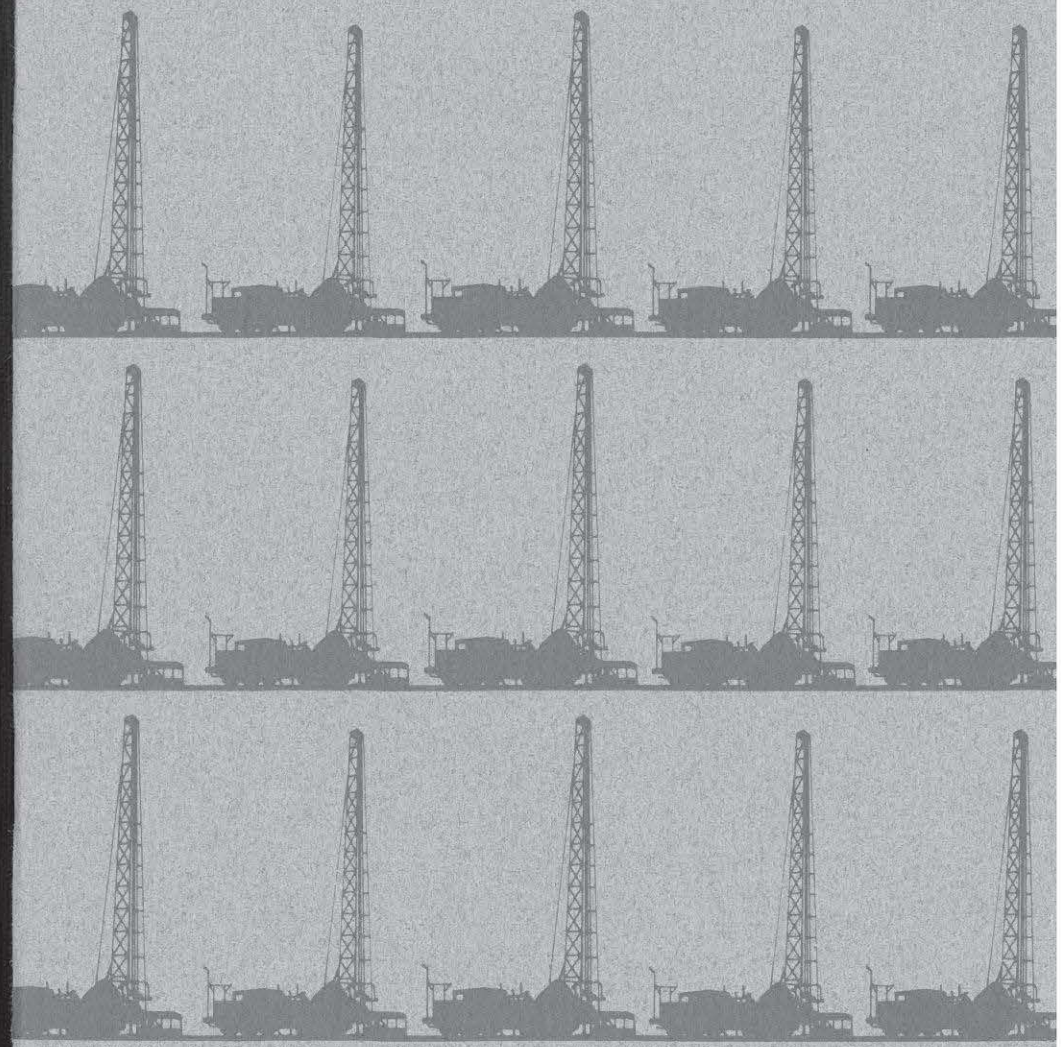
SUGGESTED DESIGN AND CONSTRUCTION OF EDWARDS AQUIFER WELLS



EDWARDS UNDERGROUND WATER DISTRICT

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TABLE OF CONTENTS

1: PURPOSE

The Edwards Underground Water District is a conservation and reclamation district created by the State Legislature for the purpose of conserving, protecting and recharging the underground water bearing formations within the District, and for the prevention of waste and pollution of such underground water, particularly the waters in the formations known as the Edwards Limestone and Associated Formations in Bexar, Comal, Hays, Medina and Uvalde Counties.

Recognizing these responsibilities and the need to improve upon inadequate well construction practices which have resulted in isolated cases of groundwater waste and/or pollution, the Edwards Underground Water District has developed these recommended minimum well construction standards. The method used to construct Edwards' wells, and the construction details themselves can be a major factor in the quality and quantity of water being produced. The unique nature of the Edwards Aquifer as a limestone formation has made water well construction specialized and different from that in all other areas of the State. This manual is provided as a service to the residents of the District to inform those unfamiliar with the water well profession about generally accepted drilling procedures, practices, and construction specifications for Edwards Aquifer wells. It primarily addresses the construction of domestic wells.

2: DEFINITIONS

2.1 ***Annular Space.*** The space between two concentric cylindrical objects, one of which surrounds the other, such as the space between the walls of a drilled hole and a casing.

2.2 ***Aquifer.*** A geologic formation that will yield water to a well in sufficient quantities to make the production of water from this formation feasible for beneficial use.

2.3 ***Artesian Zone.*** A zone where water is confined in an aquifer under pressure so that the water will rise in the well casing or drilled hole above the bottom of the confining layer overlying the aquifer.

2.4 ***Casing.*** A tubular structure intended to be watertight installed in the excavated or drilled hole to maintain the well opening and, along with cementing, to confine the ground waters to their zones of origin and prevent the entrance of surface pollutants.

2.5 ***Cement Grout.*** A mixture of water and cement in the ratio of not more than 5-6 gallons of water to a 94 pound sack of portland cement which is fluid enough to be pumped through a small-diameter pipe. To obtain a better flowing mixture, 3-5 pounds of bentonite clay may be added per sack of cement and the water increased to not more than 6.5 gallons per sack of cement.

2.6 ***Completion.*** Sealing off access of undesirable water to the well bore by proper casing and/or cementing procedures.

2.7 ***Confining Bed.*** A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers.

2.8 ***Consolidated Formation.*** The term consolidated formations is used for naturally-occurring geologic formations that have been lithified (turned to stone). The term is sometimes used interchangeably with the word "bedrock." Commonly, these formations will stand at the edges of a bore hole without caving.

2.9 ***Edwards Aquifer.*** Water bearing zone comprised of Edwards and Associated Limestones.

2.10 ***Edwards Outcrop.*** The Edwards and Associated Limestone Formations are found at the surface. This area is generally referred to as the Edwards Aquifer Recharge Zone.

2.11 ***Licensed Water Well Driller.*** Any person who holds a license issued by the State of Texas pursuant to the provisions of the Texas Water Well Drillers Act, and the substantive rules of the Water Well Drillers Board.

2.12 ***Recharge Zone.*** The area where a formation allows available water to enter the aquifer.

2.13 ***Seal.*** The impermeable material, such as cement grout, bentonite, or puddling clay, placed in the annular space between the borehole wall and the casing, to prevent the downhole movement of surface water, or the vertical mixing of artesian waters.

2.14 ***Unconsolidated Formations.*** Naturally-occurring earth formations that have not been lithified. Alluvium, soil, gravel, clay, and overburden are some of the terms used to describe this type of formation.

2.15 ***Void.*** A general term for pore space or other openings in rock. The openings can be very small, to cave size, and are filled with water below the water table.

2.16 ***Water Table Zone.*** That part of the aquifer confined only by atmospheric pressure (water levels will not rise in the well above the confining bed).

2.17 ***Water Well.*** Any artificial excavation constructed for the purpose of exploring for or producing ground water.

2.18 ***Driller's Well Log.*** A log accurately kept, on forms prescribed by the Water Well Drillers Board, at the time of drilling showing the depth, thickness, character of the different strata penetrated, location of water-bearing strata, depth, size and character of casing installed, together with any other data or information required by the Water Well Drillers Board.

3: GENERAL

The Edwards Underground District is making an effort to assure that Edwards Aquifer wells are being constructed in a manner that will guard against waste and contamination. The property owner and the well driller have the ultimate responsibility in the proper development of these wells by satisfying all State and local rules and regulations pertinent to water well construction.

In addition, any unique situation may require construction to go beyond the minimum standards in order to protect groundwater sources.

4: CONTRACT DOCUMENT

Anytime a property owner or his designated representative hires a registered water well driller to drill, deepen or otherwise alter a water well within the Edwards Underground Water District, it is recommended that a written agreement be signed by both parties. The agreement should contain a minimum of the basic drilling procedures and construction specifications. These items should include, but are not limited to:

1. Drilling method to be used.
2. Total depth of the well.
3. Well casing selection — diameter and thickness.
4. Total depth of casing.
5. Grout material selection and placement method.
6. Total depth of grout placement.
7. Additional work (i.e. furnish and install pump, pressure tank, pipe and fittings, etc).
8. Completion of well and general conditions.
9. Time frame for job completion.
10. Contract price and method of payment.

5: WELL LOCATION

The State Health Department recommends that a well be located a minimum horizontal distance of one hundred fifty (150) feet from any possible sources of contamination, such as existing or proposed livestock and poultry yards, privies, septic system absorption fields and at a site location not generally subject to flooding.

6: DRILLING METHOD

Well drilling methods are many and varied, ranging from simple digging with hand tools to high speed drilling with sophisticated equipment.

The most commonly used method of drilling to the Edwards Aquifer and the method recommended as being the best suited and most appropriate for Edwards Aquifer wells is the conventional rotary method. Drilling is accomplished by rotating a drill pipe and bit by means of a power drive. The drill bit cuts and breaks up the rock material as it penetrates the formation. Drilling fluid (air, mud or water) is pumped through the rotating drill pipe and holes in the bit. The fluid swirls in the bottom of the hole, picking up material broken by the bit, then flows upward in the annular space between the drill pipe and the wall of the hole, carrying the cuttings to the surface. The drill pipe and bit move progressively downward, deepening the hole as the operation proceeds. This method usually allows for a straighter, more uniform hole in less time than other drilling methods (provided however, that excessive pulldown pressure is not exerted on the drill pipe). The drilling fluid selected must be fresh, non-polluted water and can be mixed with a bentonite clay material or other additives which must comply with recognized industry standards and practices. A suitable drilling mud is generally used when necessary to seal off flow from the formation into the hole to prevent caving and to transport the cuttings out of the hole to the surface.

The cable tool method is another effective and familiar procedure in constructing Edwards Aquifer wells. This method consists of alternately lifting and dropping a set of drilling tools suspended on a wire cable so that with each stroke the drill bit strikes the bottom of the hole chiseling and crushing the formation material. The drill cuttings are mixed with water by action of the drill bit and the resulting slurry must be removed from the drill hole by a bailer carried on a separate cable line. Although not as common as the rotary method, cable tool drilling is an acceptable, effective procedure used in constructing Edwards Aquifer wells.

7: WELL CASING SELECTION AND INSTALLATION

Casing is installed to prevent the collapse of the walls of the borehole; to exclude, along with grouting, pollutants, either surface or subsurface, from entering the water source; and to provide a channel for conveying the water to the surface. Casing, in most cases, will also provide a housing for the pump mechanism. Casing must be strong enough to resist the pressures exerted by the surrounding materials, forces imposed on it during installation, and corrosion by soil and water environments. Steel pipe is the most frequently used and best suited material for constructing Edwards Aquifer wells.

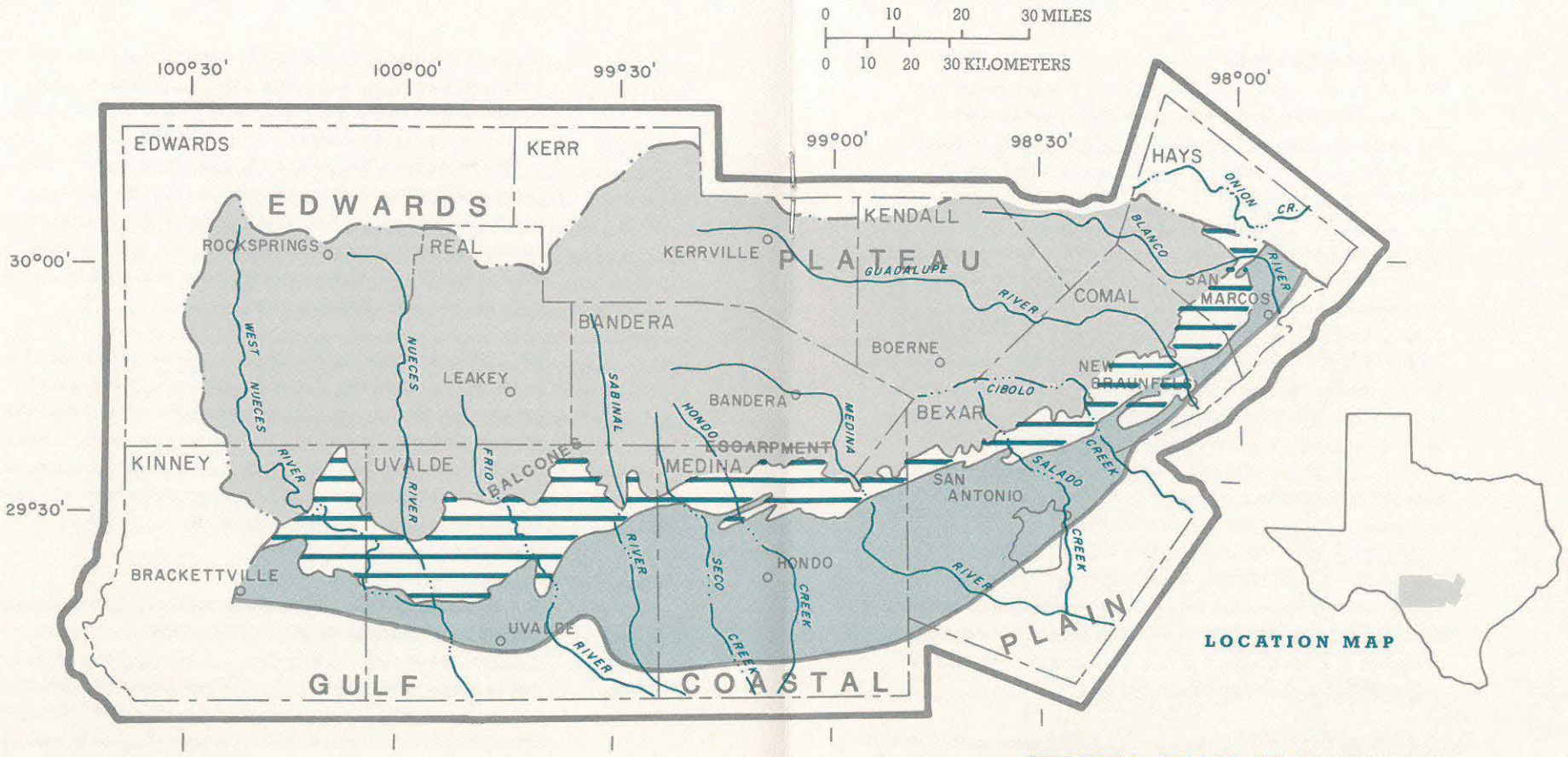
PVC (polyvinyl chloride) plastic pipe is not recommended for use in well construction. Although some controversy exists, it appears that the potential for collapse or distortion of the PVC pipe exists during the grouting process of deep wells due to the high heat generated and/or pressure exerted. It also becomes difficult to rework or repair an existing well due to the PVC casing becoming brittle over time and therefore being subject to structural failure.

The recommended wall thickness for steel casing for domestic wells to provide adequate life under moderately corrosive conditions should be 1/4 inch (0.25 in.). The diameter of the well casing is best chosen based upon the size pump to be installed and the estimated production desired from the well. Through the use of geophysical methods and/or local well records one can usually determine the general characteristics of the producing zone to be encountered.

The recommended casing diameter for domestic wells should range between 5" and 8" inside diameter of pipe. The 5" I.D. casing is generally used for shallow, small capacity wells usually located in the water table zone of the Edwards Aquifer. The larger diameter casings are preferred for the deeper Edwards Aquifer artesian zone wells, capable of producing larger volumes of water. A minimum casing diameter of 6" I.D. is preferred in the construction of any Edwards Aquifer well.

THE EDWARDS AQUIFER AND DRAINAGE AREA

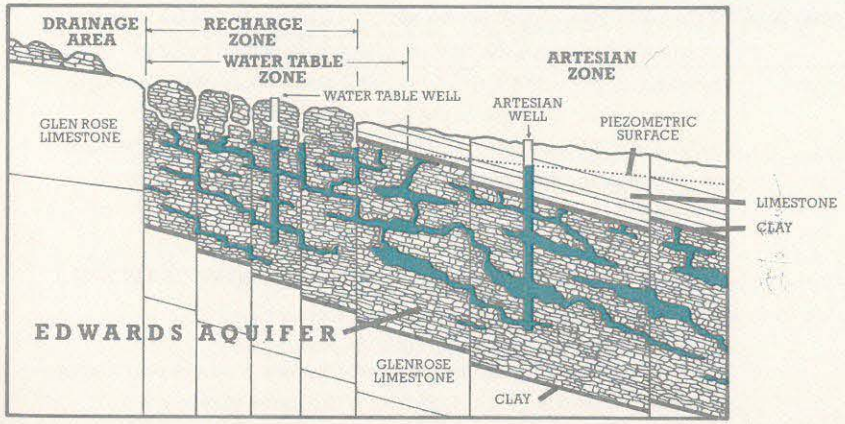
FIGURE 1



EXPLANATION

- DRAINAGE AREA
- RECHARGE ZONE — Edwards Aquifer is under water-table conditions
- ARTESIAN ZONE — Edwards Aquifer primarily under artesian conditions
- APPROXIMATE DOWNDIP LIMIT OF FRESH WATER
- EDWARDS & ASSOCIATED LIMESTONES IN TYPICAL CROSS-SECTION

TYPICAL CROSS SECTION (N-S)



8 : WELL CONSTRUCTION

8.1 ***Artesian Zone Wells*** (Figure 2)
Shallow surface casing may be necessary in some instances to maintain the well opening during the drilling process when encountering unstable formations. A surface casing of at least two inches larger in diameter than the primary well casing is recommended.

It is recommended that a new Edwards well to be constructed in the artesian zone (Figure 1) be drilled to a depth of at least 5 feet, but generally not more than 15 feet, below the base of the Del Rio Clay (Grayson Shale). This is the depth at which the well should be cased. The driller may, in some instances, drill the hole a little deeper than necessary so that any caving material fills the extra depth of the hole without affecting the setting of the casing at the desired depth. Drilling beyond the 15 foot maximum depth however, would increase the likelihood of encountering voids or caves within the Edwards Limestone Formation and could hinder the grouting process resulting in a poor seal.

The borehole should be free from obstructions throughout its depth before attempting to set casing. The casing must extend a minimum of sixteen (16) inches above ground level or one foot above the 4" thick concrete slab. It is not advisable to drill the entire well depth prior to installing casing.

The diameter of the drilled hole should be a minimum of 1 1/2 inches (2" diameter is recommended) larger than the outside diameter of the casing to be used. The casing should be lowered to a depth just above the bottom of the drilled hole prior to grouting. Some drillers will cut or drill small holes (weepholes) in the casing near the base of the first section of casing prior to installation. This is an acceptable practice in wells to be pressure grouted and in some cases may improve upon proper grout placement.

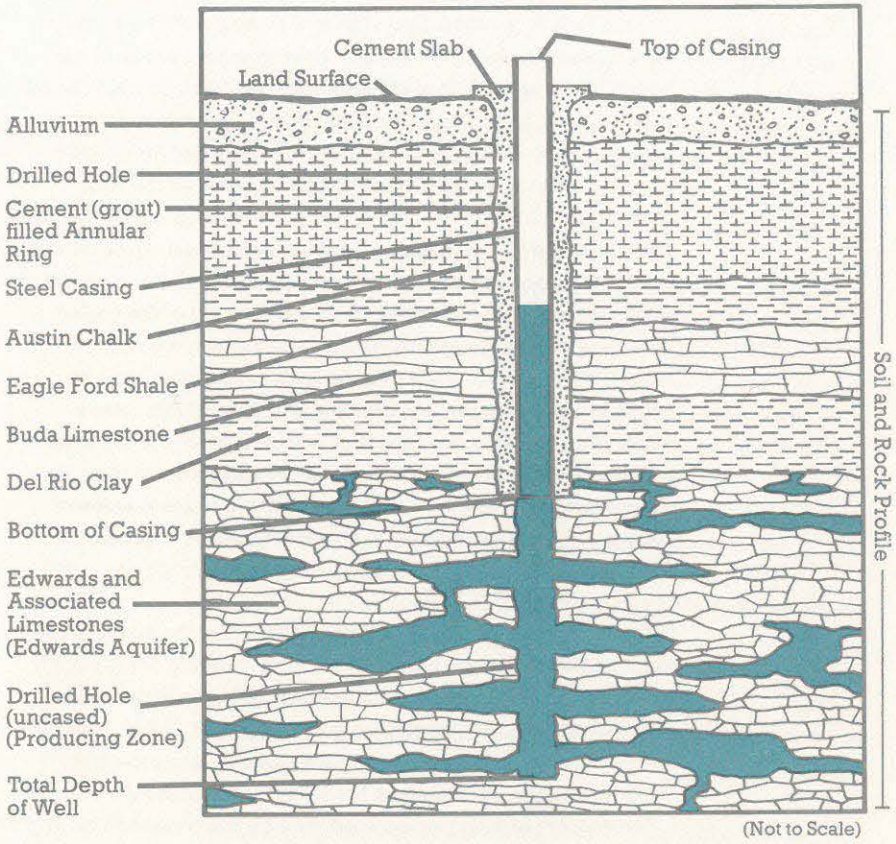
Well casing with beveled ends is preferred to ensure the proper welding of joints.

After all of the casing has been lowered down the hole the casing must be grouted in place. Grouting is the name given to the process by which a slurry or watery mixture of cement or clay is

WELL CONSTRUCTION

EDWARDS AQUIFER ARTESIAN ZONE

FIGURE 2



*In order to provide sufficient production it is recommended that the total depth of the well be at least 50 feet below the bottom of the casing.

NOTE: The geologic units illustrated represent an example only and do not necessarily represent the stratigraphic units to be encountered in all geographical areas.

used to fill the annular space between the casing and the wall of the borehole to seal out contaminated waters from the surface and other strata above the Edwards Aquifer.

It is recommended that all Edwards wells be grouted by the positive placement (pressure) method. Grout material shall be placed by pumping through an airtight grout pipe connected to a sealed cap on the casing head. First clear water or other suitable drilling fluid is injected down the well casing until the water or fluid is seen flowing from the borehole annulus outside of the casing. This circulation of water is intended to clean the hole and condition it to better take the grout. Without significant interruption, grout should be substituted for water and, in a continuous manner, the volume of grout calculated to fill the well annulus (plus a pre-determined percent excess) shall be injected down the well casing. Neat cement or sand-cement grout shall be used for this procedure. Following the grout shall be a volume of water necessary to displace and flush the inside of the casing (calculated to leave approximately 5' of grout in the bottom of the hole) after which pressure shall be maintained for at least 24 hours, or until such time as a sample of the grout indicates a satisfactory set. The ideal situation is to see grout flowing from the borehole outside of the casing at the ground surface just prior to the completion of the pumping procedure. Failure to achieve grout placement to the surface is commonly due to grout loss through voids and fractures within the borehole.

In the event grout returns were not observed at the surface, it is recommended that the completion of the grouting of the casing be accomplished by the tremie method. The size of the tremie pipe depends upon the annular space provided. When making a tremie pour, the tremie pipe shall be lowered down the well annulus until the pipe tags the hardened grout, and raised slowly as the grout material is introduced. The tremie pipe shall be kept full continuously from start to finish of the grouting procedure, with the discharge end of the tremie pipe being continuously submerged until the annular space is completely filled with grout to the land surface.

An alternate method of completing the grouting process when returns are not circulated to the surface but grout returns are known to be within 200 feet of the top, can be accomplished by pouring grout material uniformly into the annular space to ground level.

Following the necessary curing time (generally 36-72 hours), construction may resume on completion of the well.

The producing zone (Edwards Aquifer) can now be drilled by means of a drill bit having a maximum diameter one inch smaller than the diameter of the casing. The depth of the producing zone to be drilled will depend upon the volume of water required, but should not be less than 50 feet below the bottom of the casing. Generally 100' to 200' for domestic wells will allow for adequate production. The Edwards Aquifer is a consolidated formation and therefore it is not necessary to case or screen the producing zone for no formation stabilization or filtering is needed.

8.2 ***Water Table Zone Wells*** (Figure 3)

For water wells drilled on the Edwards Recharge Zone (Figure 1) or at locations where the Edwards Aquifer exists under water-table conditions, the well construction can be slightly different.

In these areas the Del Rio Clay is non-existent or is found at shallow depths, therefore the well casing should be extended to a depth equal to or near the water level in the well.

Although pressure cementing is recommended and is the preferred method for grouting all Edwards wells, alternate methods of grouting are acceptable and may be implemented on wells having 200 feet or less of casing.

The casing should be lowered to the bottom of the drilled hole and grouting accomplished either by the gravity filling method or the tremie method.

The gravity filling method consists of pouring grout material uniformly into the annular space until the zone being grouted is completely filled.

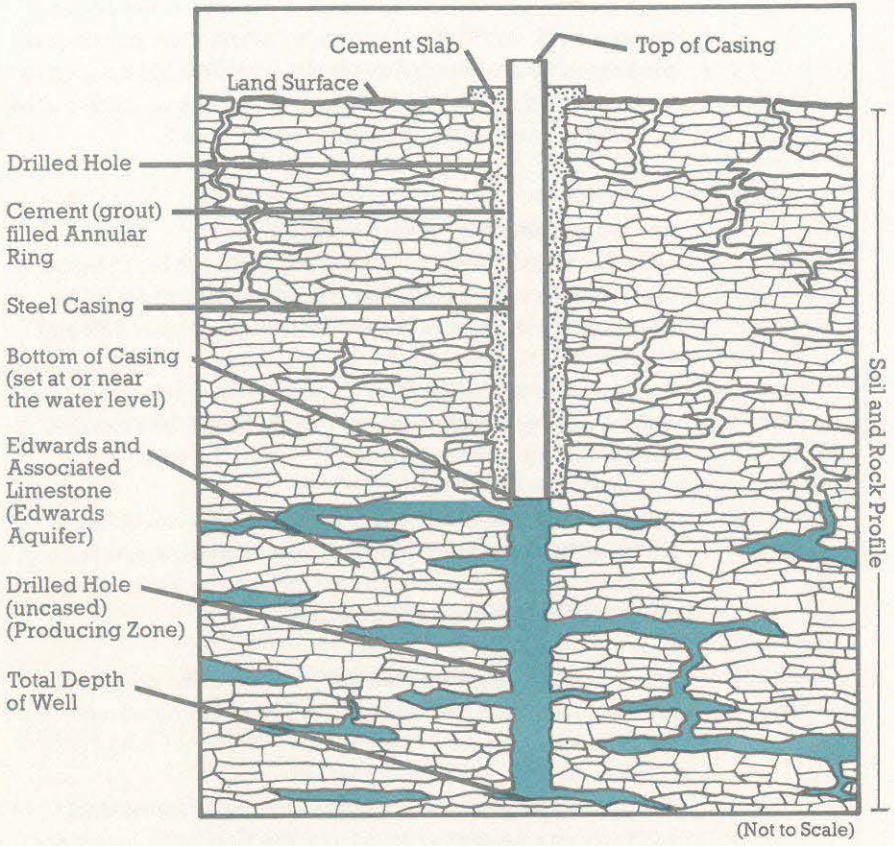
The tremie method would be the same technique as discussed in 8.1, lowering the tremie pipe down the well annulus to the bottom of the hole and working the grout back to the surface.

After the grout has cured for the necessary period of time, drilling of the production zone and completion of the well can be accomplished.

WELL CONSTRUCTION

EDWARDS AQUIFER WATER-TABLE ZONE

FIGURE 3



*It is recommended that the total depth of the well be at least 50 feet below the bottom of the casing.

9: WELL COMPLETION

In all wells a concrete slab or sealing block must be placed above the cement slurry (grout) around the well at the ground surface. The slab or block shall extend at least two (2) feet from the well in all directions and have a minimum thickness of four (4) inches and should be separated from the well casing by a plastic or mastic coating or sleeve to prevent bonding of the slab to the casing.

9:1 *Well Development*

A basic process of well completion which should be undertaken after a well has been constructed is well development. This process is the removal of cuttings, silt, and other such materials forced into fractures, bedding planes and other openings in the wall of the hole during the drilling process. The most commonly used methods of well development of Edwards Aquifer wells is pumping and/or surging.

The recommendation for pumping a new well is continually at a rate of 1-1/2 to 2 times the design capacity of the pump to be installed for a period of no less than 2 hours (4 to 10 hours recommended).

Surging is the method by which a plunger is operated up and down in the casing like a piston in a cylinder. The tool normally used is called a surge plunger or surge block. Surging can also be accomplished by utilizing the bailer as a surging device.

Another effective method of well development is hydraulic jetting or backwashing with high velocity jets of water from a high pressure pump directed horizontally out a jet nozzle into the production zone. Upon completion of the development work the well should be cleaned to the bottom.

9:2 *Well Disinfection*

Disinfection is the final step in the completion of a well. Its aim is the destruction of all disease-producing organisms introduced into the well during the various construction operations.

The well should be cleaned, as thoroughly as possible, of foreign substances before disinfection. Disinfection is most conveniently achieved by the addition of a strong solution of chlorine to the well. The contents of the well should then be allowed to stand for several hours and preferably overnight. Following this, the well should be pumped long enough to change its contents several times and so flush the excess chlorine out of it.

10: CONCLUSIONS

The suggested water well design and construction information presented herein is provided for educational purposes in an effort to improve upon individual home water supply systems.

There is a wide range of variables affecting the type of construction necessary from one well to the next. Any unusual situation, many times will require a decision to be made on the spot which may alter the construction of the well not covered in this manual.

The location of a well will also be a deciding factor in the quality and quantity of water capable of being produced. It is recommended that prior to drilling a well, the individual having the well drilled, obtain all available information on the geology and groundwater resources of the area. Much of this information can be obtained from nearby well owners, water well drillers or public agencies.

The Edwards Underground Water District maintains records of new and historical well data which is made available to the general public.

For further information, please contact the Edwards Underground Water District at 512/222-2204 or 1-800-292-1047.

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