper grouting of the casing into the bedrock to a point below the upper fractured zone prevents contaminants from flowing into the well. 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
1. Provides sanitary protection for the water supply from surface or near-surface contamination sources.
2. Protects the water bearing formation by preventing movement of water between aquifers.
3. Seals off a formation which is known to have been contaminated or which produces water of undesirable quality.
4. Preserves the hydraulic characteristics of the aquifer and provides a seal against loss of artesian pressure.
5. Increases the life of the well casing by protecting it from corrosion in areas of acid soils or where other corrosive conditions exist.
6. Provides structural support for casing when neat cement is used for grouting PVC plastic well casing.

Grouting Rules
Rule 133a
- 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
- Prevent mixing of previously distinct aquifers below grade.
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 & 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 ground water 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 lb. sack of cement (5.2 gal. of water x 8.33 lb/gal. = 43.3 lb. divided by 94 lb. of cement = 0.46).

The maximum recommended water to cement ratio for neat cement is 0.53, or 6 gallons of water per 94 lb. 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 gal./sack) to 0.62 (7 gal./sack). Bentonite is commonly used as an additive (1-2%) with these types of cement. The amount of water necessary to hydrate the slurry properly increases with addition of bentonite.

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/gal. Field experience has shown that settling of solids frequently occurs, resulting in an open upper annulus and need for the well drilling contractor to regrouting.

In recent years several new 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/gal 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 ground water movement.

**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% is the more commonly used, preferred amount.

**Calcium chloride (CaCl\(_2\))** - This accelerator 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.

**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 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 pounds per square inch [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 on page 56:

**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 1¼ inch rigid pipe is used as the grout pipe. The borehole diameter must be large enough to accommodate the grout pipe. A two 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 & 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 pound sack of Portland cement will weigh approximately 15 pounds 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.

**Grouting Wells – Volume Calculations**

The chart 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 (ft) 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.

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Grouting Wells – Neat Cement Requirements

The chart, 'Grouting Wells - Neat Cement Volume Requirements' 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 cu. ft. or 9.5 gallons)

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These figures are based on a clean borehole. Due to borehole irregularities and other factors, the actual required volume is usually greater. It is a sound practice to have 20 percent to 50 percent more material at the job site.

For additional information on grouting wells refer to "Michigan Water Well Grouting Manual," MDPH, 1988
EVALUATION OF GROUTING

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% 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 access 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.
Use of Soil 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 local health department has reason to believe may not have been grouted. The DNRE 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.

1. **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 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.

2. **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 nonhydrated, 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 more long. 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.

3. **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:

a. **Condition.** Grout not observed directly below pitless. Annulus open part way. Grout found with probe at some distance down hole.

Grout is not observed just below the pitless adapter, and a clean, dry, open annulus is present around the casing. Probing the annulus reveals that approved grout material is present, but is more than a few feet below the pitless adapter. There are no liquids in the open annulus, and the annulus has no obstructions (side wall collapse, bridged material, etc.).

**Corrective measures.**

Option #1 - Extend a tremie pipe to the depth that the grout was found, and pressure grout from that point back to the ground surface. Neat cement or an approved bentonite grout may be used.

Option #2 - If the grout is within 10 feet of the pitless adapter, pouring grout from the surface is an acceptable corrective measure. 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 the ground surface.

b. **Condition.** Grout not observed with probe. Annulus contains water. No bridging
observed.

Grout is not observed at the pitless adapter, and the annulus around the casing is open. The annulus contains muddy water or what appears to be a watery bentonite material that has not set-up. Probing the annulus deeper reveals that thicker grout material has settled 25 feet down the annulus. No bridging was found in the upper 25 feet of annulus.

Corrective measure. 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. Neat cement or an approved bentonite slurry grout may be used.


Grout is not observed at the pitless adapter, and an open annulus is present around the casing. Probing the annulus fails to locate any grout material, but the probing does reveal that the annulus to the depth probed is open (i.e., there is no bridging, sand, or any other material in the annulus.) Muddy water may or may not be present in the annulus.

Corrective measure. The well has not been properly grouted. The well drilling contractor must be contacted to discuss the violation. The contractor has two options:

Option #1 - Meet with the 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. Neat cement or an approved bentonite grout may be used.

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.

d. Condition. Annulus partially plugged with sand, cuttings, etc. Some grout found with probe.

Grout is not observed immediately below the pitless adapter but the annulus around the casing 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.
Corrective measure.

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 sealing procedure to assure that the ungrouted annulus is properly plugged.

e. Condition. Annulus plugged with sand, cuttings, etc. Grout not found.

Grout is not observed just below the pitless adapter. 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.

Corrective measure. 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. Section R 325.1669(2) of the Rules for Part 127, Act 368, PA 1978, states “If a health officer or the department determines that a registered well drilling contractor has improperly located or constructed a well, the well drilling contractor shall be responsible for plugging the well.” 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 manufacturer’s specifications. Exceeding this maximum amount will lead to the following problems:

   a. 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.

   b. Reduction in the weight per gallon of the grout. Bentonite grout must meet the manufacturer’s minimum required weight, but in no case shall it be less than 9.4 pounds per gallon with 15 percent solids. Some high solids bentonite grouts will exceed this weight.

   c. 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:

   a. 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.

   b. Excessive mixing temperatures. If mix water is warm, the time before "setting" of the grout starts is significantly speeded up because of the more rapid hydration (absorption of water) of the bentonite.

   c. "Sheering" of the bentonite during mixing. Some pumping or mixing methods tend to shear (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. Causes for grouts not setting properly include:
a. Using too much water in mixing the grout.

b. Excessive chlorine in the mix water (above 50 parts per million).

c. The pH of the mix water is too low. The pH of the mix water should be 8.5 to 9.0.

d. 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.

e. 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):

a. 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.

b. Failure of the grout to properly hydrate (using too much water, poor mix water quality, etc).

c. Failure to remove drilling mud/cuttings from the annulus prior to grouting.
Neat Cement Grout Problems
1. Using too much water. A mixing ratio of not more than 6 gallons of water to one 94# bag of Type I or 1A cement must be used. Too much water will weaken the cement, reduce the solids content (minimum weight must be at least 15 pounds per gallon) and increase the likelihood of settling.

2. 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.

3. 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 use by Michigan registered well drilling contractors:

1. 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.

2. 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.

3. 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.

4. 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.
# Properties of Common Grouting Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I Cement</td>
<td>Most common type of cement used for grouting/plugging.</td>
<td>Forms good seal. Easier to mix and pump than bentonite. Required as grout where bedrock is encountered within 25 ft. of the surface and for plugging all wells terminated in bedrock.</td>
</tr>
<tr>
<td>Type III Cement</td>
<td>High early strength.</td>
<td>Not a common cement. Ground to finer particle size which increases surface area and provides faster curing rate.</td>
</tr>
<tr>
<td>Type IV Cement</td>
<td>Low heat of hydration.</td>
<td>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.</td>
</tr>
<tr>
<td>Type K Cement</td>
<td>Expansive cement.</td>
<td>Not a common cement. Basically Type I cement with additives to provide for rapid expansion. “Type K Komponent” is used for plugging abandoned wells.</td>
</tr>
<tr>
<td>Concrete</td>
<td>Neat cement with sand added. 50% sand by weight.</td>
<td>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.</td>
</tr>
<tr>
<td>Bentonite powder</td>
<td>Contain mixtures of sodium and calcium bentonite with other clays.</td>
<td>Drilling “gel.” Various forms used in Michigan as the main component of most drilling muds.</td>
</tr>
<tr>
<td>Bentonite granular</td>
<td>Raw mined and particles are coarse granular (8 mesh is usual).</td>
<td>Intended for slurry applications to grout or plug wells. Low permeability. Slower water absorption and delayed swelling in comparison to powdered bentonite.</td>
</tr>
<tr>
<td>Bentonite chips</td>
<td>Large particle versions of granular products (.25-.75 in.).</td>
<td>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.</td>
</tr>
<tr>
<td>Bentonite pellets</td>
<td>Powdered bentonite compressed into a pellet (.25-.75 in.).</td>
<td>Uniform in size. Same application as bentonite chips. Bridges easier and are more expensive than chips.</td>
</tr>
</tbody>
</table>
# WATER WELL GROUTING MATERIALS SPECIFICATIONS

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>WATER RATIO</th>
<th>WEIGHT/GAL.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neat Cement</td>
<td>6.0 gallons max/sack of cement</td>
<td>15.0 pounds</td>
</tr>
<tr>
<td></td>
<td>5.2 gallons recommended/sack of cement</td>
<td>15.6 pounds</td>
</tr>
<tr>
<td>Neat Cement &amp; 1% Bentonite</td>
<td>6.0 gallons max/sack of cement</td>
<td>15.0 pounds</td>
</tr>
<tr>
<td>Neat Cement &amp; 2% Bentonite</td>
<td>6.5 gallons max/sack of cement</td>
<td>14.7 pounds</td>
</tr>
<tr>
<td>Neat Cement &amp; 3% Bentonite</td>
<td>7.15 gallons max/sack of cement</td>
<td>14.4 pounds</td>
</tr>
<tr>
<td>Neat Cement &amp; 4% Bentonite</td>
<td>7.8 gallons max/sack of cement</td>
<td>14.1 pounds</td>
</tr>
<tr>
<td>Neat Cement &amp; 5% Bentonite</td>
<td>8.5 gallons max/sack of cement</td>
<td>13.8 pounds</td>
</tr>
<tr>
<td>Neat Cement &amp; CaCl (accelerator)</td>
<td>6.0 gallons max/sack of cement</td>
<td>15.0 pounds</td>
</tr>
<tr>
<td></td>
<td>CaCl - 2 to 4 lbs/sack of cement</td>
<td></td>
</tr>
</tbody>
</table>

## Bentonite

Refer to the manufacturers specifications for water ratios and weights.
Refer to [www.nsf.org/certified/PwsChemicals](http://www.nsf.org/certified/PwsChemicals) for National Sanitation Foundation (NSF) Certification

## Concrete

<table>
<thead>
<tr>
<th>Product</th>
<th>Details</th>
<th>Weight/Gal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>1 sack of cement and an equal volume of sand per maximum 6 gallons water</td>
<td>17.5 pounds</td>
</tr>
</tbody>
</table>

*Calcium chloride accelerates the setting of cement. Rapid mixing and pumping of grout after adding calcium chloride is recommended.*

NOTE: Neat cement is required in areas where bedrock is less than 25 feet from ground surface.
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:
1. large percentage of open area
2. non clogging slots
3. resistant to corrosion
4. sufficient column and collapse strength

Functions:
1. easily developed
2. minimal incrusting tendency
3. low head loss through the screen
4. 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 compare to one with limited open area. The entrance velocity is low, therefore head loss for the screen is at a minimum, thus minimizing drawdown in the well.
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 use 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 are 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 attached 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 ¼ 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 & 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 .1 foot 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**
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**
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 different 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 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 insure that contaminants are not introduced into the well during the filter-packing process.
WELL DEVELOPMENT

Introduction
By definition, 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 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 place 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 sand in the water is kept to a minimum.

Air Development by Surging and Pumping
Many driller 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 air line 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 effecting 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.

*The source of information for this chapter was “Groundwater and Wells”, Second Edition, by Fletcher G. Driscoll, Ph.D.*
WELLHEAD COMPLETION AND PUMPING EQUIPMENT

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
**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:
  a. Fully exposed 12 inches above floor of basement, basement offset, pump room
  b. Fully exposed 12 inches above ground surface
  c. Concentric piping under system pressure
  d. 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 approved
- If pump can exceed working pressure of the tank, a pressure relief valve shall be installed

**Rule 158  Sampling faucets**
- Down-turned faucet
- 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 DEQ Well Construction Program website at [www.michigan.gov/deqwaterwellconstruction](http://www.michigan.gov/deqwaterwellconstruction).*
Where in the Well It All Starts:
Residential Water Pumps

By Tom McDermott and Dave Greisinger

Summary: Over 1.5 billion people use water wells as their primary source of drinking water in the United States, 18 million private water users supply drinking, washing, bathing and irrigation water needs for 29 million people. This article focuses on the electrically powered jet and submersible centrifugal pumps, and water systems that normally deliver this water to the developed world.

During the 1940s in the United States, electricity generally became available in rural areas due to the expansion of rural electrification under the federal Rural Electrification Administration (REA). As a result, the tireless job of hand pumping and hauling water from domestic water wells was, in many areas, replaced with motor-driven pumps. Generally speaking, the motor-driven water pumps most in use today are centrifugal pumps and can be classified as either jet pumps or submersible well pumps. Jet pumps are aboveground and can be further broken down into shallow well and deep well jet pumps. Submersible pumps, as their name implies, are submerged in the well water.

Shallow & deep well jet pumps

A shallow well jet pump, limited by atmospheric pressure, can lift water about 25 feet. Deep well jets are most effective to about 100 feet. Jet pumps essentially operate on the principle of lifting a vacuum. Imagine sucking on a straw and removing the air and, as this is done, the liquid rises to fill the vacuum that’s been created. Since jet pumps don’t pump or evacuate air, they use water in the system to move water from the well to the pump and into the household water system.

Jet pumps draw water from a well by creating a vacuum through the combined efforts of the impeller and diffuser as well as the jet ejector, which is made up of a nozzle and venturi (see Figure 1). As the impeller moves water out of the pump housing, it pulls water from the well. This water passes through a nozzle, which constricts the flow of the water through its progressively narrower opening, thereby increasing the speed (velocity) of the water and creating a partial vacuum at the end of the nozzle. In many pump manuals, this is compared to the nozzle on a garden hose. Once the water passes through the nozzle, it moves into a larger-diameter venturi that slows down the water and increases the pressure in the pump. The water then enters the pump housing where the impeller moves a portion of the water into the household water system while some of the water is recirculated by the impeller and used to draw more water out of the well. This recirculated water is referred to as “drive water.”

Spotted the ejector

The fundamental difference between a shallow well jet pump and a deep well jet pump is the location of the jet ejector. A shallow well jet pump has the jet ejector attached to the pump housing and is aboveground like the pump. A deep well jet pump has the jet ejector assembly down in the well, either submerged or close to the pumping level of the water.

A typical deep well jet pump installation uses a two-pipe system. One pipe is called the pressure or drive pipe that sends drive water from the surface pump (see Figure 2) to the jet ejector nozzle, creating a partial vacuum that fills with well water. This drive water along with well water flows up the second pipe (suction pipe) to the pump on the surface. Another type of deep well jet installa-
The depth from which the water is drawn and the ability to build significant pressure limit the performance of jet pumps. For example, a typical \( \frac{3}{4} \) horsepower (hp) shallow well jet pump will only produce about 8 gallons per minute (gpm) at a 15-foot suction lift at 40 pounds per square inch (psig). Likewise, a typical \( \frac{1}{4} \) hp deep well jet pump will only pump 8.5 gpm from a 60-foot water level. Nevertheless, jet pumps remain popular as over 400,000 are sold annually in the United States (see Table 1).

### Submersible Water Well Pumps

Simply put, submersible water well pumps “push” the water out of the well rather than “pull” the water out like jet pumps. Submersible well pumps are complete units with a pump end made up of a series of matching impellers and diffusers called stages, and an attached motor to turn the impellers and diffusers in the pump end. The submersible pump is submerged in the water down in the well and drives the water up the discharge piping to the pressure tank.

Submersible pump performance is a function of capacity and pressure. A submersible pump is designed to deliver certain flows at given pressures from specific pumping levels. The design of the impellers and diffusers determine the capacity and pressure of a submersible pump end. Capacity is, for the most part, based on the width of the impeller and diffuser. The pressure is dependent on the diameter of the impeller, the number of impellers, and the speed at which the impellers rotate. Most U.S. residential submersible pumps are 4-inch pumps coupled with constant speed 4-inch motors operating at 3,450 revolutions per minute (rpm).

Pump manufacturers normally design their pumps to fall into ranges such as 10-25 gpm. Within these gpm ranges, a number of motor choices will be offered based on the proper combination of capacity to pumping level to horsepower. It's important to remember that horsepower by itself isn't the arbiter of submersible pump performance. Selection of a pump based solely on horsepower is a common error.

Residential submersible pump motors are manufactured in either a 2-wire...
or 3-wire configuration. A 2-wire pump motor doesn’t have a control box with a motor-start capacitor, but rather includes the start capacitor in the submerged pump motor. A 2-wire pump motor is wired directly to the pressure switch and 3-wire submersible pump motors are wired from the well to a wall-mounted control box with relay and start capacitor and then to the pressure switch.

**Weighing the pros and cons**

The clearest benefit of the submersible pump over the jet pump is the ability to deliver higher capacities from deeper levels at significant pressures to the household water system. Of course, a negative is that a submersible pump must be pulled from the well to be serviced; not so with a jet pump, unless it’s a deep well installation with a faulty jet ejector (see Figure 3).

Nationally, submersible water well pumps have become more popular than jet pumps in residential well installations; however, there are areas where jet pumps clearly outstrip submersible pump installations. Generally, jet pumps are more common in warmer climates and areas with higher water tables (see Table 1).

**Emerging pump technology**

Within the last several years pump manufacturers have recognized an increasing demand from private water system consumers for a “constant pressure” municipal type water system. Essentially, a constant pressure private water system eliminates the pressure and volume fluctuations experienced in traditional private water systems and operates much like a municipal supply. A traditional private water system includes a pump with a fixed pumping capacity and is controlled by a pressure switch which normally turns the pump on and off in a 20 psi range. A common pressure switch setting is ‘40/60’, that means the pump turns on when the water system pressure drops below 40 psi and the pump shuts off when the system pressure reaches 60 psi. Because of a constant speed motor a regular jet or submersible pump can’t increase volume based on demand. Likewise, because of the 20 psi pressure differential from the pressure switch, a traditional private water system doesn’t deliver the normal steady pressure of a municipal water supply.

Using variable speed motor technology, several pump manufacturers have introduced “constant pressure” submersible pumping systems. These systems, still very much in the developing stage, maintain a reasonably constant volume and pressure profile as the demand for water varies.

**Conclusion**

This is an exciting time in the private water system and well water pump industry. As larger homes are being built on private wells, with correspondingly larger water supply needs, the challenges of sizing an adequate private water supply system have never been greater. The challenge for the private water system installer is to make sure that the right pump and water system have been installed to produce the water needs—supply, and pressure—that the water treatment equipment, plumbing fixtures and lifestyle of the consumer demand.

**Acknowledgment**

The authors would like to thank the pump professionals at Goulds Pumps and Grundfos Pumps for allowing their pump images to be used in this article.

**References**


**About the authors**

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<table>
<thead>
<tr>
<th>WELL TYPE</th>
<th>PUMP TYPE</th>
<th>NORMAL CAPACITY RANGE (GPH)</th>
<th>PRACTICAL SUCTION LIFT (FT) *</th>
<th>MAX. PRACTICAL PUMPING DEPTH (FT)</th>
<th>USUAL DISCHARGE PRESSURE RANGE (PSI)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHALLOW WELL</td>
<td>Shallow Well Jet (Jet on pump)</td>
<td>200-1500</td>
<td>20-25</td>
<td>25</td>
<td>20-40 30-50</td>
<td>1. Simple in construction. 2. Easy to service. 3. Can be used with 1 inch &amp; larger wells. 4. Less efficient hydraulics.</td>
</tr>
<tr>
<td>SHALLOW WELL</td>
<td>Piston or Reciprocating</td>
<td>200-800</td>
<td>20-25</td>
<td>25</td>
<td>20-40 30-50 40-60</td>
<td>1. Adaptable to low capacity &amp; high head. 2. Handles air without losing prime. 3. No longer widely used. 4. Can be used with 1 inch &amp; larger wells.</td>
</tr>
<tr>
<td>SHALLOW WELL</td>
<td>Straight Centrifugal (Single &amp; multi stage)</td>
<td>500-2000</td>
<td>15-20</td>
<td>20</td>
<td>20-40 30-50</td>
<td>1. Suitable for high capacities. 2. Efficient hydraulics. 3. Can be used with 1 inch &amp; larger wells. 4. Simple &amp; easy to service.</td>
</tr>
<tr>
<td>DEEP WELL</td>
<td>Deep Well Jet (single and multi stage) (Jet in well)</td>
<td>200-600</td>
<td>15-20 (ft. below jet)</td>
<td>200</td>
<td>20-40 30-50 40-60</td>
<td>1. Simple in construction &amp; operation. 2. No moving parts in well. 3. Less efficient hydraulics. 4. Can be installed on 2 inch &amp; 3 inch wells. 5. Can be located away from well.</td>
</tr>
</tbody>
</table>

* Practical suction at sea level. Reduce 1 foot for each 1000 feet above sea level.
ELECTRICAL CODE REQUIREMENTS
FOR WELL & PUMP INSTALLATIONS

Introduction
The electrical wiring of a water well and pump installation is regulated by the Michigan Electrical Administrative Act (MEAA) (1956 PA 217) for licensing and exceptions, rather than the Michigan Water Well Construction and Pump Installation Code (Part 127, 1978 PA 368). Registered Water Well Drilling and Pump Installation Contractors are exempt from having an electrical license for residential single-family installations only.

Local and state electrical inspectors have authority for enforcement of electrical code provisions. Local health department 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 nonpotable industrial wells) must be performed by a licensed electrical contractor.

The MEAA and the state electrical code are implemented by:

Michigan Department of Energy, Labor & Economic Growth
Bureau of Construction Codes
Electrical Division
2501 Woodlake Circle, Second Floor
Okemos, MI 48864
(517) 241-9320

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

Michigan's electrical code is the National Electrical Code 1999, with special Michigan amendments. The NEC 1999 and NEC Handbook 1999 are available from the National Fire Protection Association, Batterymarch Park, P.O. Box 9146, Quincy, MA 02269-9959, phone 1-800-344-3555.
Electrical Code Requirements for a Typical Submersible Pump Installation at a Single-Family Residence:

I. Electrical cable from submersible pump to wellhead:
   A. Cable Material: Type UF with surface marking of "submersible water pump cable" or "pump cable."
   B. Cable protection: The cable inside the casing shall be protected from damage by the use of cable guards, or by securely attaching the cable to the drop pipe.

II. Underground electrical cable from well to house:
   A. Cable Material:
      1. Direct bury - Type UF or USE.
      2. Inside a raceway or conduit - Type RHW, TW, THW, THHW, THWN, XHHW, or ZW.
   B. Conduit Raceway:
      1. The electrical cable or wiring on the outside of the casing shall be protected by a rigid conduit from the well cap/seal to a point belowgrade.
         a. The rigid conduit must be securely attached to the well cap/seal and must extend belowgrade to the minimum depth required for the cable (See #3 below).
         b. The rigid conduit must be provided with an electrical bushing or fitting at the point where the cable enters and leaves the conduit. This bushing or fitting protects against cable damage due to abrasion.
      2. Types of conduit approved for submersible pump installations:
         a. Rigid Metal Conduit - must be galvanized.
         b. Rigid Nonmetallic Conduit - must be grey (color designated for electrical components) PVC plastic, schedule 40 or 80.
         c. Intermediate Metal Conduit
      3. Minimum depth of bury:
         
         | Feeder/raceway type                                      | Minimum bury depth |
         |---------------------------------------------------------|-------------------|
         | Direct bury cable w/no raceway                          | 24 inches         |
         | Rigid metal conduit from well to building               | 6 inches          |
         | Rigid nonmetallic conduit from well to building         | 18 inches         |
         | Any of the above under a driveway or parking area       | 18 inches         |

   4. Splices and taps - Direct bury conductors or cables, when underground, shall be permitted to be spliced and tapped without the use of splice boxes. The splices and taps shall be made by approved methods and with identified materials.

III. Cables under a building: - Must be installed in a raceway.

IV. Cables through a foundation or basement wall:
   A. Type UF cable shall not be embedded in poured cement, concrete, or aggregate.
B. The cable must be protected from damage by the use of rigid conduit with approved bushings. The conduit shall be sealed after cable installation to prevent the passage of moisture through the conduit.

VII. **Cable from the foundation or basement inside wall to the first point of attachment in the building:**

A. The cable must be enclosed in conduit. The conduit may be any one of the following types:

1. Intermediate Metal Conduit
2. Rigid Metallic Conduit
3. Rigid Nonmetallic Conduit
4. Electrical Metallic Tubing
5. Flexible Metallic Tubing
6. Flexible Metal Conduit
7. Liquidtight Flexible Metal Conduit
8. Liquidtight Flexible Nonmetallic Conduit

B. The conduit shall be used only with those types of fittings identified for such use.

VI. **Grounding Requirements:**

A. Submersible pumps - The frame of the submersible pump motor must be bonded to the equipment grounding conductor installed with the branch circuit.

B. Steel casing with submersible pump.

1. Where a submersible pump is used in steel well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor.
2. The casing may be grounded by one of the following methods:
   a. With the use of a "U" bolt type electrical grounding clamp (a water bond clamp) on the outside of the casing. The ground wire extends from the grounding clamp into the conduit on the outside of the casing and then into the well cap for bonding to the branch circuit equipment grounding conductor. An inhibitor paste should be used on the grounding clamp and casing at the bonding location to prevent corrosion,

OR

b. For those pitless adapters using a support pipe hanging from the top of the casing, a grounding lug may be tapped into the support bridge resting on the top edge of the casing. The ground wire would extend from the grounding lug in the bridge to the equipment ground wire.

3. Clamp-on saddle type pitless adapters should not be used as the point of attachment (bonding) for the casing grounding conductor. Dielectric corrosion may cause failure of the pitless adapter "U" bolt or damage to the saddle of the adapter.

C. Metal well cap/seals - Where a submersible pump is used, and the well cap/seal is metal, the cap/seal shall be grounded as follows:

1. The grounding conductor shall be installed such that the cap can be loosened and removed without disconnecting the grounding conductor.
2. A grounding lug shall be provided on the inside of the well cap. The grounding lug shall be aluminum or copper.
3. The well cap/seal grounding conductor shall be bonded to one of the following:
   a. The pump circuit equipment grounding conductor.
   b. The equipment grounding bus of the panelboard supplying the submersible pump.
   c. A steel casing which has been grounded as required in VI-B above.

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.

Training on pump troubleshooting is available through the Ground Water & Wells Fundamentals Course, sponsored by the Michigan Ground Water Association. Information about the course dates, location, and cost can be obtained by visiting MGWA’s website at www.michigangroundwater.com.

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, available online at www.franklin-electric.com/Manual/contents.html, or Goulds Pump’s Single Phase Service Manual for Jets and Subs, at www.goulds.com/pdf/GSSINGLE.pdf.
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. 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:

I. 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.

II. 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.

III. 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 may not be successful. 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, sub pump cable set on the ground.
     ✓ Stepping on drop pipe and cable prior to installation.
Existing wells:
- Loose caps on pitless adapters.
- Local of potential surface contamination (e.g. sewage systems, feed lots).
- Suspect poor grout of casing at surface.

Disinfection Manual
More detailed information can be found in the DEQ’s Disinfection Manual. It contains detailed information on various disinfection methods, chlorine sources, well preparation, and water sampling for bacteria. To print a copy of the manual, visit the Well Construction Program’s website at [www.michigan.gov/deqwaterwellconstruction](http://www.michigan.gov/deqwaterwellconstruction).

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, Michigan’s Water Well Construction and Pump Installation Code) 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. Water well drillers and pump installers are responsible for disinfecting the work they perform. Once 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
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:

- HOCl - hypochlorous acid (biocidal)
- OCI - 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 organism's 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 chart demonstrates how pH affects the form of chlorine.

<table>
<thead>
<tr>
<th>pH</th>
<th>Approximate percentage at 32 to 68 degrees F</th>
<th>Hypochlorous Acid</th>
<th>Hypochlorite Ion</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>97-98</td>
<td>2-3</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>75-83</td>
<td>17-25</td>
<td></td>
</tr>
<tr>
<td>7.6</td>
<td>42-63</td>
<td>47-58</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>23-32</td>
<td>68-77</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>3-5</td>
<td>95-97</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

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.

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. Time must be provided to allow the residual chlorine to penetrate into biofilm or other materials that may be present to impact on 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 Chlorine Sources

Sodium hypochlorite and calcium hypochlorite are the most common sources of chlorine used for disinfection of on-site 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 – 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 available chlorine originally in. 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 part per million (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, looses chlorine rapidly and is corrosive

As a General Rule, 3/4 lb. (1 1/2 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 ground water 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.

So which is best - sodium hypochlorite or calcium hypochlorite?
Current experiences by water well drilling contractors and ground water specialists suggest sodium hypochlorite is more effective. However, this may be associated with the quality of the ground water 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 ground water is above 100 ppm (mg/l), the use of sodium hypochlorite is recommended instead of calcium hypochlorite.

**NSF Certification**

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 should 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.

**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**
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.**
Bulk displacement 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. If the sample 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) sanitary installation procedures, (2) chlorination of drilling water and (3) source of drilling water.

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. 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 or Act 368, Michigan’s 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 hypochlorites 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 are not to be used. “Clear” surface water can harbor numerous organisms which can result in contamination of a well. Some of these organisms (i.e., giardia) exhibit CT's 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 parts per million 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.
WATER SAMPLING & TESTING

Introduction:
According to the well code, all new drinking water wells are required to be sampled for the presence of coliform bacteria prior to being placed into service. 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 local health departments may require additional sampling such as partial chemical or arsenic. This additional sampling will typically be described on the well construction permit.

General Rules:
- 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.
- For routine monitoring of both existing and new installations, the sampling tap at the kitchen sink is often used.
- Sampling from the well head 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 at the pressure tank evaluates the following:
1. piping (drop pipe and service line)
2. pressure tank
3. pump
4. well structure
5. aquifer

Sampling at the kitchen sink evaluates the following:
1. piping (drop pipe and service line)
2. treatment equipment
3. hot water tank
4. pressure tank
5. pump
6. well structure
7. aquifer

Coliform Bacteria Sampling Procedures:
1. Flush sampling tap (into pail if at pressure tank).
2. Reduce flow.
3. Obtain correct sample container.
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. Shake bottle to dissolve thiosulfate tablet.
9. Promptly mail or deliver the sample to a certified laboratory for analysis.
Sample Interpretation:
- Coliform is an indicator.
- Coliform distribution is not uniform.
- Sampling is just a “snapshot” in time.
- Repeat unsafe = problem.

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 redisinfect a well or pump installation if unacceptable results are obtained from a tap other than the sampling faucet.

Rule 158:
Sampling tap must be installed:
✓ At least 8 inches above the floor.
✓ In a convenient location.
✓ Downturned faucet.
Drinking Water Sampling and Testing Overview

Laboratory
The DEQ drinking water laboratory and numerous other private laboratories provide testing services for the evaluation of drinking water. The DEQ 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 volatile organic compounds (VOC), even if the laboratory has the capability to perform that testing. To receive a list of state certified labs go to www.michigan.gov/deq and click on “Water”, then “Drinking Water”, then “Contamination Investigation”, then “Drinking Water Analysis Laboratory”.

General
If investigating a specific problem, always consider how the well location (including sample location) is related to suspect sources of potential problems.
When selecting a sampling point, consider the following:

- Collect the sample as close to the well as possible, generally near the pressure tank. **Caution: Do not enter confined spaces such as well pits to collect samples.**
- Outside taps may be used for sample collection. These taps allow for easy access and more extensive flushing. Typically, these taps supply untreated water.
- Intermediate plumbing or connections to the source may contribute other contaminants.
- Samples should be untreated (without softener, filter, etc.).
- Do not collect samples from plumbing materials not approved by NSF for potable water use.

The water to be sampled should be representative of groundwater quality. 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. 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 collection.

For a recently chlorinated well, sample only after the well water is free of chlorine. Check the water for chlorine residual before collecting samples. VOC samples may show disinfection byproducts such as chloroform, bromiform, and other trihalomethanes (THM).

For new wells constructed with approved 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.

- After flushing the water supply system at full flow, reduce the water flow to provide a stream of water approximately the size of a pencil diameter.
- Do not open sample container until the moment of sample collection. Do not touch the inside of the bottle or cap.
Follow the recommended procedures below for the specific type of sampling container(s).

- Do not use felt markers that contain solvents near sample vials. Complete laboratory analysis request form in pencil or waterproof black ink. All sample bottles use the same laboratory form. One form must be completed for each bottle submitted.
- Attach form to sample bottle or enclose within the single mailing container.
- Return samples to the laboratory immediately.
- Types of common analyses are explained below with the unit number in parentheses.

**DEQ Drinking Water Laboratory Sample Collection Instructions**

**Volatile Organic (36VO)**

1. The sample vials contain preservative. Tap each vial in upright position to drain preservatives from cap. Do not rinse vial before collection.
2. Do not open the vial until ready to collect the sample. Do not touch the inside of cap or vial. Select a clean faucet without attachments or leaking stem. Allow water to run for ten minutes at full flow.
3. Reduce flow and collect the sample directly into all vials provided.
   a. For 36TO, fill vial until water rounds at the top of vial.
   b. For 36VO, fill vial HALFWAY. Add 2-3 drops of the provided acid from small dropper bottle. Completely fill vial until water rounds at the top of vial.
4. Cap and invert to check for air in vial. THE SEPTA (RUBBER PART INSIDE CAP RING) MUST BE SMOOTH SIDE DOWN IN CONTACT WITH SAMPLE TO AVOID POSSIBLE CONTAMINATION.
5. If air is observed in inverted sample, remove cap, add water (DON’T DUMP SAMPLE) and recap as instructed.

**Lead/Copper (36CC)**

1. Do not open the bottle until ready to collect the sample. Do not touch the inside of cap or bottle.
2. Select a kitchen or bathroom sink or a faucet from which water is typically drawn for consumption. Sampling point should not have been used for a minimum of six (6) hours prior to sampling. Do not flush the sample tap before sample collection.
3. Samples must be received in the laboratory within 14 days of collection.

**Bacteriology (30)**

1. This testing unit contains preservatives in the sample bottle. Do not rinse the bottle with sample. Do not open the bottle until ready to collect the sample. Do not touch the inside of cap or bottle.
2. If not collecting sample from a tap (lake, pool, etc.), plunge bottle mouth down, move in continuous arc down and back up from water, discard top half-inch or to 100 ml line.
3. If using a sample tap, select a clean (disinfect as necessary) faucet and remove such attachments as aerators, dishwasher connectors, etc. Allow water to run for about ten minutes at full flow from the sampling tap. Reduce flow to avoid splashing, and collect the sample directly into the bottle. Do not use an intermediate container. Do not allow water from the outside surface of the faucet to drip into the bottle. Fill bottle only to the bottom of neck, or to 100 ml line.
4. Most bacteriological testing has a 30 hour EPA hold time. Samples must be received at the laboratory before the hold time expires. Surface water samples must be received at the laboratory within 6 hours of sampling.

**Partial Chemical (32), Complete Minerals (33), Metals (36ME), Ammonia (36AC), Cyanide (36CN), and Semi Volatiles (36HA, 36HB, 36LP, 36PT)**

1. Sample bottle may contain preservative (refer to unit label on bottle). Do not rinse bottle with sample. Do not open the bottle until ready to collect the sample. Do not touch the inside of cap or bottle.
2. Select a clean faucet and remove such attachments as aerators, dishwasher connectors, etc. Allow water to run for about ten minutes at full flow from the sampling tap. Reduce flow to avoid splashing, and collect the sample directly into the bottle. Do not use an intermediate container. Do not allow water from the outside surface of the faucet to drip into the bottle. Fill bottle to the bottom of neck.

*NOTE: Some tests require thermal preservation. If you received your kit with an ice pack, please ensure that the ice pack is frozen prior to return shipment to the laboratory.*

**Ordering Sample Bottles from the DEQ Drinking Water Laboratory**

Orders may be telephoned to (517) 335-8184, faxed (517) 335-8562, e-mailed to DEQ-RRD-DW-Bottles@michigan.gov, or mailed to WATER SAMPLE UNIT ORDERS, DEPT. OF ENVIRONMENTAL QUALITY, PO BOX 30270, LANSING MI 48909.

Orders may be picked up at the lab with a 24 hour notice. You MUST call ahead to gain access to the lab complex.

**Transporting Samples to the DEQ Drinking Water Laboratory**

1. Samples may be shipped by mail or other package delivery service.
2. Samples may also be delivered to the Lansing laboratory Monday through Friday from 7:00 am to 5:00 pm. Contact the laboratory at (517)-335-8184 with an estimated time of arrival in order to be admitted by building security personnel. Samples received after 4:30 pm may be processed the following day.

*For questions regarding testing, contact DEQ’s Drinking Water Laboratory at 517- 335-8184.*
A Review of Methodologies for Bacterial Analysis
A look at what to test for and the pros and cons of various methods.

Whether it is to meet the requirements of a home sale transaction, new well installation, or quality check for a bottled water run, analysis for bacteria is extremely critical because of the immediate concerns associated with its detection.

What to test for?
For drinking water, there are typically only three bacterial tests that are performed on a regular basis: coliform, \textit{E.coli} (a subset of fecal coliforms) and heterotrophic plate count. Other tests performed for microorganisms for USEPA Safe Drinking Water Requirements may also include \textit{cryptosporidium}, \textit{giardia lamblia}, \textit{legionella} and enteric viruses (see \url{www.epa.gov/safewater/mcl.html} for further information on these microbes).

Coliform and \textit{E.coli} are the organisms of choice to test for, as they are a great indicator species of the presence of other possibly harmful bacteria. Coliforms are naturally present and plentiful in the environment and in feces of warm-blooded animals. \textit{E.coli} bacteria only come from human and animal fecal waste, as they live and grow in the intestines.

Unlike \textit{E.coli} and coliforms, disease-causing bacteria generally do not survive long enough in water to be detected - therefore, monitoring is difficult. It is because of these traits, and the fact that these organisms are easy to test for, that they become the perfect candidates to determine if the water in question is potable. When coliforms or \textit{E.coli} are present in the sample, water should be used with extreme caution, knowing that other organisms of a more harmful nature may also be present.

What test to use?
There are several methods for the testing of coliform, \textit{E.coli} and heterotrophic bacteria that different laboratories may use. The following tests are the most common methods used. (Please note that although not discussed, a reputable laboratory would use standard quality control plates with all methods.)

\textbf{Presence/Absence Method}
The Chromogenic Substrate Test is used most often. It is also affectionately known as the "Presence/Absence Method" because of the type of results generated. This method is very accurate in determining the presence or absence of both coliform and \textit{E.coli} bacteria. Special enzymatic substrates are added to the samples that are received and the bottles are then incubated for 24 hours. After 24 hours, the samples are examined for any color change in the sampling bottle.

In this technique, Coliform bacteria are defined as the bacteria possessing the enzyme -D-galactosidase. This enzyme cleaves the chromogenic substrate used and results in a release of the chromogen, causing a distinct color change in the sample. \textit{E.coli} bacteria are identified because they have an enzyme that results in the release of a fluorogen in the presence of the fluorogenic substrate. The fluorogen can be viewed when observed under long-wavelength UV (black light). One advantage to running this type of test is that there is no interference from other types of non-coliform bacteria. There is often interference observed in some other analytical methods that yield a count of bacteria.
Standard Total Coliform Membrane Filter Procedure

One "count method" is known as the Standard Total Coliform Membrane Filter Procedure. This process is slightly more complex and can take additional time for processing if confirmations of presence results are necessary.

A sample volume of 100ml is initially filtered through a semi-permeable membrane, which has a pore size small enough that coliforms, if present, will not filter through. Once the sample is filtered, the membrane is placed in a special nutrient dish, inverted and incubated for 22 to 24 hours.

The definition of coliforms that pertains to this test is bacteria that produce metallic (golden) sheen within the incubation period. To determine specific colony counts, the analyst uses a specialized microscope.

Bacteria structure

The typical coliform colony has a pink to dark-red color with a metallic surface sheen. Colonies that lack sheen may be pink, red, white or colorless and are considered to be non-coliform colonies. If there is a colony in question, it goes through the "confirmation" process in which colonies are taken from the sample and transferred to a different broth or medium that, after an additional incubation period, causes a color change in the presence of coliforms. Unfortunately, if there is a large presence of non-coliform bacterial colonies only a "too numerous to count, non-coliform" result can be reported. Sometimes it is not known if there are coliforms on the plate that were "masked out" or unable to be seen.

This test is usually only recommended if an actual count of bacteria must be obtained - to meet regulatory requirements for example.
**Standard Plate Count Test**
In the Standard Plate Count test there are essentially three different methods and four different media that are approved for use. The end result of all these methods is that an estimate of the number of live heterotrophic bacteria in the water can be determined.

An approved counting aid specified by the method should be used to determine the results and counts should be done promptly after incubation. This test can be extremely useful in situations when an odor is detected at a site but coliforms are absent.

**How to sample?**
In order to obtain accurate results, extreme caution must be exercised in the collection procedure of a bacteria sample. To obtain the best sample that will yield truly representative results:

- Use only approved sealed, sterilized and properly preserved containers for sampling.
- Do not collect samples after a disinfection or “shock treatment” has occurred – any residual chlorine in the system can mask out a problem that may still be there. Sample after regular use has occurred for one to two weeks.
- Wash and disinfect hands prior to sampling or wear sterile gloves.
- Properly disinfect the spigot or sampling point to eliminate any contamination of the sample from the surface of the spigot. Proper disinfection would be to use either an alcohol swab or exposure to a hot flame.
- Do not open or break the seal on the bottle until ready to sample – be sure not to touch the inside of the cap or bottle after opening.

**Summary**
A bacteria test is not as simple as it may seem. Different tests are used to achieve different results and are based on the need for the analysis.

The presence/absence test is the best to generally determine if there may be a coliform or E.coli problem that could indicate a health concern. If a count of bacteria is necessary for meeting regulatory requirements or treatment clarification, a membrane filtration or standard plate count test may be ideal.

**Related Information (Article Sidebar) - Understanding Bacteria**
Bacteria are one of the oldest and most plentiful organisms on Earth, and bacteria is simply everywhere. Consider this: as many as 2.5 billion bacteria can be found in one gram (about the size of a paperclip) of fertile soil.

Although typically associated with being harmful, the health of our planet and all life depends on the activities of bacteria. Bacteria are found in the deepest depths of the ocean, in all layers of the earth, in our bodies and in the air around us. Bacteria are prokaryotes or single-celled organisms that lack a true nucleus. Without having a true nucleus to enclose the DNA - the hereditary material that defines the organism - it is allowed to float randomly within the cell.

Bacterial organisms may also be composed of a cell wall (some also have a thick outer capsule for protection), cell membrane, pili, cytoplasm, nucleoid, plasmid, ribosomes and flagellum (see diagram). Flagellum are especially significant as they provide the bacterial cell with the ability to move within their surrounding environment.
One of the significant qualities of bacteria is its ability to reproduce rapidly by binary fission. During this process, chromosomes will replicate and a new cell wall will form between the identical sets to form two new cells called daughter cells.

Each daughter cell contains an exact copy of the genetic information originally contained in the parent cell. This process continues with each daughter cell allowing the population to increase by geometric progression.

**Related Information (Article Sidebar) – 4 Stages of Bacterial Growth**
As conditions are often not optimum, except in the case of a laboratory setting, bacteria populations typically cycle through four defined stages or phases of growth. The first, or lag phase, is the time period when the bacteria become accustomed to their environment and there is fairly slow growth. In the second phase, called the log phase, the bacteria have adapted, conditions are conducive for growth, and growth occurs exponentially. With a large population, competition for food overcomes the growth rate and the population then enters the stationary phase. As toxins build and food sources dwindle, the population enters the fourth and final death phase. As enough bacteria die off and nutrients replenish, the cycle starts again. This helps explain why at any given day or time, bacterial colony counts may differ in test results depending at what point in the cycle process the sample was taken.

**Related Information (Article Sidebar) – Structure of a Simple Bacterium**
- **Capsule** - Only some have this; a sticky substance external to the cell wall that protects the bacteria from white blood cell attack.
- **Cell wall** - Usually very rigid and offers protection to the organism.
- **Cell membrane** - Also known as the plasma membrane, it regulates the passage of substances into and out of the cytoplasm of the cell.
- **Cytoplasm** - The fluid that fills the cell and gives it shape.
- **Nucleoid** - The region in the cytoplasm where the DNA is usually located.
- **Pilus (plural: pili)** - A structure that extends out of the bacteria that allows it to transfer DNA to another cell.
- **Ribosome** - Tiny structures that carry out the protein synthesis for the cell located in the cytoplasm.
- **Plasmid** - The small chromosome that carries extra genes; only found in some bacteria.
- **Flagellum** - Tiny whip-like structures found in numerous species that are used for locomotion of the organism.

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FACT SHEET

Contaminants in Well Water

Wondering what microorganisms (germs) and chemicals can be found in your well water, and what they can do to your health? Here is a list of some of them. Please see the “Well Water Testing FAQs” sheet for details on how to test your well water.

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Health Effects*</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Healthy individuals may have mild or no symptoms from these infections. They will usually recover without long-term health problems. However, persons with weakened immune systems may have more severe or life-threatening illnesses.</td>
<td></td>
</tr>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
</tr>
<tr>
<td>Campylobacter</td>
<td>Diarrhea (sometimes bloody), cramping, abdominal pain, and fever</td>
</tr>
<tr>
<td>Escherichia coli (E. coli) O157:H7</td>
<td>Bloody or non-bloody diarrhea, stomach cramps; little or no fever</td>
</tr>
<tr>
<td></td>
<td>Can cause hemolytic uremic syndrome (HUS) and kidney failure in young children or the elderly</td>
</tr>
<tr>
<td>Salmonella</td>
<td>Diarrhea, typhoid fever, stomach cramps</td>
</tr>
<tr>
<td></td>
<td>Infection can spread from intestines to blood and other body sites, causing serious illness</td>
</tr>
<tr>
<td>Shigella</td>
<td>Watery or bloody diarrhea, fever, upset stomach</td>
</tr>
<tr>
<td></td>
<td>Vomiting and stomach cramping may also occur</td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
</tr>
<tr>
<td>Enterovirus</td>
<td>Usually causes mild upper respiratory, “flu-like” symptoms with fever and muscle pains, or a rash</td>
</tr>
<tr>
<td></td>
<td>Meningitis is less common, and illnesses that affect the heart and brain may occur, but are very rare</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Jaundice (yellowing of eyes and skin), dark urine, tiredness, loss of appetite, nausea, vomiting, fever, stomach ache</td>
</tr>
<tr>
<td></td>
<td>Most infected adults will show symptoms while children often do not have symptoms (but could still pass the virus to others)</td>
</tr>
<tr>
<td>Norovirus (Norwalk)</td>
<td>Upset stomach, cramps, vomiting, and diarrhea</td>
</tr>
<tr>
<td></td>
<td>Headache and low-grade fever may also occur</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Vomiting, watery diarrhea, stomach cramps, fever</td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td></td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>Diarrhea, loose or watery stool, stomach cramps, upset stomach, and fever</td>
</tr>
<tr>
<td></td>
<td>Usually causes mild illness, but can be serious or fatal for people with weakened immune systems</td>
</tr>
</tbody>
</table>
## Contaminants in Well Water
(continued from previous page)

- **Giardia**
  - Diarrhea, loose or watery stool, stomach cramps
  - Usually causes mild illness, but can be serious or fatal for people with weakened immune systems

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Health Effects**</th>
</tr>
</thead>
</table>
| **Atrazine** | Short-term: congestion of heart, lungs, and kidneys; low blood pressure; muscle spasms; weight loss; damage to adrenal glands  
Long-term: weight loss, cardiovascular damage, eye and muscle degeneration; cancer |
| **Arsenic** | Stomach pain, nausea, vomiting, diarrhea, numbness in hands and feet, partial paralysis, and blindness  
Can also cause skin damage, circulatory system problems, and increased risk of cancer |
| **Copper** | An essential nutrient at very low levels  
High level exposure causes upset stomach, vomiting, diarrhea, and stomach cramps  
Long-term exposure at high levels can also cause liver and kidney problems |
| **Lead** | Delayed physical and mental development in babies  
Shortened attention span, hearing, and learning abilities of children  
Slightly increased blood pressures in adults  
Long-term exposure at high levels can include stroke, kidney disease, and cancer |
| **Mercury** | Kidney damage |
| **Nitrate** | Methemoglobinemia – a blood disorder that causes shortness of breath and blueness of skin, and can lead to serious illness or death  
Methemoglobinemia mainly affects infants and pregnant women  
Long-term effects include increased urination and bleeding of the spleen |
| **Radium** | Increases risk of cancer |
| **Volatile Organic Compounds (VOCs)** | Drowsiness and decreased responsiveness  
Skin irritation  
Some cause cancer after long-term exposure |

For more information, visit [www.cdc.gov/ncidod/healthywater](http://www.cdc.gov/ncidod/healthywater)
## National Primary Drinking Water Standards

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL or TT1 (mg/L)²</th>
<th>Potential health effects from exposure above the MCL</th>
<th>Common sources of contaminant in drinking water</th>
<th>Public Health Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylamide</td>
<td>TT8</td>
<td>Nervous system or blood problems;</td>
<td>Added to water during sewage/wastewater increased risk of cancer treatment</td>
<td>zero</td>
</tr>
<tr>
<td>Alachlor</td>
<td>0.002</td>
<td>Eye, liver, kidney or spleen problems; anemia; increased risk of cancer</td>
<td>Runoff from herbicide used on row crops</td>
<td>zero</td>
</tr>
<tr>
<td>Alpha particles</td>
<td>15 picocuries per Liter (pCi/L)</td>
<td>Increased risk of cancer</td>
<td>Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation</td>
<td>zero</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.006</td>
<td>Increase in blood cholesterol; decrease in blood sugar</td>
<td>Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder</td>
<td>0.006</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.010 as of 1/23/06</td>
<td>Skin damage or problems with circulatory systems, and may have increased risk of getting cancer</td>
<td>Erosion of natural deposits; runoff from orchards, runoff from glass &amp; electronics production wastes</td>
<td>0</td>
</tr>
<tr>
<td>Asbestos (fibers &gt;10 micrometers)</td>
<td>7 million fibers per Liter (MFL)</td>
<td>Increased risk of developing benign intestinal polyps</td>
<td>Decay of asbestos cement in water mains; erosion of natural deposits</td>
<td>7 MFL</td>
</tr>
<tr>
<td>Atrazine</td>
<td>0.003</td>
<td>Cardiovascular system or reproductive problems</td>
<td>Runoff from herbicide used on row crops</td>
<td>0.003</td>
</tr>
<tr>
<td>Barium</td>
<td>2</td>
<td>Increase in blood pressure</td>
<td>Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits</td>
<td>2</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.005</td>
<td>Anemia; decrease in blood platelets; increased risk of cancer</td>
<td>Discharge from factories; leaching from gas storage tanks and landfills</td>
<td>zero</td>
</tr>
<tr>
<td>Benzo(a)pyrene (PAHs)</td>
<td>0.0002</td>
<td>Reproductive difficulties; increased risk of cancer</td>
<td>Leaching from linings of water storage tanks and distribution lines</td>
<td>zero</td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.004</td>
<td>Intestinal lesions</td>
<td>Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries</td>
<td>0.004</td>
</tr>
<tr>
<td>Beta particles and photon emitters</td>
<td>4 millirems per year</td>
<td>Increased risk of cancer</td>
<td>Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation</td>
<td>zero</td>
</tr>
<tr>
<td>Bromate</td>
<td>0.010</td>
<td>Increased risk of cancer</td>
<td>Byproduct of drinking water disinfection</td>
<td>zero</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.005</td>
<td>Kidney damage</td>
<td>Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints</td>
<td>0.005</td>
</tr>
<tr>
<td>Carbofuran</td>
<td>0.04</td>
<td>Problems with blood, nervous system, or reproductive system</td>
<td>Leaching of soil fumigant used on rice and alfalfa</td>
<td>0.04</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>0.005</td>
<td>Liver problems; increased risk of cancer</td>
<td>Discharge from chemical plants and other industrial activities</td>
<td>zero</td>
</tr>
<tr>
<td>Chloramines (as Cl₂)</td>
<td>MRDL=4.01</td>
<td>Eye/nose irritation; stomach discomfort, anemia</td>
<td>Water additive used to control microbes</td>
<td>MRDLG=4³</td>
</tr>
</tbody>
</table>

**LEGEND**
- **D**: Disinfectant
- **IOC**: Inorganic Chemical
- **OC**: Organic Chemical
- **DBP**: Disinfection Byproduct
- **M**: Microorganism
- **R**: Radionuclides
<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL or TT1 (mg/L)</th>
<th>Potential health effects from exposure above the MCL</th>
<th>Common sources of contaminant in drinking water</th>
<th>Public Health Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC Chlordane</td>
<td>0.002</td>
<td>Liver or nervous system problems; increased risk of cancer</td>
<td>Residue of banned termicide</td>
<td>zero</td>
</tr>
<tr>
<td>D Chlorine (as Cl2)</td>
<td>MRDL=4.01</td>
<td>Eye/nose irritation; stomach discomfort</td>
<td>Water additive used to control microbes</td>
<td>MRDLG=41</td>
</tr>
<tr>
<td>D Chlorine dioxide (as ClO2)</td>
<td>MRDL=0.81</td>
<td>Anemia; infants &amp; young children: nervous system effects</td>
<td>Water additive used to control microbes</td>
<td>MRDLG=0.81</td>
</tr>
<tr>
<td>DBP Chlorite</td>
<td>1.0</td>
<td>Anemia; infants &amp; young children: nervous system effects</td>
<td>Byproduct of drinking water disinfection</td>
<td>0.8</td>
</tr>
<tr>
<td>OC Chlorobenzene</td>
<td>0.1</td>
<td>Liver or kidney problems</td>
<td>Discharge from chemical and agricultural chemical factories</td>
<td>0.1</td>
</tr>
<tr>
<td>IOC Chromium (total)</td>
<td>0.1</td>
<td>Allergic dermatitis</td>
<td>Discharge from steel and pulp mills; erosion of natural deposits</td>
<td>0.1</td>
</tr>
<tr>
<td>IOC Copper</td>
<td>TT7; Action Level = 1.3</td>
<td>Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level</td>
<td>Corrosion of household plumbing systems; erosion of natural deposits</td>
<td>1.3</td>
</tr>
<tr>
<td>M Cryptosporidium</td>
<td>TT3</td>
<td>Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)</td>
<td>Human and animal fecal waste</td>
<td>zero</td>
</tr>
<tr>
<td>IOC Cyanide (as free cyanide)</td>
<td>0.2</td>
<td>Nerve damage or thyroid problems</td>
<td>Discharge from steel/metal factories; discharge from plastic and fertilizer factories</td>
<td>0.2</td>
</tr>
<tr>
<td>OC 2,4-D</td>
<td>0.07</td>
<td>Kidney, liver, or adrenal gland problems</td>
<td>Runoff from herbicide used on row crops</td>
<td>0.07</td>
</tr>
<tr>
<td>OC Dalapon</td>
<td>0.2</td>
<td>Minor kidney changes</td>
<td>Runoff from herbicide used on rights of way</td>
<td>0.2</td>
</tr>
<tr>
<td>OC 1,2-Dibromo-3-chloropropene (DBCP)</td>
<td>0.0002</td>
<td>Reproductive difficulties; increased risk of cancer</td>
<td>Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards</td>
<td>zero</td>
</tr>
<tr>
<td>OC o-Dichlorobenzene</td>
<td>0.6</td>
<td>Liver, kidney, or circulatory system problems</td>
<td>Discharge from industrial chemical factories</td>
<td>0.6</td>
</tr>
<tr>
<td>OC p-Dichlorobenzene</td>
<td>0.075</td>
<td>Anemia; liver, kidney or spleen damage; changes in blood</td>
<td>Discharge from industrial chemical factories</td>
<td>0.075</td>
</tr>
<tr>
<td>OC 1,2-Dichloroethane</td>
<td>0.005</td>
<td>Increased risk of cancer</td>
<td>Discharge from industrial chemical factories</td>
<td>zero</td>
</tr>
<tr>
<td>OC 1,1-Dichloroethylene</td>
<td>0.007</td>
<td>Liver problems</td>
<td>Discharge from industrial chemical factories</td>
<td>0.007</td>
</tr>
<tr>
<td>OC cis-1,2-Dichloroethylene</td>
<td>0.07</td>
<td>Liver problems</td>
<td>Discharge from industrial chemical factories</td>
<td>0.07</td>
</tr>
<tr>
<td>OC trans-1,2-Dichloroethylene</td>
<td>0.1</td>
<td>Liver problems</td>
<td>Discharge from industrial chemical factories</td>
<td>0.1</td>
</tr>
<tr>
<td>OC Dichloromethane</td>
<td>0.005</td>
<td>Liver problems; increased risk of cancer</td>
<td>Discharge from drug and chemical factories</td>
<td>zero</td>
</tr>
<tr>
<td>OC 1,2-Dichloropropane</td>
<td>0.005</td>
<td>Increased risk of cancer</td>
<td>Discharge from industrial chemical factories</td>
<td>zero</td>
</tr>
<tr>
<td>OC Di(2-ethylhexyl) adipate</td>
<td>0.4</td>
<td>Weight loss, live problems, or possible reproductive difficulties</td>
<td>Discharge from chemical factories</td>
<td>0.4</td>
</tr>
<tr>
<td>OC Di(2-ethylhexyl) phthalate</td>
<td>0.006</td>
<td>Reproductive difficulties; liver problems; increased risk of cancer</td>
<td>Discharge from rubber and chemical factories</td>
<td>zero</td>
</tr>
<tr>
<td>OC Dinoseb</td>
<td>0.007</td>
<td>Reproductive difficulties</td>
<td>Runoff from herbicide used on soybeans and vegetables</td>
<td>0.007</td>
</tr>
<tr>
<td>OC Dioxin (2,3,7,8-TCDD)</td>
<td>0.00000003</td>
<td>Reproductive difficulties; increased risk of cancer</td>
<td>Emissions from waste incineration and other combustion; discharge from chemical factories</td>
<td>zero</td>
</tr>
<tr>
<td>OC Diquat</td>
<td>0.02</td>
<td>Cataracts</td>
<td>Runoff from herbicide use</td>
<td>0.02</td>
</tr>
<tr>
<td>OC Endothall</td>
<td>0.1</td>
<td>Stomach and intestinal problems</td>
<td>Runoff from herbicide use</td>
<td>0.1</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td>Endrin</td>
<td>0.002</td>
<td>Liver problems</td>
<td>Residue of banned insecticide</td>
<td>0.002</td>
</tr>
<tr>
<td>Epichlorohydrin</td>
<td>TT8</td>
<td>Increased cancer risk, and over a long period of time, stomach problems</td>
<td>Discharge from industrial chemical factories; an impurity of some water treatment chemicals</td>
<td>zero</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>0.7</td>
<td>Liver or kidneys problems</td>
<td>Discharge from petroleum refineries</td>
<td>0.7</td>
</tr>
<tr>
<td>Ethylene dibromide</td>
<td>0.00005</td>
<td>Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer</td>
<td>Discharge from petroleum refineries</td>
<td>zero</td>
</tr>
<tr>
<td>Fluoride</td>
<td>4.0</td>
<td>Bone disease (pain and tenderness of the bones); Children may get mottled teeth</td>
<td>Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories</td>
<td>4.0</td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td>TT3</td>
<td>Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)</td>
<td>Human and animal fecal waste</td>
<td>zero</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>0.7</td>
<td>Kidney problems; reproductive difficulties</td>
<td>Runoff from herbicide use</td>
<td>0.7</td>
</tr>
<tr>
<td>Haloacetic acids (HAAs)</td>
<td>0.060</td>
<td>Increased risk of cancer</td>
<td>Byproduct of drinking water disinfection</td>
<td>n/a6</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>0.0004</td>
<td>Liver damage; increased risk of cancer</td>
<td>Residue of banned termicide</td>
<td>zero</td>
</tr>
<tr>
<td>Heptachlor epoxide</td>
<td>0.0002</td>
<td>Liver damage; increased risk of cancer</td>
<td>Breakdown of heptachlor</td>
<td>zero</td>
</tr>
<tr>
<td>Heterotrophic plate count</td>
<td>TT3</td>
<td>HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.</td>
<td>HPC measures a range of bacteria that are naturally present in the environment.</td>
<td>n/a</td>
</tr>
<tr>
<td>Hexachlorobenzene</td>
<td>0.001</td>
<td>Liver or kidney problems; reproductive difficulties; increased risk of cancer</td>
<td>Discharge from metal refineries and agricultural chemical factories</td>
<td>zero</td>
</tr>
<tr>
<td>Hexachlorocyclopentadiene</td>
<td>0.05</td>
<td>Kidney or stomach problems</td>
<td>Discharge from chemical factories</td>
<td>0.05</td>
</tr>
<tr>
<td>HPC</td>
<td>TT7; Action Level = 0.015</td>
<td>Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure</td>
<td>Corrosion of household plumbing systems; erosion of natural deposits</td>
<td>zero</td>
</tr>
<tr>
<td>Legionella</td>
<td>TT3</td>
<td>Legionnaire's Disease, a type of pneumonia</td>
<td>Found naturally in water; multiplies in heating systems</td>
<td>zero</td>
</tr>
<tr>
<td>Lindane</td>
<td>0.002</td>
<td>Liver or kidney problems</td>
<td>Runoff/leaching from insecticide used on cattle, lumber, gardens</td>
<td>0.002</td>
</tr>
<tr>
<td>Mercury (inorganic)</td>
<td>0.002</td>
<td>Kidney damage</td>
<td>Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands</td>
<td>0.002</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>0.04</td>
<td>Reproductive difficulties</td>
<td>Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock</td>
<td>0.04</td>
</tr>
<tr>
<td>Nitrate (measured as Nitrogen)</td>
<td>10</td>
<td>Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.</td>
<td>Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits</td>
<td>10</td>
</tr>
<tr>
<td>Nitrite (measured as Nitrogen)</td>
<td>1</td>
<td>Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.</td>
<td>Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits</td>
<td>1</td>
</tr>
</tbody>
</table>

**LEGEND**

- **D** Disinfectant
- **IOC** Inorganic Chemical
- **OC** Organic Chemical
- **DBP** Disinfection Byproduct
- **M** Microorganism
- **R** Radionuclides
<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL or TT1 (mg/L)</th>
<th>Potential health effects from exposure above the MCL</th>
<th>Common sources of contaminant in drinking water</th>
<th>Public Health Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxamyl (Vydate)</td>
<td>0.2</td>
<td>Slight nervous system effects</td>
<td>Runoff/leaching from insecticide used on apples, potatoes, and tomatoes</td>
<td>0.2</td>
</tr>
<tr>
<td>Pentachlorophenol</td>
<td>0.001</td>
<td>Liver or kidney problems; increased cancer risk</td>
<td>Discharge from wood preserving factories</td>
<td>zero</td>
</tr>
<tr>
<td>Picloram</td>
<td>0.5</td>
<td>Liver problems</td>
<td>Herbicide runoff</td>
<td>0.5</td>
</tr>
<tr>
<td>Polychlorinated biphenyls (PCBs)</td>
<td>0.0005</td>
<td>Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer</td>
<td>Runoff from landfills; discharge of waste chemicals</td>
<td>zero</td>
</tr>
<tr>
<td>Radium 226 and Radium 228 (combined)</td>
<td>5 pCi/L</td>
<td>Increased risk of cancer</td>
<td>Erosion of natural deposits</td>
<td>zero</td>
</tr>
<tr>
<td>Simazine</td>
<td>0.004</td>
<td>Problems with blood</td>
<td>Herbicide runoff</td>
<td>0.004</td>
</tr>
<tr>
<td>Styrene</td>
<td>0.1</td>
<td>Liver, kidney, or circulatory system problems</td>
<td>Discharge from rubber and plastic factories; leaching from landfills</td>
<td>0.1</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>0.005</td>
<td>Liver problems; increased risk of cancer</td>
<td>Discharge from factories and dry cleaners</td>
<td>zero</td>
</tr>
<tr>
<td>Thallium</td>
<td>0.002</td>
<td>Hair loss; changes in blood; kidney, intestine, or liver problems</td>
<td>Leaching from ore-processing sites; discharge from electronics, glass, and drug factories</td>
<td>0.0005</td>
</tr>
<tr>
<td>Toluene</td>
<td>1</td>
<td>Nervous system, kidney, or liver problems</td>
<td>Discharge from petroleum factories</td>
<td>1</td>
</tr>
<tr>
<td>Total Coliforms (including fecal coliform and E. coli)</td>
<td>5.0%4</td>
<td>Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present5</td>
<td>Coliforms are naturally present in the environment as well as feces; fecal coliforms and E. coli only come from human and animal fecal waste.</td>
<td>zero</td>
</tr>
<tr>
<td>Total Trihalomethanes (TTHMs)</td>
<td>0.10 after 12/31/03</td>
<td>Liver, kidney or central nervous system problems; increased risk of cancer</td>
<td>Byproduct of drinking water disinfection</td>
<td>n/a6</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>0.003</td>
<td>Kidney, liver, or thyroid problems; increased risk of cancer</td>
<td>Runoff/leaching from insecticide used on cotton and cattle</td>
<td>zero</td>
</tr>
<tr>
<td>2,4,5-TP (Silvex)</td>
<td>0.05</td>
<td>Liver problems</td>
<td>Residue of banned herbicide</td>
<td>0.05</td>
</tr>
<tr>
<td>1,2,4-Trichlorobenzene</td>
<td>0.07</td>
<td>Changes in adrenal glands</td>
<td>Discharge from textile finishing factories</td>
<td>0.07</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>0.2</td>
<td>Liver, nervous system, or circulatory problems</td>
<td>Discharge from metal degreasing sites and other factories</td>
<td>0.20</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>0.005</td>
<td>Liver, kidney, or immune system problems</td>
<td>Discharge from industrial chemical factories</td>
<td>0.003</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.005</td>
<td>Liver problems; increased risk of cancer</td>
<td>Discharge from metal degreasing sites and other factories</td>
<td>zero</td>
</tr>
<tr>
<td>Turbidity</td>
<td>TT3</td>
<td>Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.</td>
<td>Soil runoff</td>
<td>n/a</td>
</tr>
<tr>
<td>Uranium</td>
<td>30 μg/L as of 12/08/03</td>
<td>Increased risk of cancer, kidney toxicity</td>
<td>Erosion of natural deposits</td>
<td>zero</td>
</tr>
</tbody>
</table>

**Legend:**
- **D**: Disinfectant
- **IOC**: Inorganic Chemical
- **OC**: Organic Chemical
- **DBP**: Disinfection Byproduct
- **M**: Microorganism
- **R**: Radionuclides

4 This may indicate the presence of a myriad of disease-causing organisms.
### Definitions

1. **Definitions**
   - **Maximum Contaminant Level Goal (MCLG)**—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
   - **Maximum Contaminant Level (MCL)**—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
   - **Maximum Residual Disinfectant Level Goal (MRDLG)**—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
   - **Treatment Technique (TT)**—A required process intended to reduce the level of a contaminant in drinking water.
   - **Fecal coliform**—A bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.
   - **Cryptosporidium**—A microorganism that can cause gastrointestinal illness.

### EPA's Surface Water Treatment Rules

- **Disinfection**—Leaving the residual disinfectant in the water to kill any remaining microorganisms.
- **Filtering**—Removing particles and microorganisms from the water.

### Table: Common Contaminants and Their Health Impacts

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL or TT&lt;sup&gt;1&lt;/sup&gt; (mg/L)&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Potential health effects from exposure above the MCL</th>
<th>Common sources of contaminant in drinking water</th>
<th>Public Health Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>OC Vinyl chloride</td>
<td>0.002</td>
<td>Increased risk of cancer</td>
<td>Leaching from PVC pipes; discharge from plastic factories</td>
<td>zero</td>
</tr>
<tr>
<td>OC Viruses (enteric)</td>
<td>TTT&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)</td>
<td>Human and animal fecal waste</td>
<td>zero</td>
</tr>
<tr>
<td>OC Xylenes (total)</td>
<td>10</td>
<td>Nervous system damage</td>
<td>Discharge from petroleum factories; discharge from chemical factories</td>
<td>10</td>
</tr>
</tbody>
</table>

### Notes

1. **Definitions**
   - Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
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   - Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2. **Units** are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3. EPA’s surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:
   - **Cryptosporidium** (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving ≤10,000) 99% removal.
   - **Giardia lamblia** 99.99% removal/inactivation
   - **Viruses**: 99.99% removal/inactivation
   - **Legionella**: No limit, but EPA believes that if Giardia and viruses are removed/inactivated, Legionella will also be controlled.
   - **Turbidity**: At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing ≤10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
   - **HPC**: No more than 500 bacterial colonies per milliliter
   - **Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005)**: Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
   - **Filter Backwash Recycling**: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system’s existing conventional or direct filtration system or at an alternate location approved by the state.
   - **No more than 5.0‰ samples total coliform- positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.)** Every sample that has total coliform must be analyzed for either fecal coliforms or E. coli if two consecutive TC-positive samples, and one is also positive for fecal coliforms, system has an acute MCL violation.
   - **Fecal coliform and E. coli**: Bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.
   - **Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:**
     - **Halogenated acids**—dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
     - **Trihalomethanes**—bromodichloromethane (zero); bromoform (0.06 mg/L)
   - **Lead and copper** are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.
   - **Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:**
     - **Acrylamide** = 0.09% dosed at 1 mg/L (or equivalent);
     - **Epichlorohydrin** = 0.01% dosed at 20 mg/L (or equivalent).
National Secondary Drinking Water Standards

National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Secondary Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.05 to 0.2 mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/L</td>
</tr>
<tr>
<td>Color</td>
<td>15 (color units)</td>
</tr>
<tr>
<td>Copper</td>
<td>1.0 mg/L</td>
</tr>
<tr>
<td>Corrosivity</td>
<td>noncorrosive</td>
</tr>
<tr>
<td>Fluoride</td>
<td>2.0 mg/L</td>
</tr>
<tr>
<td>Foaming Agents</td>
<td>0.5 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3 mg/L</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.05 mg/L</td>
</tr>
<tr>
<td>Odor</td>
<td>3 threshold odor number</td>
</tr>
<tr>
<td>pH</td>
<td>6.5-8.5</td>
</tr>
<tr>
<td>Silver</td>
<td>0.10 mg/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>250 mg/L</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>500 mg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>5 mg/L</td>
</tr>
</tbody>
</table>
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 would include "dry holes," wells that are being replaced by a new well, wells that no longer produce water, wells producing water of unsuitable quality, 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. Local health departments 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 DEQ Factsheet, “How to Locate Abandoned Wells”.

Permit Requirements
Local Health Departments routinely make plugging 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, neat cement, and concrete grout. The most effective abandoned well plugging material is neat cement grout.

At this time, 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 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 local health department 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 workmen 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. More detailed information on
obstruction removal and plugging wells can be found in the DEQ’s Michigan Abandoned Water Well Plugging Manual at www.michigan.gov/deqwaterwellconstruction.

**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:**
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 Michigan Department of Environmental Quality may be contacted for more information concerning this alternative. More detailed information on plugging flowing wells can be found in the DEQ’s Flowing Well Handbook at www.michigan.gov/deqwaterwellconstruction.

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 the DEQ and local health department. 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 DEQ Wellogic program. For more information on using Wellogic, please email the Wellogic Staff at wellogic@michigan.gov.

Abandoned Well Rules
The following rules from the well code apply to abandoned wells.

Rule 101 & 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’ 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 local health department.

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 local health department can order a well 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.
**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 backsiphonage. 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 [www.michigan.gov/deqwaterwellconstruction](http://www.michigan.gov/deqwaterwellconstruction).

**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 the DEQ’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. To receive a copy of the manual, go to [www.michigan.gov/deq](http://www.michigan.gov/deq) and click on “water”, then “drinking water”, then “Community Water Supply”.


50 Cross-Connection Questions, Answers, & Illustrations Relating To Backflow Prevention Products and Protection of Safe Drinking Water Supply
1 What is back-siphonage?
Back-siphonage is the reversal of normal flow in a system caused by a negative pressure (vacuum or partial vacuum) in the supply piping.

2 What factors can cause back-siphonage?
Back-siphonage can be created when there is stoppage of the water supply due to nearby fire-fighting, repairs or breaks in city main, etc. The effect is similar to the sipping of an ice cream soda by inhaling through a straw, which induces a flow in the opposite direction.

3 What is backpressure backflow?
Backpressure backflow is the reversal of normal flow in a system due to an increase in the downstream pressure above that of the supply pressure.

4 What factors can cause a backpressure-backflow condition?
Back pressure-backflow is created whenever the downstream pressure exceeds the supply pressure which is possible in installations such as heating systems, elevated tanks, and pressure-producing systems. An example would be a hot water space-heating boiler operating under 15-20 lbs. pressure coincidental with a reduction of the city water supply below such pressure (or higher in most commercial boilers). As water tends to flow in the direction of least resistance, a backpressure-backflow condition would be created and the contaminated boiler water would flow into the potable water supply.

5 What is a cross connection?
A cross connection is a direct arrangement of a piping line which allows the potable water supply to be connected to a line which contains a contaminant. An example is the common garden hose attached to a sill cock with the end of the hose lying in a cesspool. Other examples are a garden hose attached to a service sink with the end of the hose submerged in a tub full of detergent, supply lines connected to bottom-fed tanks, supply lines to boilers.

6 What is the most common form of a cross connection?
Ironically, the ordinary garden hose is the most common offender as it can be easily connected to the potable water supply and used for a variety of potentially dangerous applications.
What is potentially dangerous about an unprotected sill cock?

The purpose of a sill cock is to permit easy attachment of a hose for outside watering purposes. However, a garden hose can be extremely hazardous because they are left submerged in swimming pools, lay in elevated locations (above the sill cock) watering shrubs, chemical sprayers are attached to hoses for weed-killing, etc.; and hoses are often left laying on the ground which may be contaminated with fertilizer, cesspools, and garden chemicals.

What protection is required for sill cocks?

A hose bibb vacuum breaker should be installed on every sill cock to isolate garden hose applications thus protecting the potable water supply from contamination.

Should a hose bibb vacuum breaker be used on frost-free hydrants?

Definitely, providing the device is equipped with means to permit the line to drain after the hydrant is shut-off. A “removable” type hose bibb vacuum breaker could allow the hydrant to be drained, but the possibility exists that users might fail to remove it for draining purposes, thus defeating the benefit of the frost-proof hydrant feature. If the device is of the “Non-Removable” type, be sure it is equipped with means to drain the line to prevent winter freezing.

Can an atmospheric, anti-siphon vacuum breaker be installed on a hose bibb?

Theoretically yes, but practically no. An anti-siphon vacuum breaker must be elevated above the sill cock to operate properly. This would require elevated piping up to the vacuum breaker and down to the sill cock and is normally not a feasible installation. On the other hand, a hose bibb vacuum breaker can be attached directly to the sill cock, without plumbing changes and at minor cost.

What is an atmospheric vacuum breaker?

The most commonly used atmospheric anti-siphon vacuum breakers incorporate an atmospheric vent in combination with a check valve. Its operation depends on a supply of potable water to seal off the atmospheric vent, admitting the water to downstream equipment. If a negative pressure develops in the supply line, the loss of pressure permits the check valve to drop sealing the orifice while at the same time the vent opens admitting air to the system to break the vacuum.
Will an anti-siphon vacuum breaker protect against a backpressure backflow condition?

Absolutely not! If there is an increase in the downstream pressure over that of the supply pressure, the check valve would tend to “modulate” thus permitting the backflow of contaminated water to pass through the orifice into the potable water supply line.

Can an atmospheric vacuum breaker be used on lawn sprinkler systems?

Yes, if these are properly installed, they will protect the potable water supply. The device shall be installed 6" above the highest sprinkler head and shall have no control valves located downstream from the device.

Can an atmospheric vacuum breaker be used under continuous pressure?

No! codes do not permit this as the device could become “frozen”, and not function under an emergency condition.

Can a pressure vacuum breaker be used on a multi-zone lawn sprinkler system?

Yes. This type of vacuum breaker can be used under continuous pressure. Therefore, if properly installed, it will protect the potable water supply. The device shall be installed 12" above the highest sprinkler head.

What is continuous pressure?

This is a term applied to an installation in which the pressure is being supplied continuously to a backflow preventer for periods of over 12 hours at a time. Laboratory faucet equipment, for example, is entirely suitable for a non-pressure, atmospheric anti-siphon vacuum breaker because the supply is periodically being turned on and shut off. A vacuum breaker should never be subjected to continuous pressure unless it is of the continuous pressure type and clearly identified for this service.

Are check valves approved for use on boiler feed lines?

Most jurisdictions require backflow protection on all boiler feed lines. Some will allow a backflow preventer with intermediate vent as minimum protection for residential boilers. A reduced pressure backflow preventer is generally required on commercial and compound boilers. However, low cost, continuous pressure backflow preventers are now available which will perform with maximum protection; thus check valves are not recommended.
18 What is the difference between pollution and contamination?

Pollution of the water supply does not constitute an actual health hazard, although the quality of the water is impaired with respect to taste, odor or utility. Contamination of the water supply, however, does constitute an actual health hazard; the consumer being subjected to potentially lethal water borne disease or illness.

19 What recent case would reflect users being exposed to contamination of the water supply?

Chicken House Cross-Connection, Spring 1991. In response to a complaint from a customer on the Casa Water System (Perry County), a staff member of the Division of Engineering found that the water systems had been contaminated by backflow from chicken houses. The water system connected to the chicken houses included two single check valves in series for backflow prevention purposes. The water was being used to administer an antibiotic solution to the chickens.

20 What other case reflects users being exposed to “contamination” of the water supply?

On or about the week of the 14th of May, 1991, a back-siphonage problem occurred. A local farmer reported the problem on his farm. He was filling a spray tank on his farm with water and 2-4-D. The wind kept blowing the fill hose away from the fill spout so he extended the hose down into the tank. As the tank filled, he went onto other duties. He went into the house for some reason and his wife told him that the water had become salty tasting. He immediately thought of the 2-4-D and went to the tank and it had begun siphoning water from the tank. He told his wife not to use any more water. An artesian well, (free flow) was filling the tank. The artesian well also supplied water to the home through a storage tank and pump system. As the spray tank was filling, the pump in the house came on and created a pull on the well greater than the pressure at the well head. Consequently, as the pump was on, it was also pulling the 2-4-D and water from the spray tank.

21 Are there any records of recent cases involving unprotected cross connections?

The startling fact is that cross connections continue to occur and there are documented cases involving reverse flow. For other cases, request folder F-SBN.

22 What recently reported cases occurred in a plant?

In addition to the case described in “No. 19”, there are other reports but because of the possibility of litigation for pending cases, information can be difficult to obtain. However, in San Francisco, an industrial plant had a submerged water inlet supplying a lye vat. Immediately adjacent to this installation was the employee’s shower room. Officials fortunately discovered the cross connection, but were alarmed that employees could potentially be bathing in water contaminated with lye from the vats.
23 What case was reported involving a school?

Most people are familiar with the details of the Holy Cross Football Teams’ “hepatitis” incident, which was later determined to be caused by a backflow of contaminated water. It took close to nine months for officials to determine that a severe fire in nearby Worcester lowered the pressure in the football field area to the point where a back pressure backflow condition was created allowing contaminants from a sunken hose bibb pit to backflow into the field house drinking bubbler.

24 What case was reported involving a commercial building?

Much to the surprise of the customers of a bank in Atlanta, Georgia they saw yellow water flowing from drinking fountains and green ice rolling out of cafeteria dispensing machines.

It was later reported that a pump, used for the air conditioning system, burned out; and a maintenance man, unaware of the danger, connected the system to another pump used for potable water. The result caused large doses of bichromate of soda to be forced into the potable water supply, causing the dramatic appearance of yellow water and colored ice cubes.

25 Are there any cases involving outside processing activities?

Yes, a case occurred in a gravel pit operation in Illinois. A pump was used in the processing operation supplying 100 lbs. pressure. Contaminated water was forced back through an unprotected “prime line” overcoming the city water pressure of 45 lbs. The contaminated water entered the city main and was channeled into a nearby bottling plant. This probably would have gone undetected except that personnel in the bottling plant noticed that the water was not only dirty but was warm.

City officials were immediately called which led to the discovery of the reverse flow from the gravel pit operation.

26 What other typical cases have been reported?


Parasitical worms were found in the water at two homes after a malfunctioning lawn sprinkler coupled with a water main break sucked the nematodes into the water system.

The nematodes first showed up in the evening of Oct. 1 after the backflow prevention system on the privately owned underground sprinkler malfunctioned. When the water pressure dropped, the vacuum in the system sucked some water from the sprinkler into the city water.

A homeowner found the worms swimming around in his bathtub when he started filling the tub for his child. He said he was appalled to find the critters, as well as rust and other debris in his water. “The only reason I noticed it is because I have children and was giving my kid a bath. If you have a screen on your faucet or you were taking a shower, you wouldn’t see it.”
The contractor who installed the sprinkler system didn’t pull a city permit and used a “cheap” atmospheric vacuum breaker. When it malfunctioned, which was at the time of the water main break, the nematodes were pulled right in.

In Utah, a doctor reported two gold fish flowing into his bath tub. Earlier in the day he had been filling his gold fish pool with a garden hose when a back-siphonage condition developed resulting in the late emergence of the gold fish into the bath tub.

What is significant, however, is the number of recent cases that are not reported. The number of unprotected cross connections in existence are potential disasters which can occur any time unless adequate protective devices are installed.

27 What is meant by “Degree of Hazard”? 

The degree of hazard is a commonly used phrase utilized in cross connection programs and is simply a determination on whether the substance in the non-potable system is toxic (health hazard) or non-toxic (non-health hazard).

28 What is the difference between a toxic and a non-toxic substance?

Toxic substance is any liquid, solid or gas, which when introduced into the water supply creates, or may create a danger to health and well-being of the consumer. An example is treated boiler water. A non-toxic substance is any substance that may create a non-health hazard, is a nuisance or is aesthetically objectionable. For example, food stuff, such as sugar, soda pop, etc. Therefore, you must select the proper device according to the type of connection and degree of hazard. There are five basic products that can be used to correct cross connection.

29 What are the five basic products used for protection of cross connections?

The five basic products are:
1. Air Gap
2. Atmospheric Vacuum Breakers - which also includes hose connection vacuum breakers
3. Pressure Vacuum Breakers - which also includes backflow preventer with intermediate atmospheric vent for ½" and ¾" lines
4. Double Check Valve Assembly
5. Reduced Pressure Zone Backflow Preventers

30 What is an Air Gap?

Air Gap is the physical separation of the potable and non-potable system by an air space. The vertical distance between the supply pipe and the flood level rim should be two times the diameter of the supply pipe, but never less than 1". The air gap can be used on a direct or inlet connection and for all toxic substances.
31 Where is an Atmospheric Vacuum Breaker used?

Atmospheric Vacuum Breakers may be used only on connections to a non-potable system where the vacuum breaker is never subjected to backpressure and is installed on the discharge side of the last control valve. It must be installed above the usage point. It cannot be used under continuous pressure. (Also see No. 11)

32 Where is a Hose Bibb Vacuum Breaker used?

Hose Bibb Vacuum Breakers are small inexpensive devices with hose connections which are simply attached to sill cocks and threaded faucets or wherever there is a possibility of a hose being attached which could be introduced to a contaminant. However, like the Atmospheric Vacuum Breaker they should not be used under continuous pressure.

33 Where is a Pressure Vacuum Breaker used?

Pressure Vacuum Breakers may be used as protection for connections to all types of non-potable systems where the vacuum breakers are not subject to backpressure. These units may be used under continuous supply pressure. They must be installed above the usage point. (spill resistant models for indoor use are also available).

34 Where is a Backflow Preventer with Intermediate Atmospheric vent used?

These devices are made for 1/2" and 3/4" lines and may be used as an alternate equal for pressure vacuum breakers. In addition, however, they provide the added advantage of providing protection against backpressure.

35 Where is a Double Check Valve Assembly used?

A double check valve assembly may be used as protection of all direct connections through which foreign material might enter the potable system in concentration which would constitute a nuisance or be aesthetically objectionable, such as air, steam, food, or other material which does not constitute a health hazard.
What are typical applications for an Air Gap?

Because today's complex plumbing systems normally require continuous pressure, air gap applications are actually in the minority. It should be remembered, however, that whenever a piping terminates a suitable distance above a contaminant, this itself is actually an air gap. Air Gaps are frequently used on industrial processing applications, but care should be taken that subsequent alterations are not made to the piping which would result in a direct connection.

What are typical applications for Atmospheric Vacuum Breakers?

Atmospheric Vacuum Breakers can be used on most inlet type water connections which are not subject to backpressure such as low inlet feeds to receptacles containing toxic and non-toxic substances, valve outlet or fixture with hose attachments, lawn sprinkler systems and commercial dishwashers.

What are typical applications for Hose Bibb Vacuum Breakers?

Hose Bibb Vacuum Breakers are popularly used on sill cocks, service sinks and any threaded pipe to which a hose may potentially be attached.

What are typical applications for Pressure Vacuum Breakers?

These applications should be similar to the Atmospheric Vacuum Breaker with the exception that these may be used under continuous pressure. However, they should not be subject to backpressure.

What are typical applications of Backflow Preventer with Intermediate Vent?

For ½" and ¾" lines these devices are popularly used on boiler feed water supply lines, cattle drinking fountains, trailer park water supply connections and other similar low-flow applications. They will protect against both back-siphonage and backpressure and can be used under continuous pressure.
What are typical applications for Double Check Valve Assemblies?

Briefly, Double Check Valve Assemblies may be used where the degree of hazard is low, meaning that the non-potable source is polluted rather than contaminated. The degree of hazard is oftentimes determined by local Inspection Departments and, therefore, such departments should be questioned in order to comply with local regulations.

What are typical applications for Reduced Pressure Zone Backflow Preventers?

This type should be used whenever the non-potable source is more of a contaminant than a pollutant. Basically, they are applied as main line protection to protect the municipal water supply, but should also be used on branch line applications where non-potable fluid would constitute a health hazard, such as boiler feed lines, commercial garbage disposal systems, industrial boilers, etc.

Are there any regulations in OSHA regarding cross connections?

Yes, OSHA requires that no cross connection be allowed in an installation unless it is properly protected with an approved backflow preventer. These requirements are also covered in B.O.C.A., Southern Std. Building Code, Uniform Plumbing Code and City, State and Federal Regulations.

What Standards are available governing the manufacture of backflow prevention devices?

Table on Page 12 provides a summary of the various standards available relating to specific types of backflow preventers.

What is the benefit of a strainer preceding a backflow preventer?

A strainer will protect the check valves of a backflow preventer from fouling due to foreign matter and debris which may be flowing through the line. This not only protects the valve but eliminates nuisance fouling and subsequent maintenance and shutdown. The use of a strainer with a water pressure reducing valve has been an accepted practice for years. The amount of pressure drop attributed to the strainer is negligible and is far outweighed by the advantages provided by the strainer.
What would cause a reduced pressure zone backflow preventer to leak?

Leakage from a backflow preventer is normally attributed to foreign matter lodging on the seating area of either the first or second check valve. Most times this can be corrected by simply flushing the valve which will dislodge any loose particles. It is, therefore, most important on new installations that the piping be thoroughly flushed before installing the unit. It should be remembered, however, that spillage does provide a “warning signal” that the valve is in need of maintenance.

Is periodic testing required for reduced pressure zone backflow preventers?

Yes, and this is to ensure that the valve is working properly and is a requirement of many states and cross connection control programs. Test cocks are provided on the valve for this purpose and manufacturers are required to furnish field testing information.

Should a backflow preventer be installed in the water supply line to each residence?

Because of the growing number of serious residential backflow cases, many water purveyors are now requiring the installation of approved dual check valve backflow preventers at residential water meters. They are also educating the public concerning cross connections and the danger of backflow into the local water supply. Since water purveyors cannot possibly be responsible for or monitor the use of water within a residence, the requirements for these cross connection control programs are increasing throughout the country.

What is a cross connection control program?

This is a combined cooperative effort between plumbing and health officials, waterworks companies, property owners and certified testers to establish and administer guidelines for controlling cross connections and implementing means to ensure their enforcement so that the public potable water supply will be protected both in the city main and within buildings. The elements of a program define the type of protection required and responsibility for the administration and enforcement. Other elements ensure continuing education programs.
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<td>1⁄2, 3⁄4</td>
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<tr>
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<td>008QT</td>
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<tr>
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<td>S8C, 8, NF8, HB-1</td>
<td>3⁄8, 1⁄2, 3⁄4 HT</td>
</tr>
<tr>
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<td>WB, WBT</td>
<td>-</td>
</tr>
</tbody>
</table>

**REDUCED PRESSURE DETECTOR ASSEMBLIES**

**DOUBLE CHECK DETECTOR ASSEMBLIES**

**DUAL CHECK VALVE BACKFLOW PREVENTERS**

**SPECIALTY BACKFLOW PREVENTERS with INTERMEDIATE ATMOSPHERIC VENT**

**ATMOSPHERIC VACUUM BREAKERS**

**PRESSURE VACUUM BREAKERS**

**HOSE CONNECTION VACUUM BREAKERS**

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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, local health departments, consultants, geologists, and universities. The data is used by many other applications such as the Water Well Viewer, Map Image Viewer, Groundwater Inventory and Mapping Project, Drinking Water GIS, Michigan Groundwater Management Tool, and the Water Withdrawal Assessment Tool. The data is also available for download.

Electronic Well Record Submittal
Welogic 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, local health departments, and the DEQ. 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 provides a tax deduction for the computer system and internet charges. In addition, contractors can renew their annual contractor registration online via Wellogic and pay electronically.

Any questions regarding electronic well record submittal should be emailed to the Wellogic Staff at wellogic@michigan.gov. Visit the Wellogic website at https://secure1.state.mi.us/wellogic/Login.aspx 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 2 copies to the local health department.
- The local health department shall forward 1 copy to the DEQ within 30 days.
- Only those forms approved by the DEQ 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 local health department or DEQ 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 2 copies to the local health department.
- The local health department shall forward 1 copy to the DEQ within 30 days.

**Rule 268 Dewatering Well Records**
- The contractor shall retain a copy of the well log and shall provide 1 copy of the well log to the person responsible for plugging the dewatering well, and 2 copies to the local health department.
- Dewatering well drilling data shall be reported on a dewatering well record form.
- Contact the DEQ for additional information on dewatering well record submittal.

**Well Record Completion**
Below is an explanation of how to fill out the Water Well and Pump Record (hard copy or electronic). Water well records are expected to be accurate. It is 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.

1. **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 & Longitude**
The latitude and longitude are obtained by using a global positioning system (GPS) unit. The GPS unit receives information from satellites that orbit the Earth, and it tells you exactly where you are located on Earth. The contractor must make sure that their GPS unit is reporting the latitude and longitude in “decimal degrees”. The default setting for most GPS units 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 six miles by six 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.

**Distance and Direction from Road Intersection**
Complicated locations should be described as if you were giving someone directions on how to get to the site. Here are some acceptable descriptions:

- “1/8 mile north of Perry Road on US 23, 500 feet west of US 23”
- “North on M-18 1/2 mile past Clark Road, SE 0.2 miles on Farm Lane in Lakeview Subdivision, Lot 18”
- “Pleasant Road 1/4 mile east of Maple River, north on Shady Lane, 600 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.

2. **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, clayey, or shaley 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. Below is an example of the correct way to list formation depths:

<table>
<thead>
<tr>
<th>Thickness of Stratum</th>
<th>Depth to Bottom of Stratum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td>17</td>
<td>54</td>
</tr>
<tr>
<td>22</td>
<td>76</td>
</tr>
<tr>
<td>19</td>
<td>95</td>
</tr>
</tbody>
</table>
3. 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.”

4. Well Depth
Record the completed well depth. This may be different from the total depth drilled if the formation was backfilled. If a dry hole was drilled, record the depth of the dry hole.

5. 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.

6. Well Type
Indicate the appropriate well type.

7. Drilling Method
Mark the drilling method or methods used.

8. Well Use
Mark 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 nonpotable 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.

9. Casing & 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.

10. 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 gallons per minute.

11. 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.

12. 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.

13. 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.

14. 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”

15. 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+.”
16. 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.

17. WSSN & Source ID/Well No.
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 local health department (Type II) and from the DNRE (Type I).

18. 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.

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

20. 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, owner wants to keep old well and use for irrigation.

21. Drilling Machine Operator & 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.

22. 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 expected to be accurate and that the following statement is above the contractor’s signature: “This well/pump was constructed under my supervision and I hereby certify that the work complies with Part 127 Act 368 PA 1978 and the well code.” Falsification of water well records is a violation of state law which may result in suspension or revocation of a contractor’s registration certificate.
INSPECTIONS AND EVALUATIONS

Introduction
A Final Inspection is an on-site 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.

Local Health Departments (LHD) are required as part of their Minimum Program Requirements to conduct a final inspection on not less than 10% of new well installations. Most LHDs achieve a much higher percentage of final inspections, and some even achieve 100%. The state average is approximately 50-60%.

A Predrilling Site Review or Random Construction Inspection (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:

- Water well location to ensure adequate separation from contamination sources.
- Casing termination method (pitless adapter, well house, basement offset) and well cap.
- Visual check of sealing of annular space surrounding the water well casing.
- Water system component materials (water well casing, water service line, etc.).
- Pump installation (pump, pressure tank, piping, sample tap, valves, and controls).
- Collection of bacteriological water sample (by owner or owner’s authorized representative) and nitrate/partial chemical analysis is recommended.
- 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 can bring about improved compliance. Sanitarians should complete the Water Supply Final Inspection Checklist (see enclosed), or an equivalent, 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 any sources of contamination (e.g. septic tanks and drainfields, 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 usually provide the well owner with a written approval. This may be in the form of a letter, inspection tag, finalized permit, or other document. This ensures the well owner that the newly completed water system is suitable for the intended use.
WATER SUPPLY FINAL INSPECTION CHECKLIST

Owner _______________________________ Site Address _______________________________

Permit Number __________________________________________

A. Water Well Location Approved? ☐ YES ☐ NO

1. Same location as approved on permit? ☐ YES ☐ NO
   (If "No," make drawing showing location)

2. Properly isolated from contamination sources (standard and major)? ☐ YES ☐ NO

3. Accessible for maintenance/repair? ☐ YES ☐ NO

B. Wellhead/Casing Termination Approved? ☐ YES ☐ NO

1. Method:
   Pitless adapter ___ Well house ___ Basement offset ___ Other ________________

2. Wellhead
   a. 12 inches above grade? ☐ YES ☐ NO
   b. Approved well cap/seal? ☐ YES ☐ NO
   c. Approved conduit (grey Schedule 40 PVC or galvanized pipe)? ☐ YES ☐ NO ☐ NA
   d. Caving of soil or open annulus around casing? ☐ YES ☐ NO

C. Grouting Approved? ☐ YES ☐ NO

1. Verified on water well record review? ☐ YES ☐ NO

2. Field observation of grouting? ☐ YES ☐ NO

D. Pump Installation Approved? ☐ YES ☐ NO

1. Location? In well ____ On top of well ____ Basement offset ____ Well house ____
   Other _______________________

2. Type? Submersible ____ Deep well jet ____ Shallow well jet ____ Constant Pressure ____
   Other ________________________

E. Piping Between Well and House Approved? ☐ YES ☐ NO

1. Material? Plastic: PVC _____ PE _____ Other ______________
   NSF-pw marking ☐ YES ☐ NO
   Minimum 160 psi pressure rating ☐ YES ☐ NO

2. Diameter ______ inches
3. Protected suction line? □ YES □ NO □ NA

4. For submersible pump installations, is check valve installed within well casing? □ YES □ NO □ NA

F. Pressure Tank Installation Approved? □ YES □ NO

1. Type: Captive air ____ Galvanized ____ Buried ____

2. Number of tanks ____

3. Pressure relief valve installed? □ YES □ NO

G. Sampling Tap Approved? □ YES □ NO

H. Water Samples Collected? □ YES □ NO

1. Type: Bacteriological _____ Partial Chemical _____ Nitrate/nitrite _________
   VOC ____ Other ____________________________

2. Sample(s) collected by: LHD ____ Owner ____ Water Well driller ______
   Other ____________________________

Comments:________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Inspected by ___________________________ Date: _______ Reinspection Date: __________

Have the permit conditions been met? □ YES □ NO

Is the water well record accurate and complete? □ YES □ NO

Does the system comply with the State Well Code? □ YES □ NO

Is there a safe coliform bacteria sample? □ YES □ NO

Does any other water sampling meet acceptable levels? □ YES □ NO □ NA

**The water well system is approved** □ YES □ NO

Reviewed by ___________________________ Date ___________________________
HOW TO CONDUCT AN INVESTIGATION ON AN EXISTING WATER SUPPLY

This outline was prepared to aid the Local Health Department (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.
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 & 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 & 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, hosebibbs, water closets, etc.)

8. Water treatment devices
• What type of treatment, if any, is present? softening, iron removal, aeration/fitration, 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, volatile organic compounds 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 watertightness.

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. The measurement of outside diameter will be slightly larger - e.g., 4-inch well casing is 4.026 in. I.D. and 4.5 in. 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 foot 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.
  o 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.
  o 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.
  o Evaluation using soil probe - This process is discussed in the 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 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 Michigan Department of Environmental Quality 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. Success is more likely in fractured, high bedrock areas.

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.
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 gallons per minute

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 gal. 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.
PROBLEM WELLS

Flowing Wells
Flowing artesian wells are water wells where the pressure in the aquifer (water-bearing geologic formation) forces ground water 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 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 the DEQ’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. To receive a copy of the handbook, visit the Well Construction Program website at www.michigan.gov/deqwaterwellconstruction.

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 breeches must be sealed.

Rule 138
Flowing wells shall be grouted:
- To protect the artesian aquifer
- Prevent erosion of the overlying geologic materials
- Confine the flow to within the casing.

Rule 138(2)
Discharge control be provided to
- Conserve groundwater.
- 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.
Deviation to Allow Flowing Well to Discharge

A flowing well that is constructed after April 21, 1994 (effective date of the well code revision) may be permitted to discharge water, if a deviation is issued local health department. The DEQ recommends that discharges be throttled back to not more than 10 percent of the unrestricted flow rate, unless a deviation is obtained. 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 will likely result 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 Artesian Well Discharge Deviation form may be used by local health departments for issuing deviations to R 325.1638 of the 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.

The discharge of water from flowing wells can be stopped or significantly reduced, in most cases, if proper steps are taken during well construction. If the flow within the permanent casing is not stopped completely, it is recommended that the flow be reduced to approximately 10 percent of the unrestricted flow rate. If it is intended that the well flow more than 10 percent of the unrestricted flow rate, a deviation must be issued.
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 ___________________________ Home phone ______________________
Address ______________________________ Work phone ______________________
City ________________________ State _______ Zip code ______________________
Well site address ____________________________
Well permit application date _______________ Well permit number ______________________

Unrestricted flow rate __________ gpm Proposed discharge rate __________ gpm

Reason(s) for deviation:
☐ Control of flow not practical – Give reason(s) ________________________________
                                      ________________________________
                                      ________________________________

☐ Flow control will result in sand/turbidity production.

☐ Discharge is for beneficial use:
  ______ Maintain water level in pond ______ Fire protection
  ______ Industrial process ______ Heating/cooling
  ______ Irrigation
  Other ________________________________

Person requesting deviation ___________________________ Date ________________
Local health department official ___________________________ Date ________________
Local Health Department ________________________________
METHANE/GAS WELLS

Introduction
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\textsubscript{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 swamplike 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.

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.

The DEQ 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 1). 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 methane in water. Portable combustible gas meters can also be used for field determinations of methane levels.

The DEQ 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 2). 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.

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 3). 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 precharged 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.
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 the MDEQ 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.
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 ground waters, 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

Introduction
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 & 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 & 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 sand and turbidity problems can cause reduction of septic system capacity, and plugging of lawn irrigation systems, showerheads, water softener resin tanks, and water lines.

Complaint Evaluation & Problem Diagnosis
Investigation of a sand and turbidity complaint should involve first and foremost, confirming the problem. 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 distribution system. If so, correction will involve 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,” 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” 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 sand and turbidity 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.
9. Sand and turbidity problems in existing wells can result from mineral incrustation or biolfilm 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 sand and turbidity 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 sand and turbidity problems. Correction can often be achieved by installing a liner 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 try to 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 flushings may be needed). Be sure to turn off poser 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.
LOW CAPACITY WELLS

Introduction:
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.

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:
  o Install a greater length of screen. Doubling the well diameter only increases the well yield by 10%. However, doubling the screen length can double the well yield.
  o Use larger screen openings
    Continuous slot wire wound screen .... 20-40% openings
    Saw Cut Plastic Screen: ................. 10-12% openings
    Slotted Casing ............................ 2-5% openings
  o Change the shape of the screen openings
    ▪ V-shaped (widest to outside) - no clogging
    ▪ Straight cut - clogs easily, increases drawdown
    ▪ Perforations - creates turbulence & encrustation
  o Use filter pack
  o 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 local health department prior to installation.
# Steel Casing Specifications Comparison

## SCOPE

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<th>ASTM A589</th>
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<td>Seamless Carbon Steel Pipe-High Temperature Service with ANSI B36.10 wall thickness (Grade A or B)</td>
<td>Threaded/Coupled Carbon Steel Pipe</td>
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<td>Type I: &quot;Drive Pipe, seamless or electric resistance welded (Grade A or B)</td>
<td>Type II: Water Well Reamed and Drifted Pipe&quot;, seamless or electric resistance welded (Grade A or B) or furnace-butt welded</td>
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## SIZE

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# Steel Casing Specifications Comparison

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</tr>
</thead>
<tbody>
<tr>
<td>Open Hearth, Electric Furnace, Basic Oxygen Cast in ingots or strand cast - Tempering or other processing required on ERW weld seam (Grade B) to remove untempered martensite</td>
<td>Open Hearth, Electric Furnace, Basic Oxygen Cast in ingots or strand cast</td>
<td>Open Hearth, Electric Furnace, Basic Oxygen cast in ingots or strand cast</td>
<td>Seamless - steel hot worked to form tubular product without welded seam welded - without filler 1) Continuous: skelp heated and mech. pressed together to form weld (butt-weld) 2) Electric: steel mechanically pressed together with heat to form weld generated by electric current welded - with filler 1) Submerged Arc: coalescence by heating with electric arc, shielded by blanket of granular fusible material, filler from electrodes, no pressure</td>
</tr>
</tbody>
</table>

## Chemical Composition

<table>
<thead>
<tr>
<th>Composition, Max %</th>
<th>Grade A</th>
<th>Grade B &amp; Type F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.95</td>
<td>1.20</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.045</td>
<td>0.045</td>
</tr>
<tr>
<td>Copper</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Vanadium</td>
<td>0.08</td>
<td>0.08</td>
</tr>
</tbody>
</table>

- Combination of these elements shall not exceed 1.00%

<table>
<thead>
<tr>
<th>Composition, Max %</th>
<th>Grade A</th>
<th>Grade B</th>
<th>Grade C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.25</td>
<td>0.30</td>
<td>0.35</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.27</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
</tr>
<tr>
<td>Silicon, Min.</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Copper</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Vanadium</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
</tbody>
</table>

\* See specification for range

<table>
<thead>
<tr>
<th>Composition: Max %</th>
<th>Grade</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>Max. %</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>Max. %</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Max. % dependent on grade of pipe

See specification for details.
# Steel Casing Specifications Comparison

## ANALYSIS

<table>
<thead>
<tr>
<th>Specification</th>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical analysis</td>
<td>Shall conform to ASTM A 751</td>
<td>Composed of heat</td>
<td>Shall be performed by manufacturer</td>
<td>Shall be performed by manufacturer</td>
</tr>
</tbody>
</table>

*NOTE: Chemical analysis requirements are similar through all specifications. Refer to individual specification for details.*

## TENSILE REQUIREMENTS

<table>
<thead>
<tr>
<th>Specification</th>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength (min. psi)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type F</td>
<td>Grade A</td>
<td>Grade B</td>
<td>Grade C</td>
<td>Grade A</td>
</tr>
<tr>
<td>48,000</td>
<td>60,000</td>
<td>70,000</td>
<td>45,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Yield Strength (min. psi)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type F</td>
<td>Grade A</td>
<td>Grade B</td>
<td>Grade C</td>
<td>Grade A</td>
</tr>
<tr>
<td>30,000</td>
<td>35,000</td>
<td>40,000</td>
<td>25,000</td>
<td>30,000</td>
</tr>
</tbody>
</table>

*Elongation in 2": Similar values computed with same equation, Higher Tensile Strength = Lower Elongation*.

## BENDING REQUIREMENTS

<table>
<thead>
<tr>
<th>Specification</th>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>90° Cylindrical Mandrel 12x Pipe Diameter/No Cracks</td>
<td>Standard: 90° Cylindrical Mandrel 12x Pipe Diameter/No Cracks</td>
<td>None</td>
<td>90° Cylindrical Mandrel 12x Pipe Diameter/No Cracks</td>
<td></td>
</tr>
</tbody>
</table>
# Steel Casing Specifications Comparison

<table>
<thead>
<tr>
<th>FLATTENING TEST</th>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required on pipe over 2 in.</td>
<td>Addresses seamless/centrifugally cast pipe and welded pipe H as defined for seamless in A 53</td>
<td></td>
<td>NONE</td>
<td>Required on electric or continuous-welded pipe</td>
</tr>
<tr>
<td>Separately addresses seamless, electric-resistance welded and continuous welded methods.</td>
<td></td>
<td></td>
<td></td>
<td>Grade 25: Flatten to 75% O.D. without weld break; 60% O.D. without cracks except weld</td>
</tr>
<tr>
<td>Butt weld: H = 60% O.D.</td>
<td></td>
<td></td>
<td></td>
<td>Other Grades: Flatten 67% O.D. without weld break; 33% O.D. without break except weld</td>
</tr>
<tr>
<td>Elec.-Resist: H = 33% O.D.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seamless: Flat to H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&quot;H&quot; is defined by equation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HYDROSTATIC TEST</th>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each length must be tested by the manufacturer</td>
<td>Required unless purchaser specifies no hydrostatic testing or NDE in lieu of hydrostatic testing</td>
<td>Each length of pipe must be tested the mill</td>
<td>Similar requirements and pressures to ASTM A 589</td>
<td></td>
</tr>
<tr>
<td>Not Required on Seamless Pipe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Test Pressures:** depends on weight or schedule, grade and manufacturer

**Similar Pipe = Similar Pressure**

<table>
<thead>
<tr>
<th>NONDESTRUCTIVE ELECTRIC TESTS (NDE)</th>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERW Pipe: must be tested</td>
<td>NDE may be used as alternative to hydrostatic testing - Pipe must be marked &quot;NDE&quot;</td>
<td></td>
<td>NONE</td>
<td>Required Grade A, B</td>
</tr>
<tr>
<td>SEAMLESS Pipe: NDT may be used as alternative to hydrostatic testing - Pipe marked &quot;NDE&quot;</td>
<td></td>
<td></td>
<td></td>
<td>Submerged Arc: inspected by radiological and ultrasonic methods</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electric Weld: inspected by ultrasonic or electromagnetic methods</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gas-Metal Arc: inspected by ultrasonic and radiological methods</td>
<td></td>
</tr>
</tbody>
</table>

**[NOTE: NDT is test of structural integrity based upon electrical/ultrasonic or radiological continuity]**
# Steel Casing Specifications Comparison

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NUMBER OF TESTS</strong></td>
<td><strong>NUMBER OF TESTS</strong></td>
<td><strong>NUMBER OF TESTS</strong></td>
<td><strong>NUMBER OF TESTS</strong></td>
</tr>
<tr>
<td>Seamless, ERW: one test for tensile, bending, and flattening for each 500 lengths</td>
<td>Tensile: Under 6&quot; - 1 test/400 lengths; +6&quot; - 1 test/200 lengths</td>
<td>Similar to A 53</td>
<td>Full length inspection all pipe</td>
</tr>
<tr>
<td>Continuous Weld: one test per 50 ton lot</td>
<td>Bend: Under 2&quot; - 1 test/400 lengths or 5% each lot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flattening: same as tensile test</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RETESTS</strong></td>
<td><strong>RETESTS</strong></td>
<td><strong>RETESTS</strong></td>
<td><strong>RETESTS</strong></td>
</tr>
<tr>
<td>Failure: results in double test on remaining lots</td>
<td>Failure: one retest allowed</td>
<td>Same As A 53</td>
<td>Rejection/Retest requirements more complex and stricter than ASTM</td>
</tr>
<tr>
<td>Second Failure: reject</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOLERANCES ON WEIGHTS &amp; DIMENSIONS</strong></td>
<td><strong>TOLERANCES ON WEIGHTS &amp; DIMENSIONS</strong></td>
<td><strong>TOLERANCES ON WEIGHTS &amp; DIMENSIONS</strong></td>
<td><strong>TOLERANCES ON WEIGHTS &amp; DIMENSIONS</strong></td>
</tr>
<tr>
<td>REQUIRED</td>
<td>REQUIRED</td>
<td>REQUIRED</td>
<td>REQUIRED</td>
</tr>
<tr>
<td>Weight: +10%</td>
<td>Weight: +10%</td>
<td>Weight: +5%</td>
<td>Weight: ±10%, -3.5%</td>
</tr>
<tr>
<td>Diameter: ±1%</td>
<td>Diameter: Variation spec.</td>
<td>O.D.: ±1%</td>
<td>Diameter: ±1%</td>
</tr>
<tr>
<td>Wall Thickness: not more than 12.5% under thickness listed in specification</td>
<td>Wall Thickness: not more than 12.5% under thickness listed in specification</td>
<td>I.D.: permit drift to pass</td>
<td>Wall Thickness: not more than 12.5% under and 20% over thickness listed in specification</td>
</tr>
</tbody>
</table>

- 5 -
# Steel Casing Specifications Comparison

## Michigan Department of Environmental Quality

### Steel Casing Specifications Comparison

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td><strong>WORKMANSHIP, FINISH &amp; APPEARANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not more than 5% jointers</td>
<td>5% 12 to 16</td>
<td>Type III: random 3 - 6 or 6 - 10 ft.</td>
<td>Minimum - 16 ft.</td>
</tr>
<tr>
<td>Plain-Ends: 5% may be 12 to 16 ft.</td>
<td>Double-Random: Average 35 ft., min 22 ft., and 5% 16 to 22</td>
<td>subject to order change/negotiation</td>
<td>Maximum - 22.5 ft.</td>
</tr>
<tr>
<td>Extra-Strong and Lighter: varies</td>
<td>Jointers: None allowed</td>
<td></td>
<td>Minimum Average - 17.5 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T &amp; C: Nominal 40 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum - 20 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum - 45 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum Average - 35 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plain End: Nominal 20 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum - 9.0 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum - 22.5 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum Average 17.5 ft.</td>
</tr>
<tr>
<td>[NOTE: All lengths subject to order]</td>
<td></td>
<td></td>
<td>Plain End: Nominal 40 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum - 14 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum - 45 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimum Average - 35 ft.</td>
</tr>
</tbody>
</table>

### WORKMANSHIP, FINISH & APPEARANCE

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires: inspection, imperfection 12.5% into wall considered defects, removal by grinding if wall thickness OK, repair by welding subject to agreement, pipe to be straight</td>
<td>Requires: straight and free of defects, allows imperfections less than 12.5% wall, free of burrs, zinc coating/galvanized free of voids</td>
<td>Requires: visual inspection defects include dents, offset of plates, weld bead flaws. Correction includes repair by grinding welding or shortening</td>
<td></td>
</tr>
</tbody>
</table>

- 6 -
# Steel Casing Specifications Comparison

## END FINISH

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard Weight or Extra Strong:</strong></td>
<td><strong>NPS 2” or Smaller:</strong></td>
<td><strong>Threaded:</strong></td>
<td><strong>All pipe threaded plain-end, or bell and spigot.</strong></td>
</tr>
<tr>
<td>plain-end with bevel</td>
<td>plain-end with square cut or beveled</td>
<td>required of all, protection, dimensions specified in specifications</td>
<td>T &amp; C: thread conforming to API Standard 5B, thread protection required.</td>
</tr>
<tr>
<td>Double Extra Strong: plain-end square cut</td>
<td>Over 2” NPS: standard weight or extra strong plain-end beveled; over extra strong plain-end square</td>
<td>(ANSI B1.20.1)</td>
<td>Plain-End: Beveled</td>
</tr>
<tr>
<td>Threaded: requires compliance with ANSI B1.20.1, protection</td>
<td></td>
<td></td>
<td>Minimum Average - 35 ft.</td>
</tr>
</tbody>
</table>

## GALVANIZED PIPE

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coated inside/out by hot-dip</td>
<td>NONE</td>
<td>Same as A 53</td>
<td>No reference - pipe to be coated to protect against rust</td>
</tr>
<tr>
<td>Weight Coat: 1.8 oz/ft’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test: specified</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Test: per on base material</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## INSPECTION

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchaser: right to inspect with reasonable facilities to satisfy</td>
<td>NONE</td>
<td>Same as A 53</td>
<td>Similar to A 53</td>
</tr>
<tr>
<td>Producer: responsible for performance of inspection and tests as specified</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Michigan Department of Environmental Quality

## Steel Casing Specifications Comparison

### REJECTION

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based upon compliance with test and inspection by manufacturer or purchaser. Disposition matter of agreement.</td>
<td>NONE</td>
<td>Same as A 53</td>
<td>Similar to A 53</td>
</tr>
</tbody>
</table>

### MARKING

<table>
<thead>
<tr>
<th>ASTM A53</th>
<th>ASTM A106</th>
<th>ASTM A589</th>
<th>API 5L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legibly marked by rolling, stamping or stencil with:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) manufacturer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) kind of pipe, i.e., continuous, electric resistance (Grade A or B), seamless (Grade A or B)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) specification number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legibly marked with:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) manufacturer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) specification number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) heat number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) schedule number</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6) length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7) weight (&gt;4&quot;)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legibly stenciled or stamped with:

1) manufacturer
2) "Spec 5L" or "API 5L"
3) size
4) weight/ft.
5) grade
6) process manufacturer
7) test pressure if higher spec.
8) thread type

Supplemental requirements exist which are Group specific.
Plastic Casing Markings
Required by Michigan Well Code

Each length of pipe must be legibly marked with all of the following information:

- Manufacturer's Name & Resin Manufacturer
- Impact Classification
- Size & SDR
- Lot Number
- Date Manufactured
- ASTM Number
- Designated as Well Casing
- NSF Marking
- Type of Plastic
Steel Well Casing Markings
Required by Michigan Well Code

Each length of pipe must be legibly marked, by the producing mill, with all of the following information:

<table>
<thead>
<tr>
<th>MANUFACTURER’S NAME</th>
<th>KIND OF PIPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEIGHT OR SCHEDULE</td>
<td>(CONTINUOUS WELDED, ELECTRIC RESISTANCE WELDED, OR SEAMLESS)</td>
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<tr>
<td>SPECIFICATION NUMBER</td>
<td>NOMINAL OR OUTSIDE DIAMETER</td>
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<tr>
<td></td>
<td>LENGTH</td>
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<tr>
<td></td>
<td>HEAT NUMBER OR LOT NUMBER</td>
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</tbody>
</table>
Yard Hydrant With Stop and Waste Valve

Not Approved
WATER SYSTEM WITH SUBMERSIBLE PUMP

(Typical Household Installation)

NOTE: ELECTRICAL WIRING WITHIN WELL CASING NOT SHOWN. WIRING MUST COMPLY WITH STATE ELECTRICAL CODE.
WATER SYSTEM WITH SHALLOW WELL JET PUMP AND PRESURIZED CONCENTRIC PIPING
- WELL SEAL METHOD -

WATER SYSTEM WITH SHALLOW WELL JET PUMP AND OUTER CONCENTRIC PIPING DRAINED BY GRAVITY INTO BASEMENT

NOTE: THIS METHOD MAY BE USED ONLY WHERE THE WELL IS WITHIN 20 FEET OF THE BUILDING AND THE PUMP IS LOCATED WITHIN AN APPROVED BASEMENT, BASEMENT OFFSET, OR PUMP ROOM.
WATER SYSTEM WITH SHALLOW WELL JET PUMP AND PRESSURIZED OUTER CONCENTRIC PIPING - BOX ELBOW METHOD -

WHERE THE PIPING FROM THE BOX ELBOW TO THE PUMP MUST BE DRAINED TO PREVENT FREEZING, IT IS RECOMMENDED THAT A 1/2 INCH DIAMETER PIPE BE INSTALLED IN THE DRAIN PLUG HOLE IN THE BOX ELBOW AND EXTEND TO ABOVE THE CONCRETE SLAB. REMOVE PLUG IN TOP OF CASING ADAPTER AND BLOW WATER FROM ANNULAR SPACE BETWEEN PIPES OUT THROUGH 1/2 INCH LINE USING COMPRESSED AIR. REINSTALL PLUG ON TOP OF CASING ADAPTER AFTER BLOWING WATER OUT OF SUCTION LINE.

TIP FOR WINTERIZATION

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
DRINKING WATER AND RADIOLOGICAL PROTECTION DIVISION
GROUND WATER SUPPLY SECTION - WELL CONSTRUCTION UNIT

WATER SYSTEM WITH SHALLOW WELL JET PUMP AND PRESSURIZED OUTER CONCENTRIC PIPING - CASING ADAPTER METHOD -
WATER SYSTEM WITH DEEP WELL JET PUMP AND SINGLE PIPE PACKER JET

PRESSURIZED OUTER CONCENTRIC PIPING USING CASING ADAPTER WITH EXPOSED PARALLEL PIPING

PRESSURIZED OUTER CONCENTRIC PIPING USING CASING ADAPTER
MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
DRINKING WATER AND RADIOLOGICAL PROTECTION DIVISION
GROUND WATER SUPPLY SECTION - WELL CONSTRUCTION UNIT

WATER SYSTEM WITH DEEP WELL JET PUMP AND SINGLE PIPE
PACKER JET WITH PRESSURIZED OUTER CONCENTRIC PIPING -
BOX ELBOW METHOD -

APPROVED BASEMENT OR CRAWL SPACE

VERTICAL MULTI-STAGE DEEP WELL JET PUMP

PRESSURE REGULATOR

PRESSURE SWITCH

CASING ADAPTER BOLTED TO PUMP

MIN. 12”

WATER IN ANNULAR SPACE KEPT UNDER SYSTEM PRESSURE

PRESSURIZED ANNULAR SPACE

1 1/4” SUCTION LINE PROTECTED BY OUTER CONCENTRIC PIPING

BOX ELBOW

DRAIN PLUG

PUMP DISCHARGE LINE (TO PRESSURE TANK)

MDEQ APPROVED DWJ PITLESS UNIT (THREADS OR WELDS TO CASING)

SPOOL WITH O-RINGS

STATIC WATER LEVEL

PACKER JET ASSEMBLY

WATERTIGHT & VERMIN-PROOF WELL CAP (WITHOUT VENT)

SURFACE GRADED AWAY FROM WELL

WELL MUST BE AT LEAST 3 FEET FROM BUILDING AND OVERHANG

WATER SYSTEM WITH DEEP WELL JET PUMP AND SINGLE PIPE
PACKER JET WITH PRESSURIZED OUTER CONCENTRIC PIPING -
BOX ELBOW METHOD -
WATER SYSTEM IN BASEMENT OFFSET

- FIRST FLOOR
- SLOPE FLOOR 1/4 INCH IN 12 INCHES
- Poured concrete floor
- Union sanitary well seal
- Shallow well jet pump
- Shut off valve
- Pressure switch
- Pressure gauge
- Sampling tap at least 8" above the floor
- Approved basement
- Poured concrete slab (reinforced)
- Pressure tank (diaphragm or bladder type)
- Access to offset from basement (for service)
- Pressed concrete or cement block walls
- Access manhole located over well
- 4"-6" water system in basement offset
- Well at least 3 ft. from building or overhang water tight manhole cover
- Water tight manhole cover
- Water system in basement offset
- Seal located over well
- Access to offset from basement (for service)
- Well casing at least 12 in. above floor
- Vent to building distribution system
- Sanitary well seal with vent
- Well at least 3 ft. from building or overhang ground surface
- Ground surface
- Basement offset
- Poured concrete floor
- SHALLOW WELL JET PUMP
- PUMP MOTOR
- UNION
- PRESSURE GAUGE
- PRESSURE SWITCH
- SAMPLING TAP AT LEAST 8" ABOVE THE FLOOR
- TO BUILDING DISTRIBUTION SYSTEM
- FLOOR
- SLOPE FLOOR 1/4 INCH IN 12 INCHES
- SEAL
- Poured concrete floor
**2 INCH SCREENED WELL CONSTRUCTION**

- **Driveshoe**: Formation developed around screen to remove fines.
- **Threaded Coupling**: Casing shall extend a MINIMUM of 25' below grade.
- **Grout Material**: Seals annular space between casing and drillhole to prevent contamination.
- **1-1/4" Well Screen**: Telescoped screen installation.
- **1-1/4" Nipple (blank)**: Above screen.
- **Bremer Check Valve**: Drains from well site.
- **Well Cap**: Well casing terminates at least 12" above grade.
- **Well Casing**: 2" Steel Well Casing.
- **Formation developed around screen**: 1-1/4" Well Screen.
4 INCH SCREENED WELL CONSTRUCTION

- **Well Cap**
- **Drainage away from well site**
- **Well casing terminates at least 12 inches above grade**
- **Grout Material**
  - Seals annular space between casing and drillhole to prevent contamination
- **4 inch Steel Well Casing**
  - Casing shall extend a MINIMUM of 25 feet below grade
- **Threaded Coupling or Welded Joint**
- **K-Packer**
  - 3" X 4"
- **3 inch Nipple (blank)**
  - Above screen
- **3 inch Well Screen**
  - Telescoped screen installation
- **AQUIFER MATERIAL**
- **Formulation developed around screen to remove fines**

Authority: Act 368, PA 1978
ROCK WELL CONSTRUCTION

Well Casing
Casing shall extend a MINIMUM of 25 feet below grade

Grout Material
Seals annular space between casing and drillhole to prevent contamination

Casing Joint

Well Cap
Well casing terminates at least 12 inches above grade

Drainage away from well site

Glacial Drift

Bedrock

Diveshoe
Firmly seated in bedrock

Open Drillhole below casing

Authority: Act 368, PA 1978
5 INCH FILTER PACK CONSTRUCTION

- **PVC Well Casing**: 5 inch Minimum I.D.
  - Casing shall extend a MINIMUM of 25 feet below grade

- **Grout Material**: Seals annular space between casing and drillhole to prevent contamination

- **Coupling**: Bell and spigot with solvent weld

- **Well Screen**: Well screen attached directly to casing (Telescoped installation also permissible)

- **Filter Pack**: Graded coarse sand to increase permeability

- **Well Casing Terminates**: at least 12 inches above grade

- **Drainage Away**: from well site

- **Threaded or Solvent Weld Connection**

**Authority**: Act 368, PA 1978
BURIED PRESSURE TANK INSTALLATION

SUGGESTED PROCEDURES IF WINTERIZING
1. SHUT OFF ELECTRICAL POWER TO PUMP.
2. LEAVE SHUT OFF VALVE OPEN FOR ENTIRE PROCEDURE.
3. OPEN ALL BUILDING FIXTURES, DRAINING ALL PRESSURE FROM SYSTEM. LEAVE FIXTURES OPEN.
4. OPEN SAMPLE TAP, AND DRAIN ALL WATER FROM BUILDING PIPING.
5. REMOVE WELL CAP.
6. LOOSEN PITLESS ADAPTER SEAL (ONLY IF CLAMP-ON TYPE) TO DRAIN WATER SERVICE PIPE INTO WELL.
7. RETIGHTEN PITLESS ADAPTER SEAL, AND REINSTALL CAP.
8. CLOSE SAMPLING TAP AND ALL BUILDING FIXTURES.
ABOVE GRADE WELL HOUSE CONSTRUCTION

- Pressure Line to Building (Below Frost Line)
- Pressure Switch
- Vertical Deep Well Jet Pump
- Casing Vent
- Sampling Tap at Least 8 Inches Off Floor
- Waterproof Sealing Compound Between Well Casing and Concrete Slab
- Insulated Slop Roof (Removable or Hinged)
- Hinge for Lifting Roof
- Weather-Resistant Sheathing or Siding
- Insulated Walls
- Reinforced Concrete Slab (Minimum 4 Inches Thick)
- Well Casing Must Extend At Least 12 Inches Above Well House Floor and Ground Surface
Private/Type III Water Supply Program
Area Assignments

Lansing Office Staff
Dana DeBruyn, R.E.H.S., Chief Noncommunity & Private Drinking Water Supplies Unit
debruynd@michigan.gov
517-284-6524

Starla Walter, Secretary
walters3@michigan.gov
Phone: 517-284-6542
Fax: 517-241-1328
PO Box 30241
Lansing, MI 48909-7741

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906-346-8537

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906-346-8358

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517-346-3207

Cynthia Weaver
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616-356-0280

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517-284-6523

Kevin Holdwick
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517-284-6532

Anita Ladouceur
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517-284-6533

Mark Doyle
doylem1@michigan.gov
517-780-7923

Provided by the Michigan Department of Environmental Quality Noncommunity & Private Drinking Water Supplies Unit
August 12, 2013
<table>
<thead>
<tr>
<th>Local Health Department Directory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allegan County Health Dept.</strong></td>
</tr>
<tr>
<td>3255 122nd Ave., Suite 200</td>
</tr>
<tr>
<td>Allegan, MI 49010</td>
</tr>
<tr>
<td><a href="http://www.allegancounty.org">www.allegancounty.org</a></td>
</tr>
<tr>
<td><strong>Barry-Eaton District Health Dept.</strong></td>
</tr>
<tr>
<td>1033 Health Care Dr.</td>
</tr>
<tr>
<td>Charlotte, MI 48813</td>
</tr>
<tr>
<td><a href="http://www.barryeatonhealth.org">www.barryeatonhealth.org</a></td>
</tr>
<tr>
<td><strong>Bay County Health Dept.</strong></td>
</tr>
<tr>
<td>Washington Park Plaza</td>
</tr>
<tr>
<td>1212 Washington Ave.</td>
</tr>
<tr>
<td>Bay City, MI 48708-5994</td>
</tr>
<tr>
<td><a href="http://www.co.bay.mi.us">www.co.bay.mi.us</a></td>
</tr>
<tr>
<td><strong>Benzie-Leelanau District Health Dept.</strong></td>
</tr>
<tr>
<td>6051 Frankfort Hwy, Suite 100</td>
</tr>
<tr>
<td>Benzonia, MI 49616</td>
</tr>
<tr>
<td><a href="http://www.bldhd.org">www.bldhd.org</a></td>
</tr>
<tr>
<td><strong>Berrien County Health Dept.</strong></td>
</tr>
<tr>
<td>769 Pipestone St.</td>
</tr>
<tr>
<td>P.O. Box 706</td>
</tr>
<tr>
<td>Benton Harbor, MI 49023-0706</td>
</tr>
<tr>
<td><a href="http://www.berriencounty.org/healthdept">www.berriencounty.org/healthdept</a></td>
</tr>
<tr>
<td><strong>Branch-Hillsdale-St.Joseph Community Health Agency</strong></td>
</tr>
<tr>
<td>Human Services Building</td>
</tr>
<tr>
<td>570 Marshall Rd.</td>
</tr>
<tr>
<td>Coldwater, MI 49036</td>
</tr>
<tr>
<td><a href="http://www.bhsj.org">www.bhsj.org</a></td>
</tr>
<tr>
<td><strong>Calhoun County Dept. of Public Health</strong></td>
</tr>
<tr>
<td>190 E. Michigan Ave., Suite A-100</td>
</tr>
<tr>
<td>Battle Creek, MI 49014</td>
</tr>
<tr>
<td><a href="http://www.calhouncountymi.gov">www.calhouncountymi.gov</a></td>
</tr>
<tr>
<td><strong>Central Michigan District Health Dept.</strong></td>
</tr>
<tr>
<td>2012 E. Preston Ave.</td>
</tr>
<tr>
<td>Mt. Pleasant, MI 48858</td>
</tr>
<tr>
<td><a href="http://www.cmdhd.org">www.cmdhd.org</a></td>
</tr>
<tr>
<td><strong>Chippewa County Health Dept.</strong></td>
</tr>
<tr>
<td>508 Ashmun St., Suite 120</td>
</tr>
<tr>
<td>Sault Ste. Marie, MI 49783</td>
</tr>
<tr>
<td><a href="http://www.chippewahd.com">www.chippewahd.com</a></td>
</tr>
<tr>
<td><strong>City of Detroit Health Dept.</strong></td>
</tr>
<tr>
<td>Herman Kiefer Health Complex</td>
</tr>
<tr>
<td>1151 Taylor, Building 4</td>
</tr>
<tr>
<td>Detroit, MI 48202</td>
</tr>
<tr>
<td><a href="http://www.ci.detroit.mi.us/health/default.htm">www.ci.detroit.mi.us/health/default.htm</a></td>
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<tr>
<td><strong>Dickinson-Iron District Health Dept.</strong></td>
</tr>
<tr>
<td>601 Washington Ave.</td>
</tr>
<tr>
<td>Iron River, MI 49935</td>
</tr>
<tr>
<td><a href="http://www.didhd.org">www.didhd.org</a></td>
</tr>
<tr>
<td><strong>District Health Dept. #2</strong></td>
</tr>
<tr>
<td>630 Progress St.</td>
</tr>
<tr>
<td>West Branch, MI 48661</td>
</tr>
<tr>
<td><a href="http://www.dhd2.org">www.dhd2.org</a></td>
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<tr>
<td><strong>District Health Dept. #4</strong></td>
</tr>
<tr>
<td>100 Woods Cir.</td>
</tr>
<tr>
<td>Alpena, MI 49707</td>
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<tr>
<td><a href="http://www.dhd4.org">www.dhd4.org</a></td>
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<tr>
<td><strong>District Health Dept. #10</strong></td>
</tr>
<tr>
<td>521 Cobbs Street</td>
</tr>
<tr>
<td>Cadillac, MI 49601</td>
</tr>
<tr>
<td><a href="http://www.dhd10.org">www.dhd10.org</a></td>
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<tr>
<td><strong>Genesee County Health Dept.</strong></td>
</tr>
<tr>
<td>630 S. Saginaw St.</td>
</tr>
<tr>
<td>Flint, MI 48502-1540</td>
</tr>
<tr>
<td><a href="http://www.gchd.us">www.gchd.us</a></td>
</tr>
<tr>
<td><strong>Grand Traverse County Health Dept.</strong></td>
</tr>
<tr>
<td>2650 LaFranier Rd.</td>
</tr>
<tr>
<td>Traverse City, MI 49686</td>
</tr>
<tr>
<td><a href="http://www.co.grand-traverse.mi.us">www.co.grand-traverse.mi.us</a></td>
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<tr>
<td>Health Department Name</td>
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<tr>
<td>Huron County Health Dept.</td>
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<td>Ingham County Health Dept.</td>
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<td>Ionia County Health Dept.</td>
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<td>Jackson County Health Dept.</td>
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<tr>
<td>Kalamazoo County Health and Community Services Dept.</td>
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<td>Kent County Health Dept.</td>
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<td>Lapeer County Health Dept.</td>
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<td>Lenawee County Health Dept.</td>
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<td>Livingston County Dept. of Public Health</td>
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<td>Luce-Mackinac-Alger-Schoolcraft District Health Dept.</td>
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<td>Macomb County Health Dept.</td>
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<td>Marquette County Health Dept.</td>
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<tr>
<td>Midland County Dept. of Public Health</td>
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<td>Mid-Michigan District Health Dept.</td>
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<td>Monroe County Health Dept.</td>
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<tr>
<td>Muskegon County Health Dept.</td>
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<tr>
<td>Northwest Michigan Community Health Agency</td>
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<tr>
<td>Oakland County Health Div.</td>
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</tbody>
</table>
Ottawa County Health Dept.
12251 James St., Suite 200
Holland, MI 49424
www.miottawa.org

Public Health Delta and Menominee Counties
2920 College Ave.
Escanaba, MI 49829-9597
www.phdm.org

Saginaw County Dept. of Public Health
1600 N. Michigan Ave.
Saginaw, MI 48602-5395
www.saginawpublichealth.org

Sanilac County Health Dept.
171 Dawson St.
Sandusky, MI 48471
www.sanilachealth.com

Shiawassee County Health Dept.
310 N. Shiawassee St.
Corunna, MI 48817
http://health.shiawassee.net

St. Clair County Health Dept.
3415 28th St.
Port Huron, MI 48060
www.stclaircounty.org

Tuscola County Health Dept.
1309 Cleaver Rd.
Caro, MI 48723
www.tchd.us

Van Buren-Cass County District Public Health Dept.
57418 CR 681, Suite A
Hartford, MI 49057
www.vbcassdhd.org

Washtenaw County Public Health Dept.
555 Towner Ave.
P.O. Box 915
Ypsilanti, MI 48197-0915
www.ewashtenaw.org

Wayne County Health Dept.
33030 Van Born Rd.
Wayne, MI 48184
www.waynecounty.com

Western Upper Peninsula District Health Dept.
540 Depot
Hancock, MI 49930
www.westernuphealth.org