Estimating Private Well Yields using DEM's Well Completion Report and Pumping Test Information

One of the most frequently asked questions is how does someone estimate the yield of a private well. Since many boards of health get their information on well yield from the Department of Environmental Management's (DEM) Water Well Completion Report (Fig. 1) pumping test information, the aim of this article is to enable you to use this information and to understand how a driller estimates the yield of a well.

This article is primarily for boards of health that do not have their own requirements for pumping tests but rely on the Water Well Completion Report for the estimate of well yield.

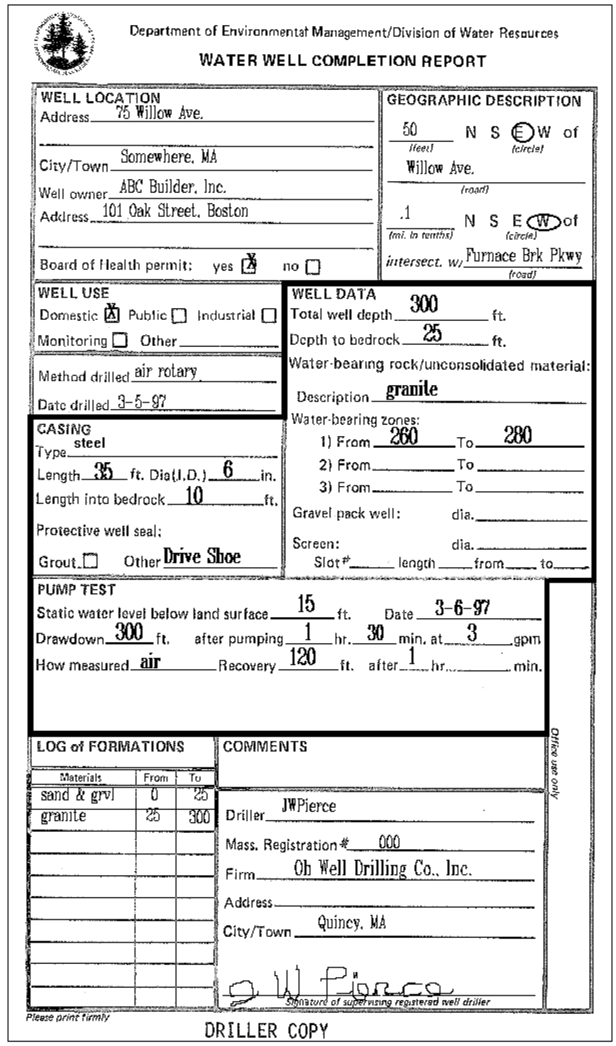
Well drillers in Massachusetts are required (313 CMR 3.00) to fill out a Water Well Completion Report for each well they complete. The Water Well Completion Report is a 5" x 8" card with 2 attached duplicates. The top sheet is retained by the driller; the second sheet (blue) is given by the driller to the board of health; and the last page, the manila card, is mailed by the driller to the DEM Division of Water Resources/Boston.

For this article, a dark outline has been drawn around the sections most relevant to estimating well yield. The data in these sections are verbatim from a Well Completion Report a homeowner sent me and are referred to frequently in this article.

Before talking about estimating yield, let's define some terms, some of these are on the Well Completion Report and some aren't. Once you understand the terminology and what the driller does, the rest falls into place.

Types of wells

For our purposes, there are two types of wells, overburden wells and bedrock wells. An overburden well is screened in the unconsolidated soil materials (e.g., till, sand and gravel, silts and clays) that lie on top of the bedrock. Overburden wells are constructed with steel casing driven into the ground, using a drill rig, until a suitable depth below the water table is reached. In Massachusetts, overburden wells are typically less than 50 feet deep because the surficial material is less than 50 feet deep. Notable exceptions include the Cape, where the sand and gravel aquifers are hundreds of feet thick, and the Connecticut River valley, where there are deep confined aquifers.


Department of Environmental Management/Division of Water Resources
WATER WELL COMPLETION REPORT

WELL LOCATION
Address 75 Willow Ave.
City/Town Somewhere, MA
Well owner ABC Builder, Inc.
Address 101 Oak Street, Boston
Board of Health permit: yes [X] no [ ]

GEOGRAPHIC DESCRIPTION
50 (feet) N S (E) W of (circle) Willow Ave. (road)
.1 (mi. in tenths) N S E (W) of (circle) intersect. w/ Furnace Brk Pkwy (road)

WELL USE
Domestic [X] Public [ ] Industrial [ ] Monitoring [ ] Other
Method drilled air rotary
Date drilled 3-5-97

WELL DATA
Total well depth 300 ft.
Depth to bedrock 25 ft.
Water-bearing rock/unconsolidated material:
Description granite
Water-bearing zones:
1) From 260 To 280
2) From To
3) From To
Gravel pack well: dia.
Screen: dia.
Slot # length from to

CASING
Type steel
Length 35 ft. Dia(I.D.) 6 in.
Length into bedrock 10 ft.
Protective well seal:
Grout [ ] Other Drive Shoe

PUMP TEST
Static water level below land surface 15 ft. Date 3-6-97
Drawdown 300 ft. after pumping 1 hr. 30 min. at 3 gpm
How measured air Recovery 120 ft. after 1 hr. min.

LOG of FORMATIONS

Materials	From	To
sand & grvl	0	25
granite	25	300

COMMENTS
Driller JWPierce
Mass. Registration # 000
Firm Oh Well Drilling Co., Inc.
Address
City/Town Quincy, MA
Signature of supervising registered well driller
Office use only
Please print firmly
DRILLER COPY

Fig. 1. DEM Water Well Completion Report

A bedrock well is completed in the rock underlying surficial unconsolidated material. Fractured bedrock is still bedrock. Unlike overburden wells, bedrock wells are usually in excess of 100 feet deep and often in excess of 400 feet deep. These wells are drilled through the overburden down into the bedrock until the borehole intercepts water bearing fractures. For water quality considerations, a bedrock well should be constructed so water from the overburden has no direct access into the borehole. Bedrock fractures are usually not exposed at the ground surface but are covered by the overburden. You can determine if the well is an overburden or a bedrock well from the information given on the Well Completion Report. Our example is a bedrock well drilled through 25 feet of sand and gravel and then through 275 feet of granite. The only water bearing fracture zone encountered during drilling of this well was hit at a depth of 260 feet to 280 feet below land surface.

Static Water Level

As a well is drilled, water in the surrounding geologic formation moves through the well screen into the casing (overburden well) or through the fractures into the borehole (bedrock well). Given a few hours to stabilize, the depth to water in the well before pumping is the static water level. This is recorded on the Well Completion Report as the static water level below land surface (in our example, 15 ft).

Measuring the Pumping Rate during the Test

The simplest tools a driller has to determine the rate at which water is pumped out of the well is a 5 gallon bucket and a wrist watch. The bucket can be marked on the side at one gallon increments. As the well is pumped, the water is discharged into the bucket, and the driller looks at his watch to see how fast the bucket fills. This is the gallons per minute pumping rate.

Throughout this article, reference is made to the 'pumping test' of a well; however, unless otherwise specified by the board of health, the pumping test of a new well typically is conducted without a pump down inside the well. Instead, water is evacuated from the well with compressed air from the drill rig which is still sitting over the drillhole, and the rate at which water is evacuated from the well, the 'pumping rate', is measured using the bucket and the wristwatch. This is still called a pumping test, even though there is no pump in the well. When using compressed air, versus a submersible pump, to force the water up and out of the borehole, the drawdown can go all the way to the bottom of the well. In our example, the total depth of our well is 300 feet, and the drawdown is 300 feet.

Casing Storage

Casing storage is the volume of water which has moved from the surrounding geologic formation into the borehole. Casing storage is the water which sits in the well and is instantly available to be pumped when the pump is turned on.

A common problem in estimating well yield occurs when the volume of casing storage is large and, during the pumping test, the water is drawn down to the bottom of the borehole. This is a frequent occurrence with deep wells. For this reason it is worth understanding how casing storage is calculated. The driller doesn't calculate casing storage for you, but you can determine it from information on the Well Completion Report.

First, determine the height, or length, of the column of water in the well; then determine the volume of water in this column using the following formula:

Vol. of casing storage = length of water column (ft) x 1.5 gal/ft of water column.

The length of the water column is the total depth of the well minus depth to static water. In our example, 300 ft minus 15 ft gives a length of water column of 285 feet.

To complete the calculation of volume of casing storage, you need to know that a 6 inch diameter borehole holds 1.5 gallons of water per linear foot and that private wells are typically 6 inches in diameter. So multiply the total water column length by 1.5 gallons/ft to get the total gallons of water sitting in the well. This is the casing storage.

In actuality, in a finished well, the pump sits some distance above the bottom of the well. This in effect shortens the column of *available water* in the borehole by that distance since you would not want to draw down water below the level of the pump.

The following table illustrates the difference in amount of casing storage between a typical overburden well and our typical bedrock well.

Well Type:	Overburden	Bedrock
Total Well Depth	45 feet	300 feet
Depth to Static Water	20 feet	15 feet
Length of Water Column	25 feet	285 feet
Casing Storage	37 gallons	427 gallons

How Casing Storage Confounds Interpretation of the Pumping Test Results

If a driller pump tests this overburden well at, say, 3 gallons per minute (gpm), in *less than* 15 minutes (37 gal. divided by 3 gpm = 12.3 minutes) the pump will empty the well of this 'stored' water. This means for the remainder of the pumping test, the water pumped out of the well is water that has come into the well since the pump was turned on. If the driller pumps this overburden well for a few hours at 3 gpm, you can be reasonably certain the well will produce about 3 gpm under normal domestic operating circumstances.

In this type of situation, the volume of water stored in the casing is not sufficient to mask the yield of the well. This does not hold true for deep wells, in this case, our bedrock well.
We determined our bedrock well has 427 gallons of water sitting in the borehole (see table above). If the driller pumps our well at 3 gpm, it will take 142 minutes, or almost 2.5 hours, to pump out just the water that is already sitting in the borehole (e.g., the casing storage).

If the driller pump this well for only 2 hours, the well will produce 3 gpm whether or not there is water coming into the well from the surrounding formation. Unless you have other data you have no idea if the water being pumped out of the well is casing storage or water that comes into the well as the casing storage is pumped out.

You can find the other data you need in the Well Completion Report. The question is, how good is this information. In our bedrock well, we have casing storage of 427 gallons. The pumping test information says the well was pumped at 3 gpm for 1 hour and 30 minutes and the drawdown was 300 feet. In other words, the water level was drawn down to the bottom of the well.

Now think about this. At 3 gpm, assuming no additional water enters the well, it would take almost 2.5 hours to pump all 427 gallons of casing storage out of the well; however, the pumping test data records the drawdown at 300 feet after pumping 1 hour and 30 minutes at 3 gpm. That means the well had about 427 gallons removed in 90 minutes, but 3 gpm for 90 minutes would produce only 270 gallons, not 427 gallons.

How do you resolve this? For starters, sometimes inadvertent errors are made when the driller writes the information on the Well Completion Report. *If you have any questions, call the driller!* It is helpful to witness at least part of the pumping test, but at a minimum, you should read the Well Completion Report carefully and do a little arithmetic. The greater the volume of casing storage, the harder it is to estimate the yield of a well using just the pumping test information, *particularly if the pumping test is run for only an hour or two.* This is why many boards of health require a minimum of 4 hours for the test. In general, the longer the pumping test, the less the data is confounded by casing storage and the more realistic the result is.

Here is one more piece of information on the Well Completion Report you need to look at. This is called recovery.

<u>Recovery</u>

Recovery is the rate, in gallons per minute, at which water in the well returns to its static water level after the pump is turned off. The recovery rate is another estimate of well yield. To get this data, the driller measures depth to water in the well immediately at the end of the test. This is the drawdown. Then, at some later time, say one hour, depth to water is measured again. From this information, the driller figures *the amount the water level rose in the well (e.g., the length of the water column) in that period of time. This is the recovery of the well.*

Using what you know to calculate the volume of water per foot of water column in a 6 inch diameter well (1.5 gallons/ft), you can calculate the recovery rate. In our example, the recovery rate is 120 feet (x 1.5 gallons/ft) in 1 hour, or 180 gallons in 60 minutes, which further simplifies to a recovery rate of 3 gpm.

The rate of recovery should roughly approximate the results obtained from the pumping test, assuming the pumping test data was recorded accurately. If the rate of recovery is wildly different from the pumping test data, then it is appropriate to ask the driller for an explanation.

In the event the well yield based on the pumping test does not agree generally with the recovery rate, a rule of thumb is the recommendation given in the DEP's <u>Private Well Guidelines</u> (Oct. 1989, p. 49) that the well should recover to within 85% of the pre-pumped static water level within 24 hours after the end of the test. A well that recovers at a slower rate might not be able to provide sufficient water to meet demand. In our example, since the drawdown is 300 feet, the well should recover at least 255 feet within 24 hours after the pump is turned off. This means within 24 hours, not whenever. In our bedrock well, the water level recovered to within 40% of the static water level one hour after the end of the test.

However, use of this rule of thumb implies the well can meet the demand as calculated in the <u>Private Well Guidelines</u> and described later in this article.

In our example, it seems the well yield estimated using recovery (3 gpm) is greater than that estimated using the pumping test data in which the well apparently was dry after an hour and, thus, appeared to have very little water entering the borehole. However, if the well had 3 gpm coming in and really was pumped at 3 gpm, then the well should have experienced almost no drawdown, not 300 feet. It is possible the water was evacuated from the well at more than 3 gpm, or maybe the recovery data wasn't written down correctly. If you have a question, ask.

Sometimes you may have difficulty interpreting the information. For example, is the 120 feet for recovery in our bedrock well the depth to the water level measured from the land surface, the way drawdown and static water level are measured, or is this 120 feet the amount the water level rose in the well (e.g., the length of the water column) after the end of the test? Most drillers will tell you the recovery measurement on the Well Completion Report is the length of the water column after the pump has been shut off for the stated time.
Since the recovery rate is measured without interference from any pumping, some consider the recovery data to give a more easily interpreted estimate of the yield of a well; however, you need both pumping test and recovery

data to get an idea of what is going on and to develop a sense of how much you can rely on the information.

What Boards of Health Can Do to Ensure Better Well Yield Estimates

Ideally, you should witness at least part of the test. In addition, the Private Well Guidelines (p. 49) recommend boards of health require pumping tests at a rate and for a period of time such that, during the test, the well actually pumps a volume of water equal to the casing storage *plus* the estimated domestic needs of a house for a 24 hour period. Some may consider this to be an overly cautious amount, but this is what the Private Well Guidelines recommends.

For this, let's review how much water a typical house needs.

Estimating Domestic Water Use

In the Private Well Guidelines, (p. 51), the domestic (as opposed to outdoor use) water needs of a 4 bedroom house is estimated at 110 gal/day/bedroom, plus recommended safety margins of an extra bedroom and double the gallons per bedroom. This means a 4 bedroom house has an estimated water use of 220 gpd per bedroom. Including the extra bedroom, this translates into an estimated domestic water use of 1,100 gal/day for a 4 bedroom house. DEP recommends a well to serve this house produce 1,100 gpd plus the volume of casing storage in a 24 hour period.

Our bedrock well had 427 gallons of water sitting in the borehole. To supply a 4 bedroom house, this well must be pumped at a rate equivalent to that of 1,527 gallons/ day divided by 1440 minutes/day, or about 1 gpm.

This 1 gpm rate is for a well producing at this rate constantly over a 24 hour period This is not a number which readily translates into the results of a pumping test lasting only an hour or two for a well 400 feet deep.

Using our example, the well should be pump tested at a rate equivalent to 1,527 gpd. Since the driller is unlikely to pump a well for 24 hours straight (it ties up the drill rig unless the driller uses a pump down in the well for the test), an alternative would be, for example, for the driller to pump test the well for 4 hours at approximately 6 gpm (6.3 gpm x 4 hours x 60 minutes/hour = 1,527 gals). Some boards of health require a driller to perform a pumping test for a specified length of time at a specified rate, such as 4 hours at 3 gpm. In general, the longer the test, the closer it approximates real conditions.

If a house is going to have substantial outdoor water uses, like a swimming pool or lawn irrigation, an estimate of water needs that includes only domestic uses will not be sufficient. Use your judgment that the pumping test and the recovery data show a reasonable approximation for the yield of the well and that the estimated yield of the well is sufficient for the intended uses.

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