Borehole Diameter: How Large is Large Enough?

Introduction

In order to address the topic of appropriate borehole diameter, we begin by emphasizing the importance of perspective. What does perspective have to do with appropriate borehole diameter? Well, actually quite a bit. This memorandum is written from the perspective of a well designer in 2005. However, one would get a much different view of the well design from a 1960's perspective. Interestingly, water well design, well drilling, and well construction methods changed markedly over the years. Well drilling has evolved from the simple cable tool method to direct rotary, reverse-circulation and others including percussion and air-rotary drilling. With the use of these more advanced drilling methods came the ability to drill deeper and larger diameter wells with complex completions. This memorandum addresses how these developments affect everyday well design.

Drilling Methods

With cable tool drilling, borehole diameters were usually equal to or slightly larger than the outside diameter (O.D.) of the well casing. Most cable tool wells were completed without a gravel pack since there was essentially no annular space between the casing and borehole wall. When it was desirable to drill deep wells, it was often necessary to reduce the diameters of the borehole and casing due to the frictional forces of driving or jacking long strings of casing into the borehole. In many instances, several reductions were required to reach a target depth.

When rotary drilling rigs came onto the scene, the borehole was drilled larger than the installed casing and screen. This ushered in the era of the gravel envelope well. Today, most rotary-drilled wells are gravel packed. Although there is some debate on the preferred thickness of a gravel pack, it typically ranges from 3 to 6 inches.

Well Appurtenances

Over the years, it has become design practice to install one or more small-diameter access pipes into the annular space for various purposes, as described below.

Gravel Feed Pipe. The early method of installing gravel was to simply shovel it into the annulus and let it free fall. That method was generally suitable for relatively shallow wells. However, free-falling gravel, particularly in deep wells, often led to bridging, especially at the top of the screen section. Eventually, bridging problems were addressed by placing gravel through a small-diameter tremie pipe, which was withdrawn as the gravel pack was placed. Subsequently, many wells were completed with a 3- to 4-inch gravel feed pipe through which gravel could be placed when the well was in service. This gravel feed pipe became a common fixture when designers included grout seals that extended from ground surface down to the gravel pack.

Sounding Pipe. A sounding pipe makes it possible to make water level measurements inside the well with an electric sounder or transducer even under pumping conditions. Sounding pipes are typically about 2 inches in diameter, extend from ground surface, and enter the well at a depth below the pump setting.

Camera Port. A camera port is an optional design feature that provides access to the interior of the well at a depth below the pump bowls. With a port, a camera can be lowered into the well to inspect the condition of the casing and screen without having to remove the pump bowls, pump column, and wellhead equipment. The camera port connects to the surface through a small-diameter pipe.

Treatment Pipe(s). Recently, some wells have been constructed with one or two 2-inch diameter pipes that extend from ground surface and connect to the well casing at a depth below the pump. Treatment tubes are used to introduce chemicals into the well without having to remove the pump.

Reduced Borehole Diameter Below The Pump Chamber

Some wells are constructed with a large diameter blank casing (i.e., pump chamber) that connects to a smaller-diameter well screen with a reducer. In those wells, the borehole diameter can be reduced around the screen so that the thickness of the gravel envelope is on the order of 3 to 6 inches. Thinner gravel packs are more easily developed and are less costly to install.

The Effect of Access Pipes on Borehole Diameter

The degree to which the borehole diameter is affected by installing one or more access pipes in the annulus in a gravel-packed well depends upon the diameter of each access pipe and their arrangement around the well casing. As suggested by Figures 1 and 2, there are many combinations of casing diameter, screen diameter, and access pipes from which to choose. Therefore, each designer and well drilling contractor should decide on the borehole diameter based on his experience, equipment, and knowledge of the local subsurface conditions.

FIGURE 1

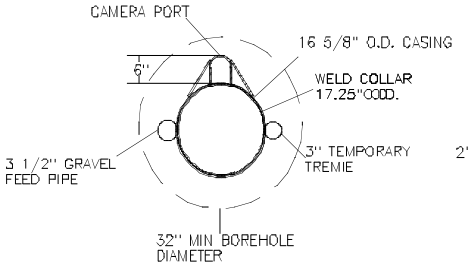
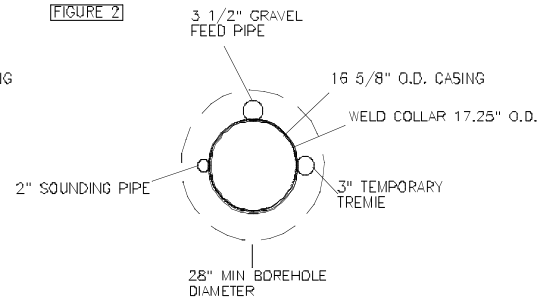


FIGURE 2



When deciding the appropriate diameter, the following should be considered:

- What is the possibility of swelling clay? Would a slightly larger borehole be preferable to reduce risk from such conditions?
- Is the site underlain by sediments prone to caving? Will the borehole remain open and stable until the casing, screen, gravel pack, and access pipes are installed?
- What is the likelihood of a deviated borehole? Should a larger borehole be drilled to allow for this?

For the purposes of this memorandum, the term “minimum diameter” (MD) is defined as the widest cross-sectional diameter of the casing and access pipe(s) with an added 2 inches, as shown below, referring to Figure 1:

MD = (casing radius + largest access pipe diameter) x 2 + 2 inches

= (8.62 in. + 6 in.) x 2 = 29.24 + 2 in.

= 32 in.

It is prudent to drill the borehole somewhat larger than the minimum diameter as a precautionary measure. Therefore, for the design shown as Figure 1, the recommended borehole diameter is 34 inches.

Summary

With the growing trend to design gravel packed wells with a number of access pipes for sounding, gravel placement, downhole cameras, and downhole water treatment, it is time to revisit the topic of minimum borehole diameter for water wells. Given the increasing complexity and depth of water wells that have become common, one should not overlook the possible negative consequences of drilling a borehole that is undersized. Well designers carefully review the proposed array of the well casing, screen and access pipes within the proposed borehole. Well designers should also discuss their proposed designs with a well drilling contractor.

References

Handbook of Ground Water Development, 1990, Roscoe Moss Company, John Wiley and Sons, New York, NY