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PRIVATE WELL GUIDELINES

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Temporary Abandonment

When a well is not abandoned, but is out of use for an extended period of time, it should be the owner's responsibility to properly maintain the well and to prevent the development of defects which may facilitate the impairment of water quality in the well or in the water bearing formations penetrated by the well Until a well is permanently abandoned by plugging procedures, as described in the following section entitled "Decommissioning Abandoned Wells, Test Holes, and Dry or Inadequate Borings", all provisions for protection of the water from contamination and for maintaining sanitary conditions around the well should be carried out to the same extent as though the well were in routine use.

To temporarily abandon a well, the top of the well casing should be sealed with a watertight threaded cap or with a steel plate welded watertight to the top of the casing. If the pump or well seal is water tight, the pump may be left in place. A well that has, after extended use, been temporarily abandoned for 3 years should be permanently abandoned.

WELL REHABILITATION

This subsection consists of the following parts;

- General Considerations
- Major Causes of Deteriorating Well Performance

GENERAL CONSIDERATIONS

Well rehabilitation is defined as restoring a well to its most efficient condition by various methods of treatment or reconstruction. The necessity for well rehabilitation depends on the effectiveness of the maintenance program and how faithfully it has been followed. In some cases, a major reconstruction of the well may be necessary, such as replacing the screen or lining a portion of the casing. Timely maintenance designed to overcome specific problems can sustain well performance, thereby prolonging well life.

It is important to take note of any changes in the operating characteristics of the well and pump, because both can deteriorate to the point where rehabilitation is difficult, if not impossible.

Experience indicates that if the specific capacity of a well declines by 25 percent, it is time to initiate rehabilitation procedures. Further neglect significantly increases maintenance costs.

Major Causes of Deteriorating Well Performance

(1) Incrustation and Biofouling of the Screen and Surrounding Formation
(2) Physical Plugging of the Screen and Surrounding Formation *
(3) Onset of Sand Pumping
(4) Structural Collapse of the Well Casing or Screen

Incrustation and Biofouling of the Screen and Surrounding Formation

Well yield may be reduced by chemical incrustation or biofouling of the well screen and the formation materials around the intake portion of the well. Water quality chiefly determines the occurrence of incrustation. The surface of the screen itself may also play a part in regulating the rate at which incrustation occurs. Screens constructed of rough-surface metal may be more prone to incrustation. The kind and amount of dissolved minerals and gases in natural waters determine their tendency to deposit mineral matter as incrustation. The incrustation often forms a hard, brittle, cement like deposit similar to the scale found in water pipes. Under different conditions, however, it may be a soft, paste like sludge of a gelatinous material. The major forms of incrustation include;

(1) incrustation from precipitation of calcium and magnesium carbonates or their sulfates;
(2) incrustation from precipitation of iron and manganese compounds, primarily their hydroxides or hydrated oxides;
(3) plugging caused by slime producing iron bacteria or other slime-forming organisms (biofouling).

Prevention and Treatment of Incrustation Problems

For most wells where incrusting materials cannot be removed before reaching the well, several actions can be taken to delay incrustation and make it a less serious problem. First, the well screen should be designed to have the maximum possible inlet area to reduce the flow velocity to a minimum through the screen openings. Second, the well should be developed thoroughly. Third, the pumping rate may be reduced and the pumping period increased, thereby decreasing entrance velocities.

Chemical incrustation can best be removed by treating the well with a strong acid solution that chemically dissolves the incrusting materials so they can be pumped from the well. The acids most commonly used in well rehabilitation are hydrochloric (HCL), which is prepared commercially under the name muriatic acid, and is one of the most effective acids for mineral scale removal; sulfamic (H_3NO_3S), a dry white, granular material that produces a strong acid when mixed with water; and hydroxyacetic ($C_2H_4O_3$), also known as glycolic acid, which is a liquid organic acid available commercially in 70-percent concentrations.

Provisions should be made to neutralize acids and other chemicals used to rehabilitate a well. For example, acid solutions should be pumped to waste through agricultural lime or other suitable material.

Great care should be taken in placing liquid acid into a well. Only experienced personnel with specialized equipment should attempt to use it in rehabilitating a well. When using any liquid acid, the following precautions should be followed;

(1) wear protective rubber clothing and goggles
(2) a breathing respirator should be used by all personnel handling the acid and by persons near the well
(3) all mixing tanks, chemical pumps, and piping (tremie pipes) should be constructed of plastic or black iron to minimize reaction to acid
(4) a large quantity of water, or a water tank with a mixture of sodium bicarbonate, should be available in the event that an accident occurs
(5) proper ventilation must be maintained because the fumes released from the well treatment are lethal

Liquid acid should be introduced into the well through a small diameter pipe. If the screen is more than 5 feet long, enough acid should be added to fill the lower 5 feet of screen. Then the pipe should be raised and the next 5 feet of screen filled with acid, continuing in this manner until the entire screen is full.

After the acid is placed in the well (or the pellets dissolve), a volume of water equal to that standing in the well screen should be poured into the well to force the acid solution through the screen into the formation. Some form of mechanical agitation, such as surging, should be employed while the acid is in the well to help break up the incrustation and improve the overall efficiency of the process. This step is particularly important because it exposes the incrustant to the acid, thereby assuring maximum removal. The use of surge blocks or jetting tools are effective methods of agitating the well. The agitation time will depend on the amount of incrustant in the well

Another method available for the removal of incrustants is by mechanical means. This method is useful in either the preparation for acid treatment or as a primary method of removing incrustants. Wire brushing or other means of mechanical scraping can remove incrustants that have been deposited on the inside of the well screen. The loosened material is then removed from the well by bailing, airlift pumping, or other means. Removal of these incrustants minimizes the quantity of acid that must be used in any subsequent acid treatment, enhances the effectiveness of this treatment, and reduces the time required for the acidizing process.

Well Failure Caused by Physical Plugging of the Screen and Surrounding Formation

It can be expected that over time, almost all screened wells will experience some loss in specific capacity. This loss may be partially due to the slow movement of fine formation particles into the area around the screen. Many of these particles may partially plug the screen itself, depending on the type of screen slot opening, or even erode the slot openings under certain conditions. In summation, the movement of small particles reduces the yield, increases the drawdown, and may damage the screen.

The movement of these fine particles may be the result of a number of factors including (1) improper screen placement, poor slot selection, or inaccurate aquifer sampling techniques, (2) insufficient or improper development before the well was placed in service, (3) removal of cement holding the sand grains together around the well screen, (4) corrosion of the screen or casing, (5) increase in the pumping rate beyond the designed capacity, and (6) excessive pump cycling, although this may pertain more to high yield wells than small yield private wells.

Thorough development of the well during its completion can greatly decrease the movement of sediment into the formation around the well screen. The application of an appropriate development technique for a sufficient length of time will stabilize the formation material so that subsequent pump cycling and higher discharge rates will not result in sediment movement.

Onset of Sand Pumping

Some wells always pump sand, a condition attributable to poor well design or inadequate development. Other wells may begin to pump sand after months or years of service. Localized corrosion of the well screen or casing, or incrustation on only a portion of the screen, can produce higher velocities through either the corroded opening or the nonincrusted areas of the screen. Thus corrosion and incrustation are major factors in sand pumping problems that develop over time. In some well-cemented sandstones, removal of the cement by water passing into the well can weaken the sandstone to the point where sand particles begin to move into the well.

Structural Collapse of the Well Casing or Screen

Corrosion is defined as chemical action on a material exerted by outside factors, which causes destruction of the material. Corrosion of the well screen, casing or pumping equipment can severely limit the useful life of the well. Due to either the corrosive or incrustive nature of most natural waters, the effect will be a matter of degree and nature. The rate at which corrosion takes place depends on several factors such as the acidity of the groundwater, presence or absence of oxidizing agents, movement of the water over areas being corroded, electrolytic effects, formation of films or protective deposits and temperature of the corrosive reactions.

WELL ALTERATION

This subsection consists of the following parts;

- Extension of Existing Casing
- Reconstructing Dug Type Wells

Extension of Existing Casing

An existing casing can be extended above ground by welding a casing extension to the existing casing. Another method is to carefully telescope a section of larger casing over the existing one for a length of 5 feet. The casing should extend 18 inches above the surrounding ground and the inside diameter of the addition should be 3 inches greater than the inside diameter of the existing well casing. The annular space between the casings should be made equal all around and then filled with cement grout. The space around the outside of the casing extension should be filled with tamped concrete. Regardless of the method used to extend the well casing above ground, it is necessary to provide a sanitary well seal. The well should then be disinfected as previously described in the section entitled “Disinfection".

Reconstructing Dug Type Wells

A drilled type well may be constructed through an existing dug well in accordance with the following procedure;

(1) Remove any sediment or debris from the bottom of the dugwell.

(2) Disinfect the existing dug well with a chlorine solution containing a chlorine concentration of 100 mg/l.

(3) Drill through the bottom of the dug well following the appropriate procedures for drilled wells.

(4) "Dug and drilled" type wells should be effectively protected against the entrance of surface water by extending the casing of the drilled part of the well to an elevation of at least 12 inches above the established ground surface and filling the dug part of the well with neat cement grout or sand cement grout. Removing the top 7 or 8 feet of curbing creates a good soil to soil bond.

DECOMMISIONING ABANDONED WELLS, TEST HOLES, AND DRY OR INADEQUATE BORINGS

This section consists of the following subsections;

- Purpose
- Criteria for Abandoning a Private Water Supply Well
- Responsibility
- Decommissioning Report
- Plugging Procedure

PURPOSE

Private water supply wells are removed from service for a number of reasons, including construction of a replacement well, failure of the well to produce safe water, extension of a municipal water system to an area formerly served by individual private wells, or destruction of the building being served. When private wells are removed from service, they are seldom used again and are often forgotten after a property transfer. Over time, they may be covered by vegetation, a parking lot, or a building and they may act as a conduit, or channel, for the vertical movement of contamination from the ground surface to the groundwater or from one aquifer to another.

All abandoned private water supply wells, test holes, and dry or inadequate borings associated with private well installation and not used for water quality monitoring should be plugged in a manner that will permanently prevent vertical movement of water within the borehole, the well, and the annular space between the well casing and the wall of the boring. Unplugged or improperly plugged wells, test holes, and dry or inadequate borings constitute a potential hazard to public health and a danger to ground-water supplies used for drinking water and other beneficial purposes.

Proper plugging will;

(1) eliminate physical hazards

(2) prevent the groundwater from being contaminated by flooding, or the accidental or intentional disposal of waste materials

(3) prevent the intermingling of potable and non-potable groundwater

(4) conserve the yield and hydrostatic head of confined aquifers

(5) prevent localized surface flooding in the vicinity of artesian wells

CRITERIA FOR ABANDONING A PRIVATE WATER SUPPLY WELL

A private water supply well should be abandoned and properly plugged if the well meets any of the following criteria;

(1) construction was terminated prior to completion of the well

(2) the well owner has notified the local Board of Health that the use of the well has been permanently discontinued

(3) the well has, after extended use, been out of service for at least three years

(4) the well is a potential hazard to public health or safety and the situation cannot be corrected

(5) the well is in such a state of disrepair that its continued use is impractical

(6) the well has the potential for transmitting contaminants from the land surface into an aquifer or from one aquifer to another and the situation cannot be corrected

RESPONSIBILITY

It should be the responsibility of the property owner to ensure that all abandoned wells and test holes or borings associated with private well installation are properly plugged. Any person having knowledge of the location of any unplugged abandoned wells, test holes, or dry or inadequate borings should inform the local Board of Health.

One must be a registered well driller to plug abandoned wells, test holes, and dry or inadequate borings. In addition, when an old well is replaced by a new well, it is generally more economical to have the well driller plug the old well at the same time that the replacement is being constructed. In the case of new well construction, it is recommended that any test holes and dry or inadequate borings be plugged before the well driller completes work at the site.

DECOMMISSIONING REPORT

Within 30 days following the completion of the plugging procedure, the registered well driller who plugged the abandoned well, test hole, or dry or inadequate boring must submit a Well Completion Report to the Division of Water Supply Protection and should submit a Decommissioning Report to the owner of the property where the well, test hole, or boring is located. It is recommended that the local Board of Health require that the property owner file a copy of the Decommissioning Report with the appropriate Registry of Deeds or Land Court as part of the chain-of-title. Another copy of the Decommissioning Report should be submitted to the Board of Health. It is recommended that the copy submitted to the Board of Health include the Book and Page reference and the name of the Registry of Deeds where the report was filed or, in the case of registered land, the appropriate Land Court reference.

The following information should, when available, be included in the Decommissioning Report;

(1) name and address of the property owner

(2) name and address of the registered well driller who performed the plugging

(3) reason for abandonment

(4) location of the well, test hole, or boring referenced to at least two permanent structures or, when possible, location coordinates determined by a registered land surveyor or registered civil engineer
(5) all information known about the well, test hole, or boring including but not limited to:
a. depth
b. diameter
c. type of casing
(6) calculations made to determine the volume of the well, test hole, or boring

(7) static water level before plugging
(8) types of plugging material used, including mix specifications
(9) quantity of each type of plugging material used
(10) description of the plugging procedure including, but not limited to, notes regarding;
a. removal of pump and other obstructions
b. removal of screen
c. perforation or removal of casing
d. method used to place plugging material (s)
(11) a copy of the original well driller's report, when available
(12) a copy of the abandonment permit, if a permit is required by the local Board of Health

PLUGGING PROCEDURE

This subsection consists of the following parts:

- Preparation Prior to Placement of Plugging Materials
- Plugging Materials
- Placement of Plugging Materials
- Surface Seal

Preparation Prior to Placement of Plugging Materials

The first step in preparing to plug a well is to obtain information regarding the construction of the well. The construction details are critical for determining whether or not an effective well seal was emplaced during well construction. This, in turn, determines whether or not it is necessary to remove or perforate the well casing prior to emplacement of the plugging materials.

A copy of the “Water Well Completion Report" required by the State may be obtained from the well owner or from the Division of Water Resources, which maintains records dating back to 1965. Information on wells constructed prior to 1965 may be available from the well owner or from the well driller. When construction details cannot be obtained, or when there is any doubt as to the integrity of the original well seal, the casing should be removed or perforated, as discussed below.

The next step is to check the well or boring, from the land surface to the completed depth, for any debris or obstruction which may interfere with effective placement of the plugging materials: wells should be disconnected from the water system and all pumping equipment and associated piping should be removed from the well. A variety of fishing tools are used to remove obstructions. For example, threaded taps on the end of a drill rod may be used to screw into the top of a pump or drop pipe; or an over shot (casing with inner teeth), corkscrew, or spear may be used to hook the obstacle. In some instances, it may be necessary to drill, chop or grind up the obstacle and wash it out of the well. Explosives, however, should not be used.

When an effective well seal was not emplaced throughout the entire annular space above the well screen or other intake port during well construction, when construction details are unavailable, or when there is any doubt as to the integrity of the original well seal, the well screen and casing should be removed or perforated in order to plug the full volume of the original borehole.

When it is not feasible to remove the casing of an inadequately sealed well, the casing should be perforated and pressure grouting should be used to place the sealing materials. Perforations should be at least four inches long and should consist of at least four equidistant cuts per row with one row of perforations per linear foot of casing.

Once the well or boring has been cleared of obstructions, the static water level should be measured and recorded. It is important to know where the static water level is because certain types of plugging materials should be placed only above the level of the water in the well or boring.

In order to ensure a proper seal, the volume of grout used to plug the well or boring must equal or exceed the volume of the casing or borehole being plugged. By knowing in advance the minimum volume of grout required to fill the well or hole, it will not be necessary to stop the grouting process in order to prepare more grout. In addition, if the well or boring appears to be filled before the minimum volume of grout has been placed, the contractor knows immediately that the seal is not continuous and is, therefore, inadequate.

The volume of the casing or borehole can be calculated using the cylindrical volume formula, $\pi r^2 h$; where r is the radius of the well or borehole, in feet, and h is the depth. For example, the volume of a well constructed with six-inch diameter casing and a depth of 100 feet can be calculated as follows;

volume = $\pi r^2 h$
= 3.142 x 0.25 feet x 0.25 feet x 100 feet
= 20 cubic feet

If neat cement is used, for example, as the sealing material, the number of bags of cement needed to fill the well or boring can be calculated using the assumption that a 94 pound bag of cement plus 5 to 6 gallons of water yields 1.1 cubic feet of material. The following formula can be used to calculate the number of bags of cement needed to fill the well or boring;

number of bags volume of well or borehole (cubic feet)
of cement needed = cubic feet of material produced per bag

For the preceding example,

number of bags 20 cubic feet = 18 bags
of cement needed = 1.1 cubic feet

Due to borehole irregularities, however, it is advisable to have on hand 25-50 percent more sealant than the calculated volume. Also, when a borehole or uncased well penetrates cavernous limestone or highly fractured bedrock, it should be kept in mind that grout is often lost to the formation.

Plugging Materials

It should be noted that the U.S. Environmental Protection Agency (1975) and the guidelines and regulations for several states recommend or require an abandoned well to be sealed in a manner that restores, to the extent feasible, the hydrogeologic conditions existing before the well was constructed. Some states, for example, recommend that sand and gravel be placed opposite more permeable subsurface zones and clay be placed opposite less permeable zones. While restoration to preexisting hydrogeologic conditions is an admirable goal, it is, in the opinion of the Massachusetts DEP, unattainable in practice.

It is recommended that an abandoned well or boring be completely filled with a grout that, after curing, has a permeability of less than $1x10^{-7}$ cm/sec. There are a variety of grouts which may be used and each has distinct properties which may make one grout more appropriate than another for plugging a given well or boring. The selection of the most appropriate grout or combination of grouts depends primarily on the construction of the well and the geologic and hydrologic nature of the formation or formations penetrated by the well or boring. Regardless of the type used, the grout;

(1) should be sufficiently fluid so that it can be applied through a tremie pipe from the bottom of the well upward,

(2) should remain as a homogeneous fluid when applied to the subsurface rather than disaggregating by gravity into a two-phase substance,

(3) should be resistant to chemical or physical deterioration, and

(4) should not leach chemicals, either organic or inorganic, that will adversely affect the quality of the groundwater where it is applied.

The following types of grout are acceptable plugging materials. Comments regarding their use are also noted.

(1) **Neat cement grout** is a mixture consisting of one bag (94 pounds) of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A) to not more than six gallons of clean water. Bentonite (API Standard 13A), up to two percent by weight of cement, shall be added to reduce shrinkage. Other additives, as described in ASTM Standard C494, may be used to increase fluidity and/or control setting time. Although one bag of cement to six gallons of water produces a very fluid mixture, it sets up like concrete when it hardens. Neat cement grout may be used in all geologic formations and is ideal for sealing small openings, for penetrating annular space outside of casings, and for filling voids in the surrounding formation. When applied under pressure, it is favored for sealing wells under artesian pressure or borings that penetrate more than one aquifer. Unlike many other grouts, neat cement will not separate into a two-phase substance.

(2) **Sand cement grout** is a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, and water in the proportion of one part cement to three or four parts sand, by volume, and not more than six gallons of water per bag (94 pounds) of cement. Up to five percent, by weight, of bentonite (API Standard 13A) shall be added to reduce shrinkage.

(3) **Concrete** is a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 1OA, Class A), sand, gravel, and water in a proportion of not more than five parts of sand plus gravel to one part cement, by volume, and not more than six gallons of water. One part cement, two parts sand, and three parts gravel are commonly used with up to six gallons of water. When a tremie pipe is used to place the concrete, the gravel size should not be greater than 1/3 the inside diameter of the tremie pipe. Concrete may be used in all geologic formations but should never be used below the static water level in the well or boring. Concrete is generally used where extra strength or bulk are required.

(4) **Bentonite** grout is a mixture of bentonite (API Standard 13A) and water in a ratio of not less than one pound of bentonite per gallon of water. Bentonite grout should not be used where it will come in contact with water having a pH below 5.0 or a total dissolved solids concentration greater than 1,000 mg/l, or both.

The advantages and disadvantages of cement-based grouts and bentonite-based grouts are summarized below;

(1) Cement-Based Grouts:

(a) Advantages

- suitable for most types of geologic formations
- easily mixed and pumped
- hard, positive seal; sets up like concrete

- properties can be altered with additives
- proven effective over decades of use

(b) Disadvantages

- mix water must contain less than 500 mg/l of total disolved solids
- separation of constituents (can be overcome by using correct proportion of water to cement)
- high density results in loss to formations
- shrinkage (can be overcome by adding bentonite to the cement slurry)
- saline groundwater may cause flash set
- long curing time
- prompt equipment cleanup essential

(2) Bentonite-Based Grouts:

(a) Advantages

- suitable permeability with high solid grouts
- non-shrinking
- low density
- no curing time required

(b) Disadvantages

- Usage instructions vary with each bentonite product
- difficult mixing
- premature swelling and high viscosity result in difficult pumping
- subject to washout in fractured bedrock
- equipment cleanup difficult
- high density results in loss to formations
- shrinkage (can be overcome by adding bentonite to the cement slurry)
- prompt equipment cleanup essential

Placement of Plugging Materials

The plugging materials should be introduced at the bottom of the well or boring and placed progressively upward to a level approximately four feet below the ground surface. Sealing materials should never be poured from the land surface into the well, borehole, or annular space being sealed because bridging may occur at depth, causing the plug to be discontinuous. An improperly plugged well or boring can be as much of a threat to groundwater quality as an unused open well or boring.

Methods of placement that utilize a grout pipe or tremie tube, either with or without a grout pump, are recommended. To avoid breaking the seal, however, it is important to ensure that the discharge end of the grout pipe or tremie tube is submerged in grout at all times during the placement procedure. Although dump bailers are generally not recommended for placing sealing materials, they may be appropriate when plugging a dug well. Regardless of the method of placement used, care should be taken to prevent segregation or dilution of the sealing materials. When neat cement or cement grout is used, it should be placed in one continuous operation. It should be noted that when bentonite based grout is used, it should be capped by at least six feet of neat cement terminating four feet below the ground surface. The neat cement cap reduces the potential for desiccation cracks in the seal. When the original well seal is inadequate and the casing has been perforated, rather than removed, the well should be pressure grouted in order to ensure that the plugging materials will fill the annular space outside the casing. The entire screened or perforated section of a gravel packed well should also be

pressure grouted so that the plug extends into the gravel pack materials. When it is necessary to
use pressure grouting, the pressure should be maintained for the length of time that is necessary for the grout to set.

In situations where casing is removed from a well constructed through an unconsolidated formation, it is necessary to introduce the plugging material into the bottom of the hole as the casing is removed. This prevents an excessive amount of material from collapsing into the space at the bottom of the hole. It is recommended that the casing be removed in one to two foot increments followed immediately by pressure grouting of the space at the bottom of the hole.

It should be noted that the entire uncased portion of a bedrock well should be plugged.

When zones of lost circulation are encountered when plugging a well or boring that penetrates highly fractured bedrock or cavernous limestone, it is recommended that the grout be pumped until it is certain that it is being lost to the formation. Grouting should then be stopped and the material that has been placed should be allowed to set. Generally, three hours is sufficient time for the grout to set. If grout continues to be lost when placement resumes, three-eighth-inch to one-half-inch diameter pea gravel may be inserted, judiciously, from the surface while simultaneously inserting grout through the tremie pipe. The pea gravel, which floats on top of the cement, should restrict the flow of grout into the formation enough to permit completion of the plugging operation.

For wells completed in artesian aquifers, it is important to ensure that the groundwater is confined to the aquifer in which it occurs. In order to prevent surface or subsurface leakage from the artesian zone, it is recommended that the entire zone be pressure grouted using neat cement. The remainder of the well or boring may be grouted with or without pressure, as warranted by conditions. Flowing artesian wells that are not contained by existing casing should be made static before plugging. For wells in which the hydrostatic pressure producing the flow is relatively low, the well casing may be extended high enough above the artesian pressure surface to stop the flow. For wells in which extension of the casing is not feasible, flow may be restricted by placing an inflatable packer at the bottom of the confining formation immediately above the artesian zone. After the artesian zone has been grouted, the packer should be deflated and removed prior to plugging the remainder of the well. Flow may also be contained by introducing high-specific-gravity fluids at the bottom of the well or boring and filling the hole with fluids until flow ceases. Specific procedures for this method vary with the depth and artesian pressure of the well or boring.

When plugging standard type dug wells, the cover and upper four feet of curbing should be removed before placement of the plugging materials. The curbing may be caved into the well, but only when it is done in a manner that will not prevent any blockage of plugging materials part
way down the well. It is recommended that a dump bailer be used to place the plugging materials below the water table in a standard type dug well. The remainder of the well, above the water table, may be plugged using either a dump bailer or a tremie pipe. Use of a dump bailer is not recommended, however, for plugging dug wells constructed with a buried slab.

Surface Seal

In order to allow time for settlement of the plugging materials, the contractor should emplace the surface seal no sooner than 24 hours after the well or boring has been plugged. Before the surface seal is placed, casing remaining in the hole should be cut off. The remaining four feet at the top of the well or boring should then be filled with concrete and the top of the seal
formed so as to create a concrete slab above the top of the plugged well or boring. This concrete slab should be at least six inches thick and should be at least two feet greater in

diameter than the well casing or borehole wall.

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GLOSSARY

Unless the context or subject matter requires otherwise, the following words and phrases shall, for the purposes of this document, have the meanings specified in this section.

Words and phrases used in the present tense include the future; words and phrases used in the masculine gender include the feminine and neuter; and the singular number includes the plural and the singular.

Words and phrases not defined in this section shall have their conventional meanings unless expressly stated otherwise.

Abandoned water well means a well that meets any of the following criteria: (1) construction was terminated prior to completion of the well, (2) the well owner has notified the local Board of Health that use of the well has, after extended use, been permanently discontinued, (3) the well has been out of service for at least three years, (4) the well is a potential hazard to public health or safety and the situation cannot be corrected, (5) the well is in such a state of disrepair that its continued use is impractical, or (6) the well has the potential for transmitting contaminants from the land surface into an aquifer or from one aquifer to another and the situation cannot be corrected.

Alteration means a major change in the type of construction or configuration of a private water system, including but not limited to, adding a disinfection or treatment device, converting a water well with a buried seal to a well with a pitless adapter, extending a distribution system, converting a well using a well pit to a well with a pitless adapter, extending the casing above ground; deepening a well, changing the type of pumping equipment when that requires making new holes or sealing or plugging existing holes in the casing or wall of a well, and repairing, extending or replacing any portion of the inside or outside casing or wall.

Annular space means the space between two cylindrical objects, one of which surrounds the other. For example, the space between the wall of a drillhole and a casing pipe, or between an inner and an outer well casing.

API means American Petroleum Institute.

Aquifer means a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian aquifer means an aquifer that is bounded above and below by impermeable materials or materials of distinctly lower permeability than the aquifer itself. The water in an aquifer confined in this manner will rise in a drilled hole or well casing above the point of initial penetration (above the bottom of the confining, or impermeable, layer overlying the aquifer).

Artesian well means a well producing from an artesian aquifer. The term includes both flowing wells and nonflowing wells.

ASTM means American Society for Testing and Materials.

AWWA means American Water Works Association.

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Bedrock see "Consolidated formation”.

Bentonite means a mixture of swelling clay minerals containing at least eighty-five percent of the mineral montmorillonite (predominantly sodium montmorillonite) which meets the specifications of the most recent revision of API Standard 13A.

Bentonite grout means a mixture of bentonite (API Standard 13A) and water in a ratio of not less than one pound of bentonite per gallon of water.

Casing means an impervious durable pipe placed in a boring to prevent the walls from caving and to serve as a vertical conduit for water in a well.

CMR means *Code of Massachusetts Regulations.*

Community water system means a public water system which serves at least fifteen (15) service connections used by year-round residents or regularly serves at least twenty-five (25) year-round residents.

Concrete means a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, gravel, and water in a proportion of not more than five parts of sand plus gravel to one part cement, by volume, and not more than six gallons of water. One part cement, two parts sand, and three parts gravel are commonly used with up to six gallons of water.

Confined aquifer means an aquifer in which the groundwater is under pressure greater than atmospheric pressure: the static water level in a well tapping a confined aquifer rises to a level above the top of the aquifer.

Confining bed means a layer or body of soil, sediment, or rock with low vertical permeability relative to the adjacent aquifers above or below it.

Consolidated formation means any geologic formation in which the earth materials have become firm and coherent through natural rock forming processes. The term is sometimes used interchangeably with the word "bedrock" and includes, but is not limited to, basalt, granite, limestone, sandstone, and shale. An uncased drillhole will normally remain open in these formations.

Contaminant means any physical, chemical, biological, or radiological substance or matter in water.

Contamination means the presence of any physical, chemical, biological, or radiological substance or matter in water at a concentration and for a duration or anticipated duration which, in the opinion of the regulating agency, would present a threat to the public health, using existing federal and state standards and guidelines where applicable.

Cross connection means any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water and the other water of unknown or questionable safety, whereby water may flow from one system to the other, the direction of flow depending on the pressure differential between the two systems.

Curbing means either precast or poured-in-place, concrete well casing used to construct dug wells.

Domestic water supply means "private water supply."

Drawdown means the difference between the static and pumping water levels.

Drilled well means a well in which the hole is excavated using mechanical means such as rotary, cable tool, or auger rigs.

Drive shoe means a forged or tempered steel collar, with a cutting edge, attached to the lower end of a casing by threading or welding, to protect the lower edge of the casing as it is driven.

Flushing means the act of causing a rapid flow of water from a well by pumping, bailing or similar operation.

Formation means an assemblage of earth materials grouped together into a unit that is convenient for description or mapping.

Groundwater means subsurface water in the zone of saturation.

Grout means a stable impermeable bonding material which is capable of providing a watertight seal.

Grouting means the process of mixing and placing grout.

Hydrofracturing means a process whereby water is pumped under high pressure into a well to fracture the surrounding rock thereby increasing the well yield.

MGL means *Massachusetts General Laws.*

Neat cement grout means a mixture consisting of one bag (94 pounds) of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A) to not more than six gallons of

clean water. Bentonite (API Standard 13A), up to two percent by weight of cement, shall be added to reduce shrinkage. Other additives, as described in ASTM Standard C494, may be used to increase fluidity and/or control setting time.
Non-community water system means a public water system that is not a community water system.
Overburden see "Unconsolidated formation.
Person means an individual, corporation, company, association, trust, partnership.
Pitless adapter means a commercially manufactured device which attaches to a well casing and provides watertight subsurface connections for suctions lines or pump discharge and allows vertical access to the interior of the well casing for installation or removal of the pump or pump appurtenances.
Private water supply means a system that provides water for human consumption, if such system has less than fifteen (15) service connections and either (1) serves less than twenty-five individuals or (2) serves an average of twenty-five (25) or more individuals for less than sixty (60) days of the year.
Private water system means "private water supply."
Public water system means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen (15) service connections or regularly serves an average of at least twenty-five (25) individuals daily at least sixty (60) days of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such a system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" or a "non-community water system."
Pumping test means a procedure used to determine the characteristics of a well and adjacent aquifer by installing and operating a pump.
Registered well driller means any person registered with the Department of Environmental Management/Division of Water Supply Protectionto dig or drill wells in the Commonwealth of Massachusetts.

Sand cement grout means a mixture consisting of Portland cement (ASTM Standard C150, Type I or API Standard 10, Class A), sand, and water in the proportion of one part cement to three or four parts sand, by volume, and not more than six gallons of water per bag (94 pounds) of cement. Up to five percent, by weight, of bentonite (API Standard 13A) shall be added to reduce shrinkage.
Septic tank means a watertight receptacle which receives the discharge of sewage from a building sewer and is designed and constructed so as to permit the retention of scum and sludge, digestion of the organic matter, and discharge of the liquid portion to a leaching facility.
Static water level means the level of water in a well under non-pumping conditions.
Structure means a combination of materials assembled at a fixed location to give support or shelter, such as a building, framework, retaining wall, fence, or the like.
Surface water means water that rests or flows on the surface of the Earth.
Thermoplastic casing means ABS (acrylonitrile-butadiene-styrene), PVC (poly-vinyl chloride) or SR (styrene rubber) casing specified in the most recent revision of ASTM Standard F480.
Tremie pipe means a device, usually a small diameter pipe, that carries gravel pack or grouting materials to the bottom of a drillhole or boring and which allows pressure grouting from the bottom up without introduction of appreciable air pockets.
Unconfined aquifer means an aquifer in which the static water level does not rise above the top
of the aquifer.
Unconsolidated formation means any naturally occurring uncemented, unlithofied material

such as sand, gravel, clay, or soil.
Water table means the upper surface of the zone of saturation in an unconfined formation at which the pressure is atmospheric.
Watertight means a condition which does not allow the entrance, passage or flow of water or other fluids under normal operating conditions.
Watertight casing means a water well casing that has a wall thickness of 1/8 inch or more, has no seams or has welded seams, and has sections that can be joined together by watertight threads, by a weld, rubber gasket, or by cement that is not limestone or clay based that seals the well against the entrance of surface water into the groundwater.
Watertight construction means cased and grouted construction through firm formations like clay or rock. Through granular material like sand or gravel, it means that the casing pipe is of approved quality and assembled watertight.
Well development means a procedure consisting of the removal of fine sand and drilling fluid from the water bearing sand, gravel, or rock materials opposite the well screen.
Well vent means an outlet at the upper end of a well casing or basement end of a non-pressure conduit to allow equalization of air pressure in a well but at the same time so constructed as to prevent entry of water and foreign material into the well.
Yield means the quantity of water per unit of time which may flow or be pumped from a well under specified conditions.
Zone of saturation means the zone below the water table in which all interstices are filled with groundwater.

REFERENCES CITED

American Water Works Association, 1984, *AWWA Standard for Water Wells,* AWWA A1OO-84, Denver, CO, 75 p.
Driscoll, F.G., 1986, *Groundwater and Wells,* 2nd Ed., Johnson Division, St. Paul, MN, 1089 p.
Frimpter, M.H., 1985, "Massachusetts: Ground-Water Resources," *in* U.S. Geological Survey, 1985, *National Water Summary 1984: Hydrologic Events, Selected Water-Quality Trends, and Ground-Water Resources,* U.S. Geological Survey Water Supply Paper 2275, Denver, CO.
Johnson, E.E., Inc. 1966, *Ground Water and Wells,* Edward E. Johnson, Inc., St. Paul, MN, 440 p.
Midwest Plan Service, 1979, *Private Water Systems Handbook,* Midwest Plan Service, Ames, Iowa, 73 p.
Noake, K., 1988, *Guide to Contamination Sources for Wellhead Protection,* U. S. Dept. of Commerce, National Technical Information Service, Springfield, VA, 75 p.
Salvato, J.A., Jr., 1958, *Environmental Sanitation,* John Wiley & Sons, Inc.
U.S. Department of Health, Education, and Welfare, Public Health Service, 1965, *Recommended State Legislation and Regulations,* Washington, D.C.
U.S. Environmental Protection Agency, 1975, *Manual of Water Well Construction Practices,* EPA 570/9-75-001, Office Water Supply, Washington, D.C., 156 p.
U.S. Environmental Protection Agency, 1973, "Manual of Individual Water Supply Systems," EPA
430/9-74-007, Office of Water Programs, Water Supply Division, Washington, D.C. *in* E.G. Driscoll, 1986, *Groundwater and Wells,* MN, 1089 p.
Wisconsin, State of, 1985, "Wisconsin Administrative Code NR 112, *"Wisconsin Register,"* no. 358.