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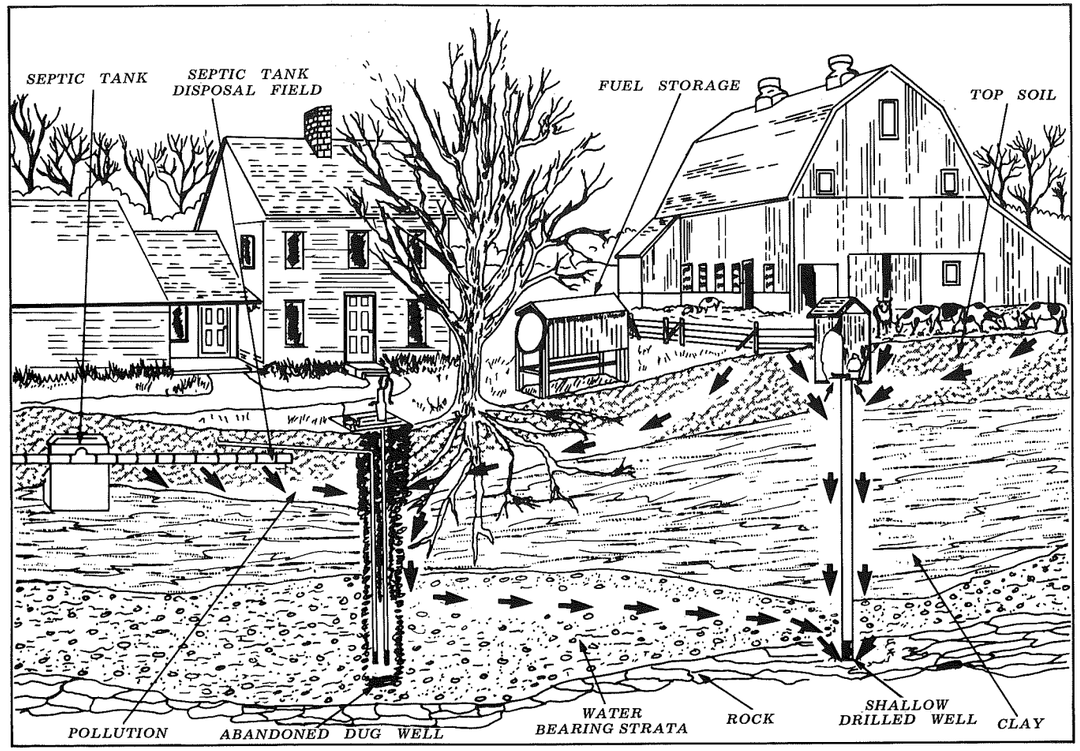
GROUTING AND PLUGGING OF DOMESTIC WATER WELLS IN GEORGIA



DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

CIRCULAR 13

Editor: Patricia Allgood

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GROUTING AND PLUGGING OF DOMESTIC WATER WELLS IN GEORGIA

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CIRCULAR 13

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INTRODUCTION

The State of Georgia is blessed with an abundance of fresh and clean ground water. Incidents of ground-water pollution have been rare and isolated. Nevertheless, beginning in the late 1950's and continuing to the present, Georgia has experienced population growth substantially in excess of the national average. While most of the population is served by municipal drinking water supplies, a considerable portion relies on domestic wells for drinking water. Domestic wells, if properly constructed, can provide a safe and reliable source of water. Improperly constructed wells and abandoned wells, on the other hand, can provide significant pathways (e.g., drains) for pollutants to enter the ground-water regime.

Figure 1 illustrates how a domestic well can act as a drain and draw pollutants down into an aquifer.* In this illustrated case, motor oil dripping from a leaking automobile crankcase is transported by rainfall runoff to the vicinity of an improperly constructed well and then down the well to the water table. Another example is illustrated in Figure 2. Here agricultural chemicals applied to a field migrate down an abandoned well, contaminating a nearby municipal water supply well.

The most effective methods for preventing domestic wells from becoming pollutant pathways are:

(1) properly grouting the well casing in new wells; and
(2) properly plugging abandoned wells.

Grouting the well casing involves filling the annular space between the casing and the drilled hole with a suitable slurry of cement or clay. Plugging involves injecting a cement or clay slurry into the well so that the aquifer is sealed from surface and near-surface sources of pollution.

With the above in mind, the purpose of this circular is to provide information to Georgia's general public on the need for grouting water wells and plugging abandoned water wells. The circular also describes grouting and plugging methods commonly employed in drilling domestic water wells in Georgia. For a more comprehensive discussion of both grouting and plugging, the reader is referred to the latest edition of *Groundwater and Wells* by Fletcher G. Driscoll (St. Paul, Minnesota: Johnson Division, 1986).

Legal Requirements

The Georgia Water Well Standards Act of 1985 requires that all new water wells be grouted and all abandoned wells be plugged. Specifically, the Act states:

> A well having an open annular space between the casing and borehole shall be grouted and shall be filled with neat or sand-cement grout or other impervious material to prevent the entrance of pollutants or contaminants to the well. The following shall be considered minimum depths of seal below ground surface:
>
> (i) Individual wells - ten feet
> (ii) Nonpublic wells - 25 feet in igneous or metamorphic rock
> (iii) Nonpublic wells - 50 feet in sedimentary rock
> (iv) Irrigation wells - 20 feet
>
> For large diameter water wells (e.g., bored wells) cased with concrete pipe or other acceptable casing material, if the casing joints are not sealed, the annular space shall be grouted as specified above, and the annular space below the grout shall be filled with sand or gravel.
>
> A water well shall be considered as temporarily abandoned when its use has been interrupted for a period of more than one year and not more than three years. Such a well shall be sealed and the well maintained whereby it is not a source or a channel of contamination or pollution when not in service.
>
> A water well shall be considered as permanently abandoned when its service has been interrupted for a period of more than three years or continued use for obtaining ground water is not practical.

The Act also requires that all of the above activities be performed by a water well contractor licensed to practice in Georgia.

The owner of the well also shall construct a watertight concrete pad, at least four inches thick, extending at least two feet in all directions from the well casing, and sloping away from the casing. Normally, a water well contractor performs this service for an additional fee. The construction of this protective pad, however, is clearly the owner's responsibility and not the well driller's.

There are two legal points that are important. Firstly, the water well contractor is required to grout the annular space between the well casing and hole. The contractor has no option; if the contractor fails to grout, the contractor's license could be revoked. The owner of an abandoned well, on the other hand, has the responsibility for plugging abandoned wells. While well plugging must be performed by a licensed water well contractor, it is **not** the contractor's responsibility to perform plugging. This latter point often results in the owner being required to plug a dry hole.

Any improperly constructed or abandoned water well that provides a pathway for surface runoff to enter the ground-water regime also is a drainage well and legally

*An aquifer is a geologic formation that yields water in sufficient quantity to be economically useful. The geologic formation, whether it be soil or rock, must contain interconnected pores or open spaces that are filled with water.

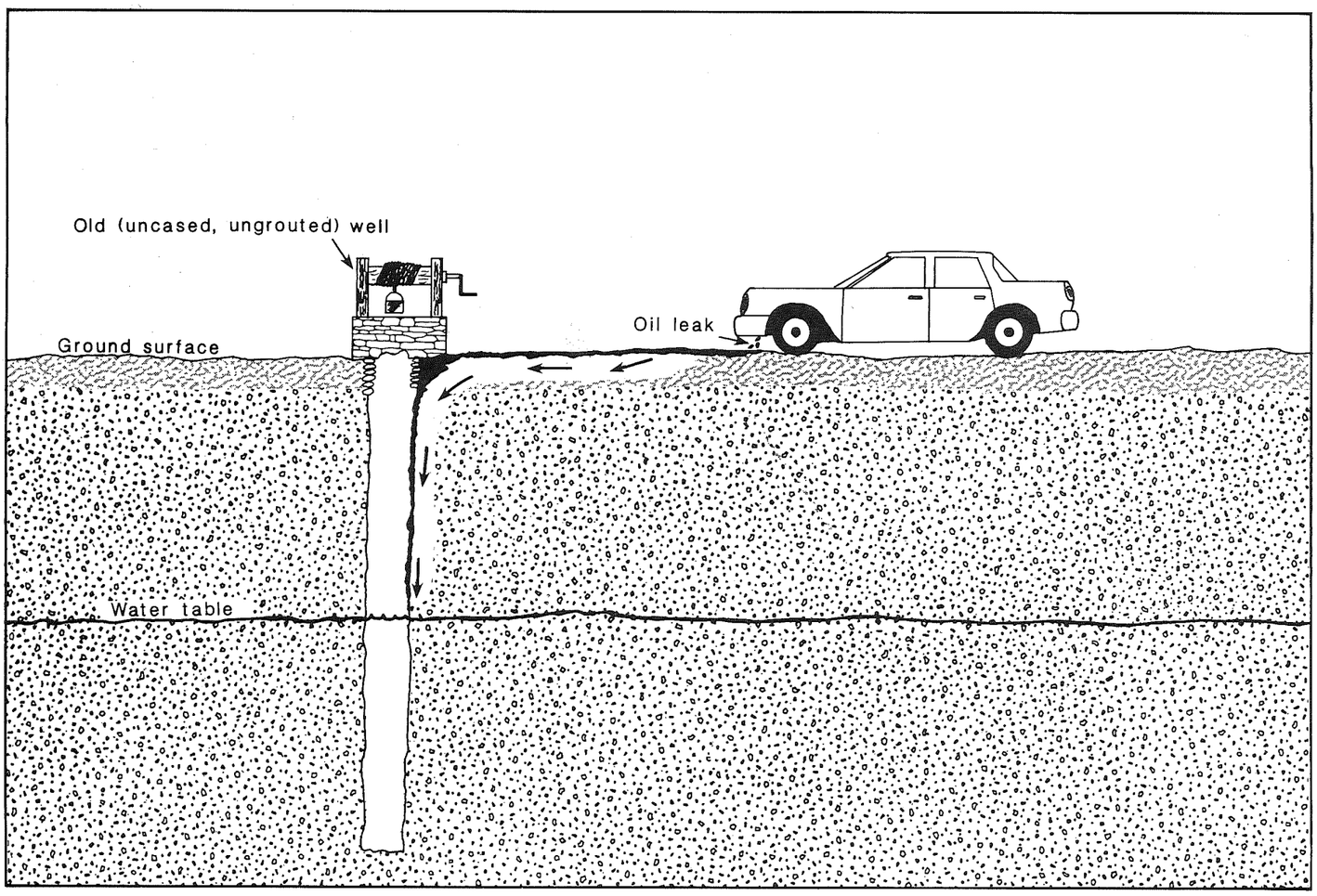

Figure 1. Motor oil entering improperly constructed well.

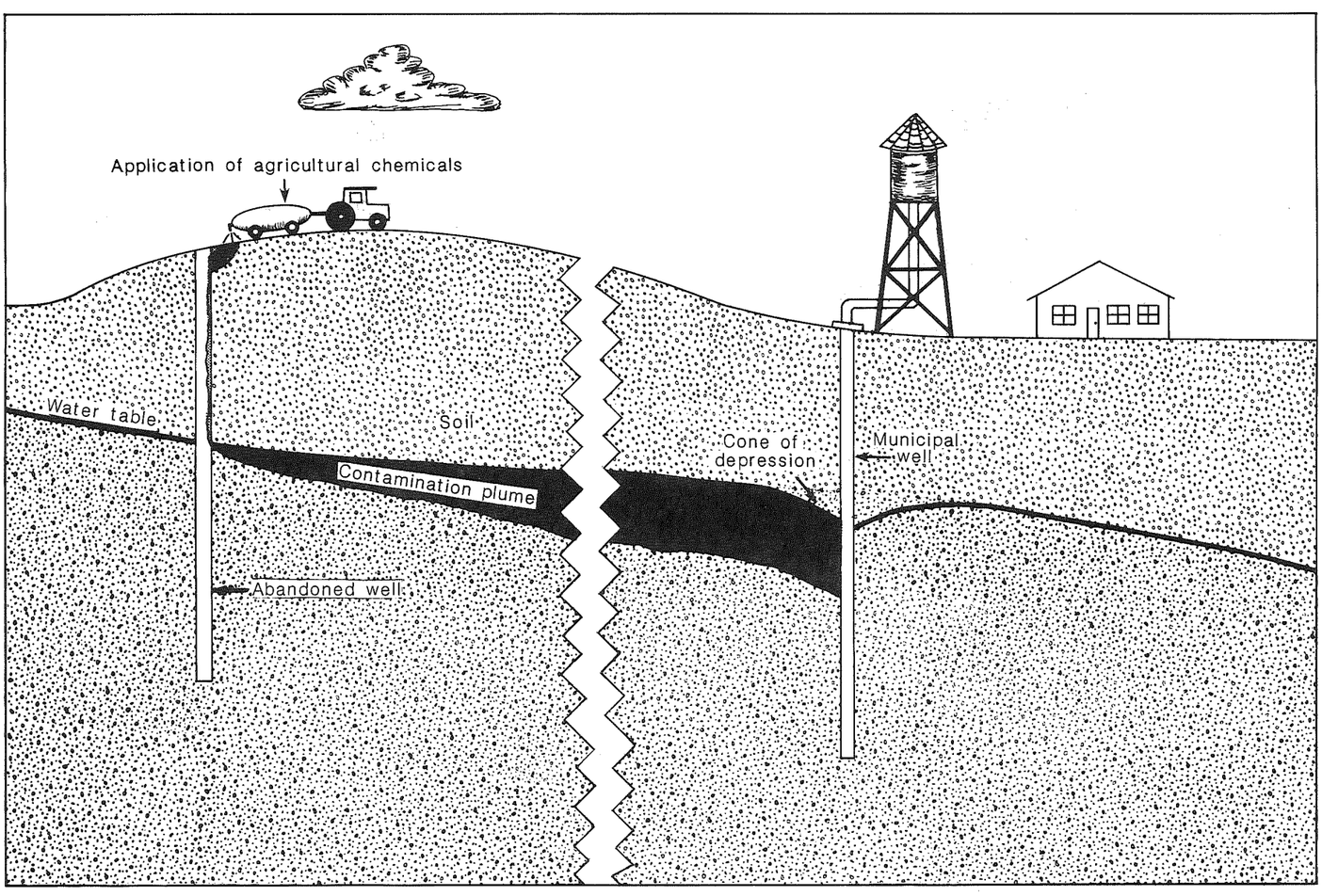

Figure 2. Agricultural chemicals reaching a municipal well via an abandoned well.

regulated as part of the Underground Injection Control (UIC) Program under Part C of the Federal Safe Drinking Water Act (Section 1426 of the Safe Water Drinking Act as amended, 42 U.S.C. 300 h-5). The law defines injection, quite simply, as the subsurface emplacement of fluids. This means that any surface runoff flowing down a well is an "injected fluid." Moreover, any such well that provides a drain for surface runoff to migrate to an aquifer is to be considered as a Class V injection well.

The Environmental Protection Division (EPD) of the Georgia Department of Natural Resources has been authorized by the U.S. Environmental Protection Agency (EPA) to administer the UIC Program in Georgia. In this regard, EPD takes the position, that while there are no documented cases in Georgia of ground-water pollution from drainage wells, the danger of ground-water pollution from drainage wells is significant; therefore, such wells should not be permitted.

GROUTING (Adapted from Driscoll, 1986)

Grouting is the process of forcing a slurry, typically cement or bentonite, into the annular space around well casings and the crevices, cracks or other voids in subsurface rocks. The pressure employed to force the grout into place may be either gravity or pump pressure.

Each year the Geologic Survey Branch of EPD attempts to resolve complaints between the owners of domestic wells and water well contractors. In many cases, these complaints are directed toward problems of "dirty water," which usually can be attributed to poorly or inadequately grouted wells. While the Water Well Standards Act of 1985 requires that all domestic wells have a **minimum** of ten feet of grout, more extensive grouting is usually necessary to protect the well and/or increase the well's useful life expectancy. In some cases, for example in Glynn County, an excess of 500 feet of grouted casing is appropriate. Recommended grouting depths in Georgia are as follows (see Figure 3):

(1) North Georgia - from ground surface to top of rock

(2) South Georgia -
   (a) Dougherty Plain - from ground surface to top of limestone,
   (b) Recharge region - from ground surface to at least ten feet below the water table
   (c) Floridan Aquifer Region - from ground surface to top of limestone

There are, however, numerous exceptions to the above recommendations.

Experienced well drillers generally can provide recommendations appropriate to local conditions. Obviously, the greater the volume of grout placed in a well, the greater will be the construction costs. The owner of the well should discuss this matter with the water well contractor so that the costs incurred by additional grout are commensurate with the increased health and safety benefits.

Regretfully, well grouting in Georgia often has involved little more than concrete being hand mixed at the well site and then shoveled down the annular space between the well casing and the borehole. In some cases, the well driller may arrange for a cement truck to drive up to the site and "pour" cement/concrete into the annular space. Since neither of these two methods is adequate for preventing voids (resulting from collapse of earth or rock into the borehole or from cement bridging), EPD does not recommend that these methods be used. The well owner should clearly understand that such methods may have limited success.

The grouting methods as described by Driscoll focus primarily on the use of cement and water (neat cement), although in certain situations the slurry may contain sand, bentonite, hydrated lime, or well cuttings. (The Georgia Water Well Standard Advisory Council has taken the position that well cuttings are not acceptable for grouting materials except when they have been admixed with cement.) In fact, geologists and engineers prefer a bentonite-cement slurry as this mixture is somewhat plastic and can tolerate slight movement of the casing without cracking. "A clay slurry, made with a high-grade bentonite without cement, can also serve for grouting — provided it is used at a depth where drying and shrinking of the grout will not occur and where water movement will not wash away the clay particles. Synthetic materials, such as polymers, may be used as grouting materials; but their low solids content and shrinkage, if dried, make them less suitable for sealing wells."

When using portland cement, an acceptable ratio of water to cement is 4-6 gallons of water per 94-pound bag of cement. Excess water causes shrinking and settling of the cement while less water will not hydrolyze the cement. This recommended ratio produces a mixture which is especially effective in bridging the pores of permeable formations, while also preventing excessive penetration of the grout into those formations.

Bentonite is often added by Georgia drillers to improve handling and reduce shrinkage, in which case the quantity of water may be increased by about 10 percent. The amount of bentonite added will usually vary between 3 to 5 pounds per sack of cement. Bentonite minimizes settling out of the cement particles and serves to extend the time during which the slurry can be pumped.

Driscoll also points out, "that water used for grout should be free of oil and other organic material. Salty or brackish water should not be used; dissolved minerals should be less than 2,000 parts per million. High sulfate content is particularly undesirable. Grout should be thoroughly mixed and free of lumps. If the mixture is purchased from a ready-mix concrete plant, the correct

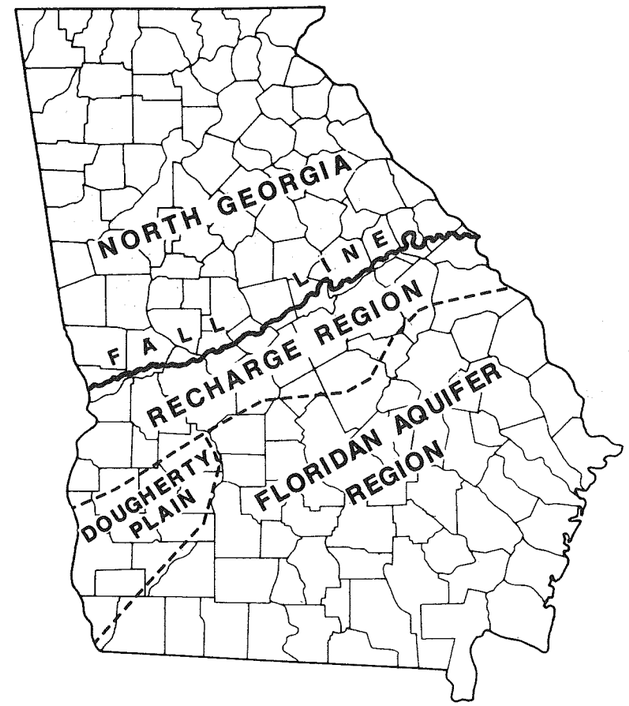

Figure 3. Recommended grout thicknesses.

(A) North Georgia - from ground surface to top of rock

(B) South Georgia -
   — Dougherty Plain - from ground surface to top of limestone
   — Recharge Region - from ground surface to at least ten feet below the water table
   — Floridan Aquifer Region - from ground surface to top of limestone

proportions should be assured. To avoid stones and lumps of concrete, the driller should insist that delivery trucks be thoroughly cleaned between batches when the grout is going to be delivered to the drill site."

Equipment for mixing and placing cement grout need not be elaborate for domestic water well work. Using a centrifugal pump, the grout often can be pumped from the drilling rig's "mud pan" or from 55-gallon drums. The chemical reaction that causes grout to set and harden begins as soon as cement and water are mixed. This means that the equipment used to mix and place the grout must be adequate to complete the installation while the grout is still fluid. Some larger water well contractors use a small portable grouting machine that combines both mixing and pumping operations. According to Nye (1987), licensed water well contractors seldom use the drilling equipment mud pump for grouting with cement because of the difficulty in cleaning and the fear of clogging the mud pump. A separate pump is generally designated for grouting use.

"The size of the annular space required for grouting depends on the method of grouting (Driscoll, 1986). It is very difficult to properly grout a well if the annular space is too small. The annular space to be grouted should have a diameter that is 4 to 8 inches larger than the casing. The grout should form a uniform sheath around the casing. Tight places and "dead spots" can result where casing, not properly centered, touches the wall of the hole, causing channeling of the slurry. [Moreover] the volume of grout required cannot always be determined accurately. Irregularities in the size of the borehole and losses into fractured rock occur in many wells. Therefore, the driller must be prepared to augment initial estimates of grout volume on short notice." In Georgia, it is expected that the volume of grout introduced into the annular space will be adequate to reach the surface. That is, regardless of whether the grout is pumped upward from the base of the casing or "poured" or pumped from the surface downward, there should be a grout "spill-over" directly at the surface.

There are two acceptable methods of grouting with variations to each method. This circular, however, will describe only a few variations, leaving the details to the preference and convenience of the owner and water well contractor.

The two basic grouting methods are:

(1) tremie pipe grouting methods and

(2) casing grouting methods.

The tremie pipe method involves using a small diameter pipe (commonly a 1 or 1-½-inch diameter galvanized steel or plastic pipe), either outside or inside the casing. The casing method involves filling the casing with grout and; then, using a plug to force the grout out of the bottom of the casing string, upward through the annular space, back to the surface.

As shown in Figure 4, grout can be placed through a tremie pipe outside the casing. The casing is carefully lowered into the hole and centered (often with centering guides). While grout can be placed by gravity through the tremie pipe, pumping is preferred because the required volume of grout can be introduced rapidly with little chance of leaving voids or open spaces in the grout. Typically the tremie is raised as the annular space fills with grout.

When the use of a tremie pipe outside the casing is not practical, grouting may be done by using a tremie pipe (temporarily) installed within the casing (Figure 5). Here a cementing plug (called a float shoe) is attached to the bottom of the casing, which allows the grout to enter the annular space but prevents it from leaking back into the casing (Driscoll, 1986). For the inside method, the casing is filled with water or drilling fluid, and grout is pumped through the float shoe and forced upward around the casing to the surface.

In the casing method of grouting, the slurry is forced down the casing into the annular space. There are several variations to this methodology. In one method, two spacer plugs* are used. The first plug introduced separates the slurry from the drilling fluid in the casing; the other separates the slurry from water pumped in above it to wash the slurry from the casing (Driscoll, 1986). "After pumping water or drilling fluid through the casing to circulate fluid in the annular space and clean any obstructions from the hole, the first plug is inserted and the casing capped. A measured volume of grout is then pumped in; the casing is opened; a second plug is inserted; and the casing is recapped. A measured volume of water is [next added, pushing the plug] to the bottom of the casing, forcing most of the cement slurry from the casing and into the annular space. The water in the casing is held under pressure to prevent backflow of the slurry until it has set and hardened. When the cement has hardened sufficiently, the [two plugs and any cement remaining in the casing are drilled out; drilling is continued into the formation below the grouted section, (Figure 6). A modification of the above procedure is used by some drillers.] After pumping a predetermined quantity of grout into the casing, a single plug is installed on top of the grout and enough water is added to force most of the grout from the casing."

A third technique is often employed in Georgia. In this case, the casing if filled with cement, and a plug is attached to the end of the drill rods. The drill rods are then inserted into the hole with the cement slurry being forced upward into the annular space (Figure 7).

*Spacer plugs insure that there is separation between the cement slurry and water. Plugs typically are made of material that can easily be drilled out; such as, cement.

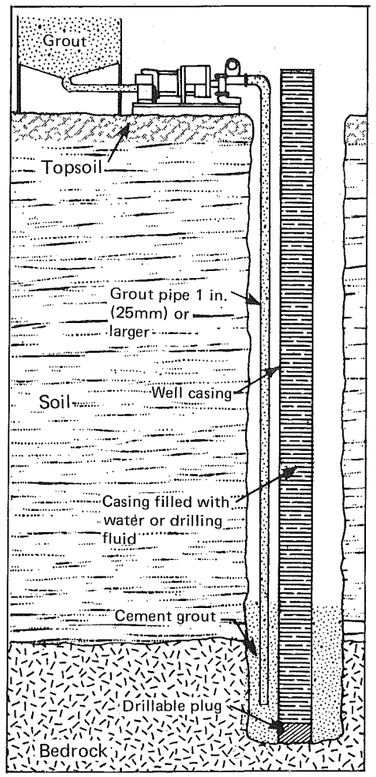

Figure 4. Outside tremie pipe grouting method. (From Driscoll, 1986)

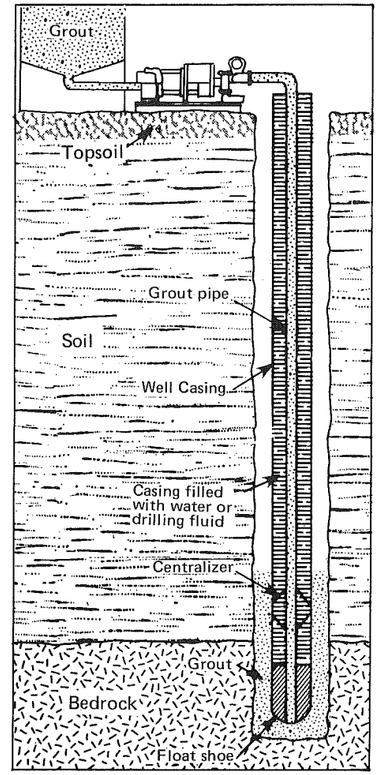

Figure 5. Inside tremie pipe grouting method. (From Driscoll, 1986)

After the grout slurry has been introduced into the well bore, the mixture begins to harden or "set-up." While the actual set-up time varies with the cement-to-water ratio, most Georgia drillers discontinue activities at the well site "overnight," as soon as grouting has been completed. The reason for this is that continued drilling activities would agitate the grout, possibly cracking the partially hardened slurry.

"Several factors may contribute to grouting failures (Driscoll, 1986). Some common problems are premature setting, partial setting, insufficient grout, voids or gaps in the grout, excessive shrinkage, and collapse of soil and/or rock around the casing. Premature setting of the cement can be a serious problem and is usually caused by incorrect

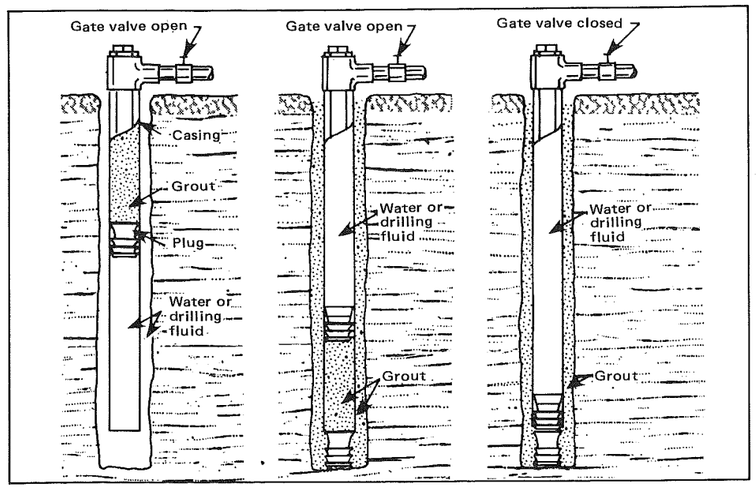

Figure 6. Casing method of grouting. (From Driscoll, 1986)

assumptions concerning borehole temperature, hot mixing water, improper water-to-cement ratios, contaminants in the mixing water, mechanical failures, or interruptions of the pumping operation. Voids within the grouted annulus, another major grouting problem, usually are caused by contact of the casing with the borehole wall or by the pressence of washouts."

The grouting of bored wells is relatively simple. Typically these wells are shallow, rarely exceeding a depth of 100 feet (Figure 8). Bored wells are usually constructed by using a bucket auger to excavate material. The bucket auger consists of a relatively large-diameter bucket with a cutting edge on the bottom which is slowly rotated by a square kelly bar or drill stem. When the bucket fills with the cuttings it is brought to the surface and emptied. Once the hole is drilled, pipe is installed to serve as casing and the annular space is grouted to a depth of at least ten feet below the ground surface. Because the grouted portion of the well is relatively short (e.g., 10 to 20 feet), well drillers usually just pour the cement or concrete into the annular space.

WATER WELL PLUGGING

(Adapted from Driscoll, 1986)

Properly constructed water wells normally are not sources of ground-water pollution. However, as a well falls into a state of disrepair, casings and screens begin to corrode and the well can become a conduit through which pollutants can travel vertically through the borehole. These open holes permit water to migrate freely from the surface into an aquifer or from one aquifer to another. Clean water may thus be contaminated by water from a polluted aquifer or from polluted surface water.

There are four ways ground-water resources or human health can be impaired by failing to properly plug an abandoned well (Gass, 1981):

(1) Polluted surface runoff may enter and travel down the casing and contaminate an aquifer. For example, wells may be abandoned in areas where reservoirs are to be constructed. As the reservoir fills, these wells are submerged. As well covers or

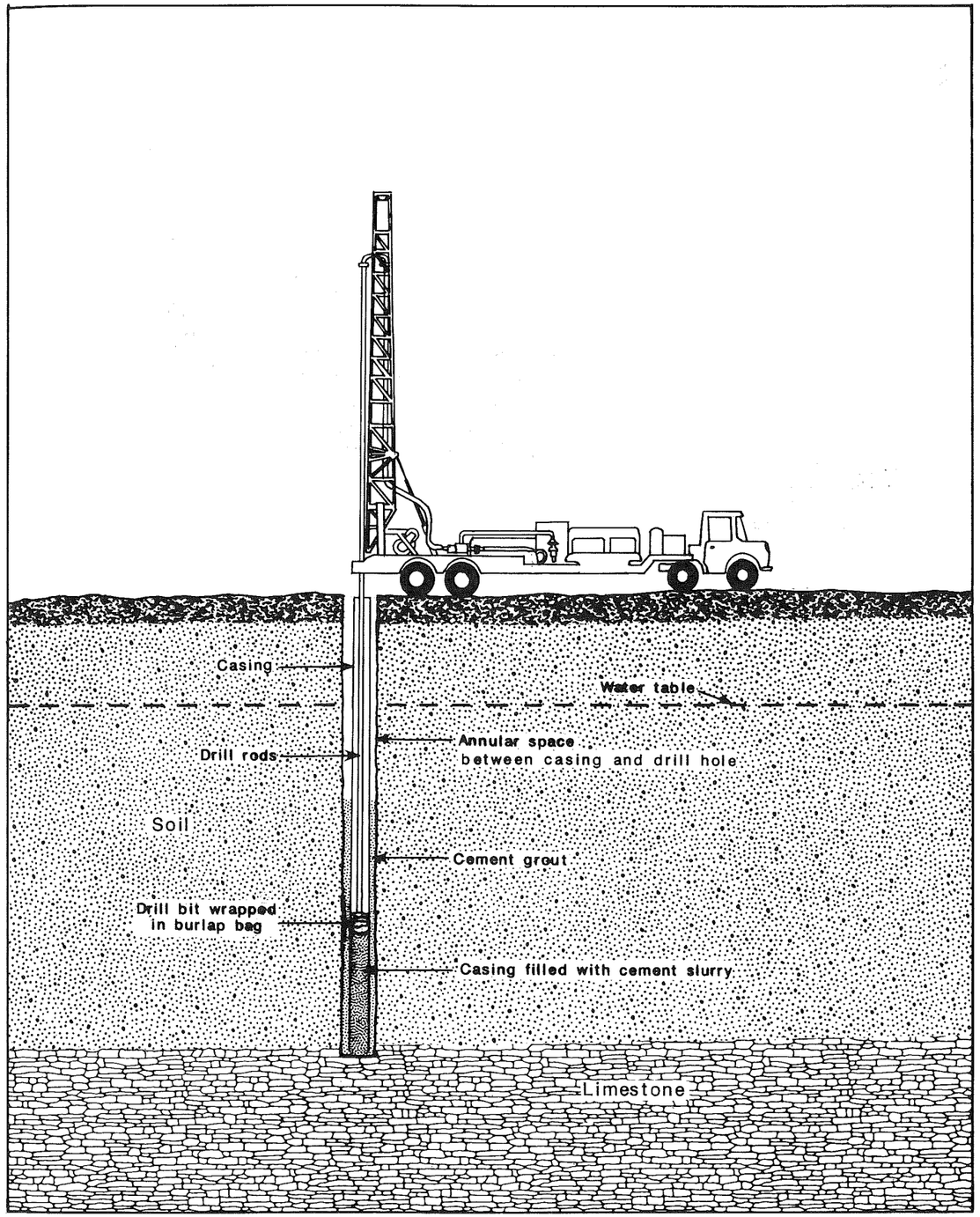

Figure 7. Casing method of grouting commonly used in Georgia.

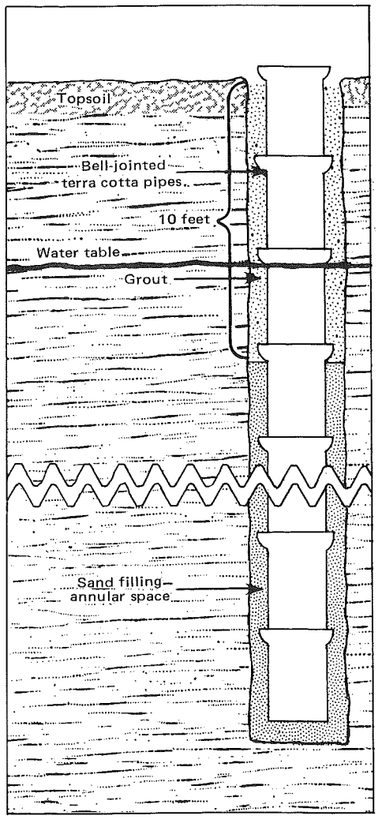

Figure 8. Typical grouted bored well.

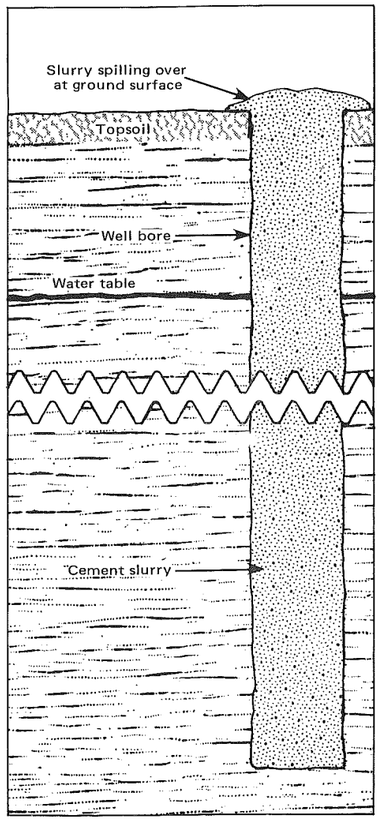

Figure 9. Sealing abandoned well in unconfined or water-table conditions.

seals corrode, the higher hydrostatic head of water in the reservoirs causes injection of often poorer quality surface water into an aquifer.

(2) Wells penetrating different formations often encounter water under different hydrostatic pressure. If the abandoned well is uncased or if the casing has corroded, then the transfer of water from one rock formation to another can cause degradation of water quality in the cleaner aquifer(s).

(3) Unplugged abandoned flowing artesian wells can result in an unnecessary loss of valuable water, reduction of regional artesian head, and localized surface flooding.

(4) Uncovered and unplugged abandoned wells represent a physical hazard to animals and human beings. There have been several instances in Georgia where children have fallen into wells and drowned.

To prevent the above, the State of Georgia enacted the Water Well Standards Act of 1985. In this regard, the Act states:

> A water well shall be considered as temporarily abandoned when its use has been interrupted for a period of more than one year and not more than three years. Such a well shall be sealed and the well maintained whereby it is not a source or a channel of contamination or pollution when not in service.
>
> A water well shall be considered as permanently abandoned when its service has been interrupted for a period of more than three years or it meets the definition of abandoned well as defined in this part. Such a well shall be filled, sealed, and plugged.
>
> Whenever a well or borehole is excavated for exploration, testing, or use as a source of water supply but is no longer used for that purpose, it shall be the owner's responsibility to have the borehole filled, sealed, and plugged within 30 days of the excavation or disuse to protect against the entrance of pollutants into the subsurface.
>
> No abandoned water well or borehole shall be used for the purpose of disposing of any wastes or pollutants that may contaminate the ground water.

"The principal objective of sealing abandoned wells is to restore, as far as possible, the original hydrogeologic conditions. Before being sealed, the well should be checked to insure that there are no obstructions that may interfere with effective sealing operations (Driscoll, 1986)." For domestic wells this typically is done either by lowering a weighted steel tape, a wire line tool, or drilling rods down the well to determine if the well is open to the total reported depth. In most cases, however, there is no information about the well to be plugged; thus, it usually is prudent to assume that the well is at least partially open below the point where the tape, tool, or drill rods cannot pass.

Hand dug or bored wells can be readily plugged by pumping a cement or cement-bentonite slurry into the well and filling the entire well bore (see discussion of grouting above for a description of recommended slurry mixtures). In some cases, if the well is relatively deep, the well may be backfilled to about five feet below the water table and then filled to the surface with a slurry.

According to Driscoll (1986), abandoning a drilled well is quite complex. "If the casing has not been grouted, it often can be removed by hydraulic jacks or by bumping the casing up using a cable tool drilling rig. A vibration hammer also can be used to remove ungrouted casing." Removal of ungrouted casing is usually necessary in order to assure an effective seal. If the casing can not be removed, then those portions of the casings opposite water-bearing zones should be perforated with a casing ripper prior to sealing to assure proper sealing throughout these zones. In all cases, the upper portion of an ungrouted casing should be removed to assure contact of the slurry with the whole well, and to form a watertight seal in the upper 10 or 20 feet. On the other hand, if the annular space around the casing was carefully grouted when the well was originally drilled, the casing need not be removed or ripped. "To seal an abandoned well properly the ground-water conditions at the site must be considered. [If] the ground water occurs under unconfined [or water-table conditions], the objective is to prevent the percolation of surface water through the well bore or along the outside of the casing to the water table. [As shown in Figure 9,] this is accomplished by [sealing] the entire well bore [(e.g. simply filling the hole with a slurry)]. When confined conditions exist, the sealing operations must confine the water to the aquifer in which it occurs. This prevents the loss of confining pressure that results from uncontrolled flow from the aquifer [(Figure 10)]. In a flowing well, [it is necessary to control the flow before placing the seal.] Flow usually can be controlled [in domestic wells] by introducing high-specific-gravity fluids to stop the flow or by extending the casing high enough above the land surface to stop the flow," or by pumping the cement slurry through a packer (Figure 11).

All domestic well plugging operations must be performed by a water well contractor licensed to practice in Georgia. These persons generally are quite knowledgeable about local hydrogeology and can make the determinations as to whether or not an abandoned well is under unconfined, confined, or flowing conditions. The owner, on the other hand, is legally required to have abandoned wells plugged, but must utilize the services of a licensed driller.

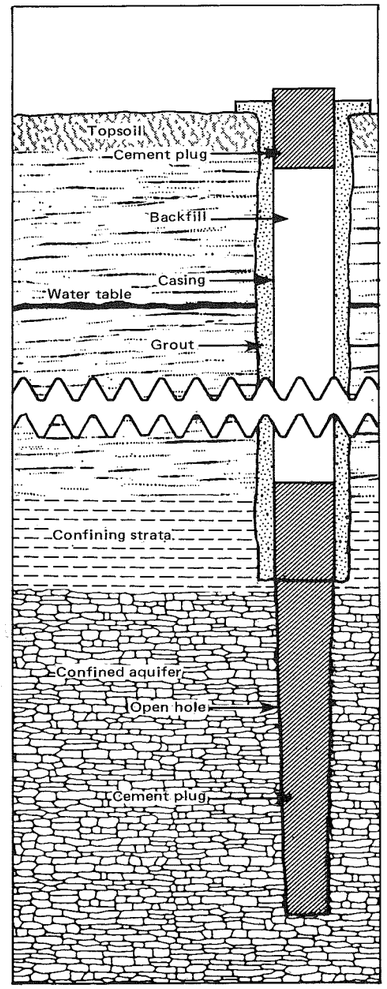

Figure 10. Sealing abandoned well in confined conditions.

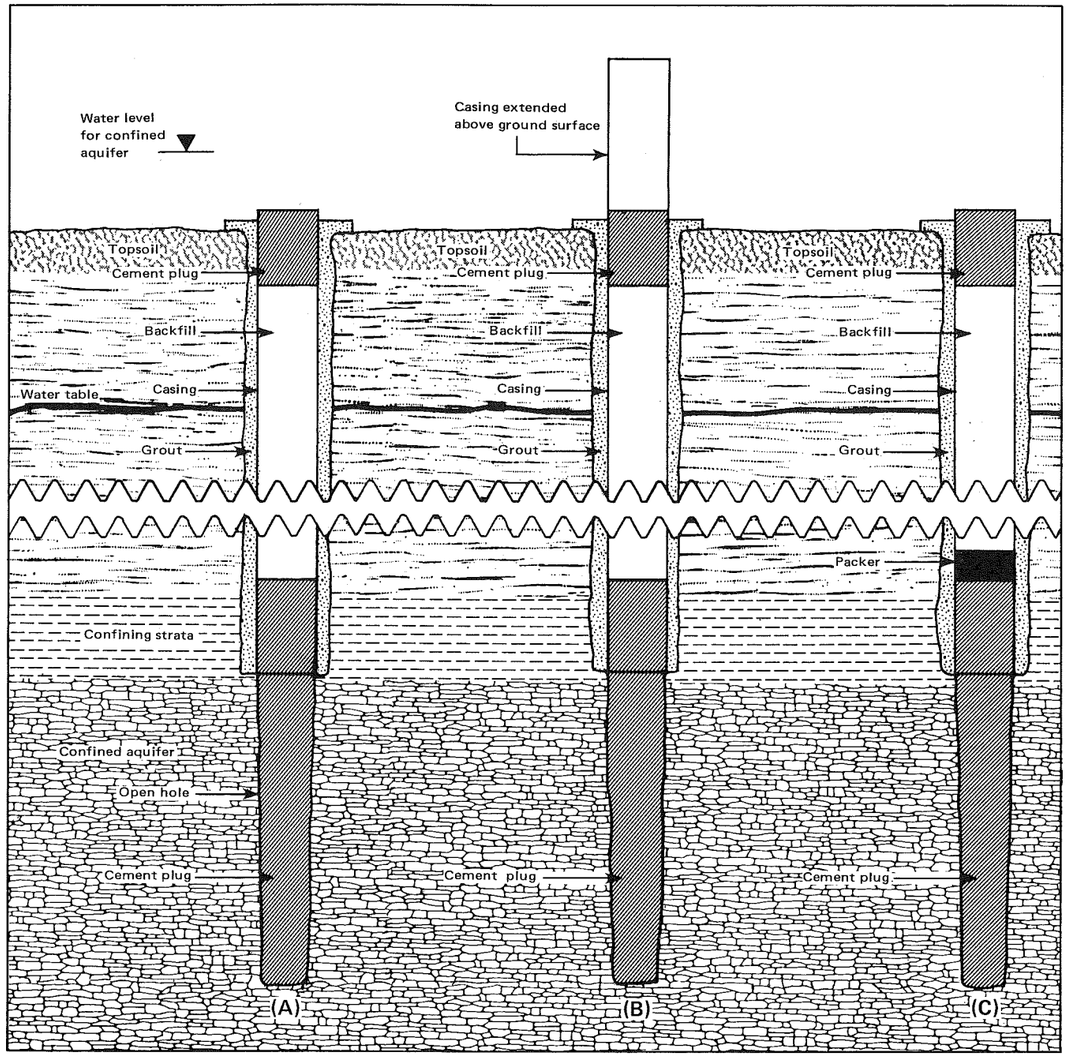

Figure 11. Sealing abandoned flowing wells.

(A) Weight of cement plug pressure exceeds artesian plug hydrostatic pressure; cement may be admixed with barite to increase weight.

(B) Casing extended above land surface so that well no longer flows. After cement plug has set the casing extension is typically cut off below grade.

(C) An inflatable packer is installed so that well no longer flows. Packer may or may not be removable.

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