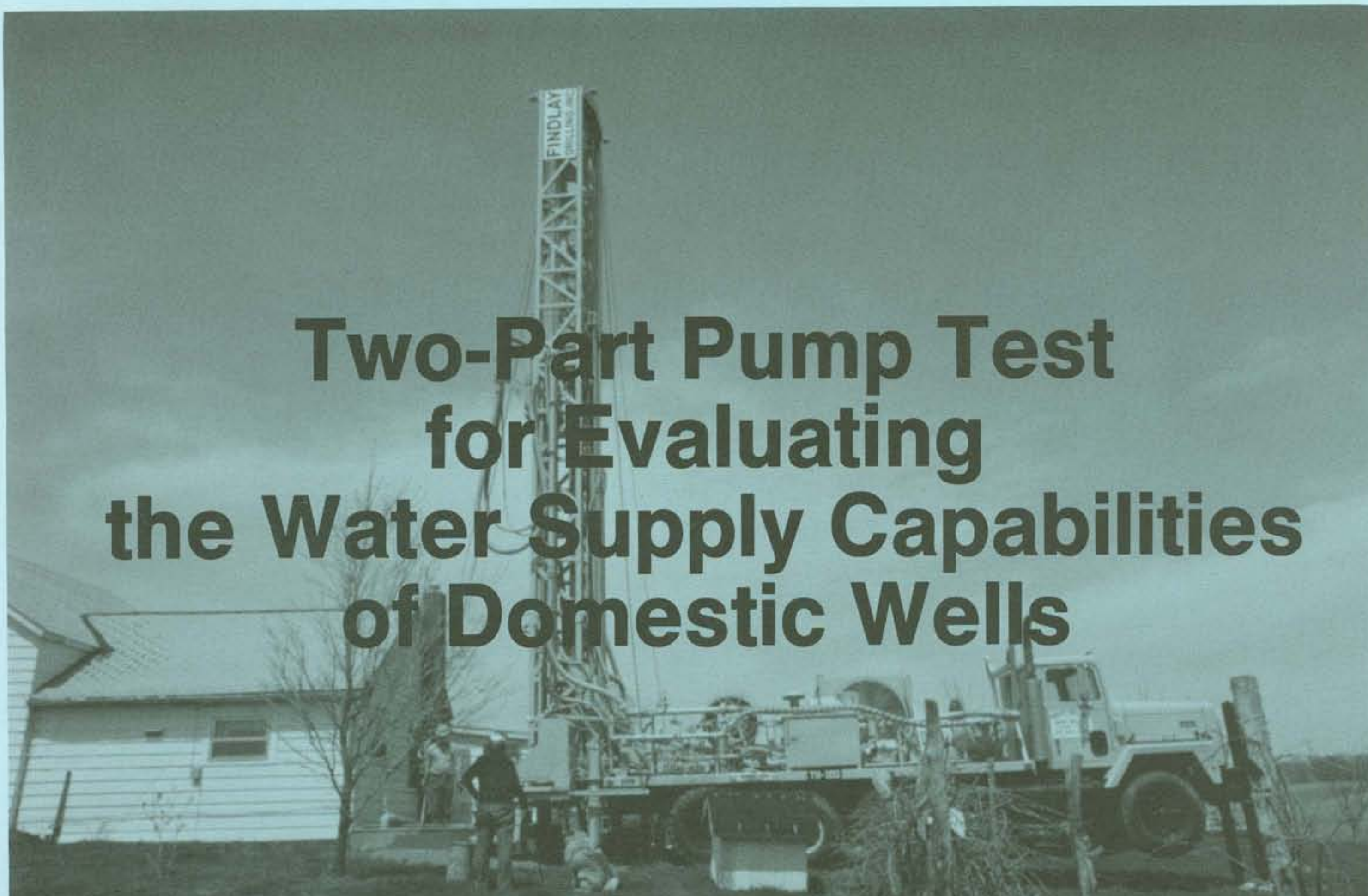
New Jersey Geological Survey
Ground-Water Report Series No. 1

Two-Part Pump Test for Evaluating the Water Supply Capabilities of Domestic Wells



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TWO-PART PUMP TEST FOR EVALUATING THE WATER-SUPPLY CAPABILITIES OF DOMESTIC WELLS

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by
Jeffrey L. Hoffman and Robert Canace

Department of Environmental Protection
Division of Water Resources
CN029
Trenton, NJ 08625

John W. Gaston, Jr., P.E., Director
Haig F. Kasabach, State Geologist

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Key terms: aquifer test, water yield, well construction, constant head test
New terms: peak demand rate, peak demand test

ABSTRACT

An evaluation of the capability of a well drilled in rock to supply domestic needs can be based on predicted household water use patterns and characteristics of the well. Household water demand is estimated using a residency rate of two per bedroom and a usage rate of 100 gallons per capita daily. Water use is assumed to be split between equal morning and evening periods of peak demand. Rate of usage during peak periods is estimated at 3 gallons per minute per bathroom. Duration of the peak demand periods is estimated by dividing total usage during peak demand periods by the average rate of usage during peaks.

Capability of the well to meet peak demand and total daily demand is evaluated through a two-part pump test. The first part, a peak demand test, is a drawdown test to determine whether or not the combined well storage and aquifer contribution to well flow can meet peak needs. The second part, a constant head test, is to determine whether or not flow from the aquifer is sufficient to meet total daily needs. If so it is assumed that the aquifer can meet long-term household needs. Measurements of drawdown during the pump test are used in determining the depth at which the pump should be placed in the well and the necessary depth if the well needs to be deepened to provide additional storage.

The method does not take into account extreme droughts, interfering stresses on the aquifer from other pumping or decreasing efficiency of the well and pump due to aging.

INTRODUCTION

In response to inquiries by local health agencies and the public concerning domestic well failures, the New Jersey Geological Survey has developed a method to estimate the water supply needs of private homes and to evaluate the adequacy of wells drilled to supply those households. The method consists of a calculation to estimate total daily needs and peak demand needs of a household and a two-part pumping test to determine whether or not a well can meet these needs. The procedure is intended primarily for use in areas of consolidated bedrock (Regions 2 and 3 of the New Jersey water well construction regulations (NJAC 7:10-35), shown in figure 1).

The yield of a well is usually established by pumping the well and measuring the discharge (well flow), in gallons per minute, from the well head. Unfortunately, pump test requirements for domestic water wells have not been standardized. The New Jersey Department of Environmental Protection requires only that "each well be tested for yield and drawdown" (NJAC 7:10-3.58). No testing procedures are stipulated under the code. A variety of local ordinances regulate well testing. Most of these have been established on the basis of experience in the field or other local ordinances. Most have fixed minimum yield requirements regardless of household size for issuance of the certificate of occupancy.

The method outlined in this report is modified from a procedure developed by the Connecticut Well Drillers Association (Hunt, 1978). It supplements the Connecticut approach by providing a systematic method based on anticipated peak and long-term demand to design, perform and evaluate a pump test.

The pump test is divided into two parts. The first part, the **peak demand test,** is to see if the well can meet the predicted water demand of the house during twice-daily periods of peak use. The second part, the **constant head test,** is to measure the aquifer's ability to transmit sufficient water to the well for the total daily water demand of the household.

The pump test identifies satisfactory wells and, for wells that are not satisfactory, whether the problem lies with insufficient storage or with inability of the aquifer to transmit sufficient water to the well. Insufficient storage can be corrected by deepening the well to provide additional storage within the borehole, redrilling to a greater diameter or constructing a surface storage tank. The necessary depth to which the well must be deepened can be estimated using measurements of aquifer yield and drawdown taken during the constant head

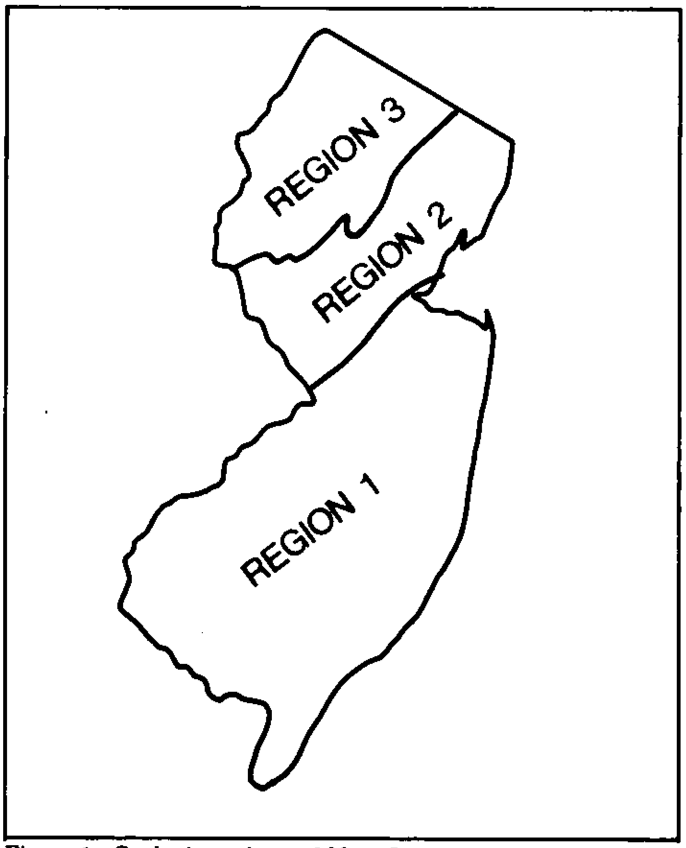

Figure 1. Geologic regions of New Jersey as defined in water well construction regulations. (NJAC 7:10-35)

test. Insufficient aquifer yield may, in some instances, be corrected by developing the well or deepening it to encounter additional water-bearing zones.

Equations, tables and worksheets are provided to assist in the recording and analysis of pump test data. A flow diagram is also provided which shows the evaluation procedures and options should the well fail. Hypothetical examples have been included to demonstrate the method.

It must be recognized that this method is a simplified mathematical approach that cannot take into account many of the physical factors that can influence long-term well performance. These include seasonal fluctuations in ground water availability, extreme drought, permanent dewatering of fracture zones, stresses on the aquifer from nearby wells and reduction of well and pump efficiency due to clogging or wear. These factors may result in failure of wells which were rated as satisfactory at the time of testing.

BASIS AND BACKGROUND

A method for estimating the water needs of individual households and evaluating domestic wells was developed by the Connecticut Well Drillers Association (Hunt, 1978). The impetus for the development of the **Connecticut minimum well formula** was an objection to a requirement by the Federal Housing Authority that a home have a well with a yield of 5 gpm (gallons per minute) or more to qualify for loan assistance. The Well Drillers Association, convinced that 5 gpm was an unreasonable across-the-board requirement, demonstrated that smaller yields could be certified as adequate for domestic needs if household demand were taken into account. The Connecticut minimum well formula:

1. estimates **peak load** (household water demand, in gallons, within each of two daily peak use periods);
2. estimates **peak time** (the length of peak use periods in minutes);
3. evaluates the capability of the well to meet the peak demand of the household, and;
4. establishes a minimum pump capacity and pump installation depth to assure an adequate supply.

In the Connecticut method, if the well can deliver the peak load within the peak time it is considered to be satisfactory. This determines whether or not the well can supply peak needs. But like many domestic well tests, it does not evaluate the long-term ability of the aquifer to supply the well. Also, for a well which fails the pump test, the Connecticut method does not determine whether the cause of failure is inadequate storage or inability of the aquifer to transmit sufficient water. The two-part pump test presented here uses a peak demand test followed by a constant head test. The constant head test measures the rate at which water can move from the aquifer to the well. This test determines whether or not the aquifer can transmit sufficient water for long-term needs. If the well fails either test, the constant head test provides guidance as to how the well might be modified to meet the household demand. For instance, if the well can meet the total daily demand but not the peak demand, the constant head test results can be used to estimate the depth to which the well would have to be drilled to provide sufficient storage in the bore-hole to meet the peak demand. If flow from the aquifer falls short of total daily demand, then the well must be deepened to encounter additional water-bearing zones or redrilled at another location, but the test cannot provide an estimate of the required well depth.

ASSUMPTIONS

In order to calculate peak load and peak time, the Connecticut formula and the modification presented here rely on four assumptions concerning water use. The assumptions are conservative. While one or more of the assumptions may not be met by a particular household, there is a sufficient margin of safety that water use estimates will be valid for determining the adequacy of wells for most peak periods for most families. Orndorff (1966) reported that on days when intensive chores are performed the peak demand may be several times the average demand. The assumptions are not valid for these days. The assumptions are:

1. Each person uses 100 gpd (gallons per day).

   Comments: The use of 100 gpd per capita is consistent with *Standards for the Construction of Public Non-Community and Non-Public Water Supplies* (NJAC 7:10-3.32), in which this value is applied as a planning criterion. This is a conservative figure which exceeds most measured values for water consumption. Reported average per capita consumption is approximately half this volume, or about 50 gpd (U. S. Environmental Protection Agency, 1978; Orndorff, 1966, p. 30, table 7). Average per capita consumptions of up to 80 gpd have been reported (Linaweaver and others, 1967, p. 2). In addition, in a detailed study of domestic water use Orndorff (1966) found that though total usage increases with family size, per capita usage decreases. This provides an additional margin of safety for larger families.

2. Two people occupy each bedroom.

   Comments: The average residency rate in the United States in 1980 was reported to be 2.75 residents per dwelling (U.S. Department of Commerce, 1981, table 10). Inasmuch as most new dwellings have two or more bedrooms, an estimate of two people per bedroom is conservative and allows for later addition of bedrooms or higher-than-average occupancy rates.

3. Most daily water usage occurs during two peak periods.

   Comments: In his study of domestic water use Orndorff (1966, p. 23) concluded that "peak demands tend to occur during two particular times of the day." One of these is in the morning and the other in the evening. While most water use occurs during these peaks, there is additional use at other times. Because of water use during off-peak times, it is reasonable that no more than half the total daily water use will occur during a single peak demand period. Differences in habitual water use patterns among families will thus seldom be such that peak water use will be underestimated.

4. Water flows through fixtures at the rate of three gallons per minute per bathroom during peak periods.

   Comments: This is the key assumption in estimating peak time (the duration of peak demand periods). In the Connecticut formula it is assumed that water use during peak time is in large part bathroom use. Orndorff (1966) points out that, although a normal daily peak demand can be determined statistically, water demand of particular households is established by habitual patterns. Bathroom use would be the prime example.

   New Jersey's *Standards for the Construction of Public Non-Community and Non-Public Water Systems* (NJAC 7:10- 3.10, et seq., 1978) require that water systems provide a minimum flow rate of 2 gpm at each plumbing fixture. Orndorff reported average peak demand rates of 1.60 gpm for a subdivision served by on-site wells and 2.29 gpm in homes served by an external water source. The use of 3 gpm provides a margin of safety above measured rates of water usage and the requirements established for domestic water supply systems.

For making calculations, it is assumed that water flows through the fixtures of a half bath at 1.5 gpm.

THEORY

Calculation of Household Water Demand

In order to establish conditions for a pump test, it is necessary to quantify the total daily demand and peak demand which will be placed on the well. Total daily demand is a function of the number of residents and per capita usage. Peak demand can be quantified in terms of volume, time and rate. The total volume of water the household will require during each of two daily periods of peak demand is the **peak load.** The average rate of use during peak demand times is the **peak demand rate.** The length of time within which the peak load demand for water will be exerted is the **peak time.**

To quantify the concepts of peak load, peak time and peak demand rate the following assumptions, discussed above, are applied:

1. each person uses 100 gallons per day.
2. two people occupy a bedroom.
3. most daily water usage occurs during two peak periods.
4. water flows through fixtures at the rate of three gallons per minute per bathroom during peak periods.

Under these assumptions equations for peak load, peak time and peak demand rate can be expressed as:

$$\text{peak load (gallons)} = \frac{\text{(no. of bedrooms) (persons/bedroom) (gallons/person/day)}}{\text{peak periods/day}}$$

$$= \frac{\text{(no. of bedrooms) (2) (100)}}{2} = \text{(no. of bedrooms) (100)} \qquad (1)$$

$$\text{peak demand rate (gpm)} = \text{(gpm/bathroom) (no. of bathrooms)}$$

$$= \text{(3) (no. of bathrooms)} \qquad (2)$$

$$\text{peak time (minutes)} = \frac{\text{peak load (gallons)}}{\text{peak demand rate (gpm)}} \qquad (3)$$

As an example, a three bedroom house with two bathrooms will have:

$$\text{peak load} = 3 \text{ bedrooms} \times 100 \text{ gallons/bedroom}$$
$$= 300 \text{ gallons}$$
$$\text{peak demand rate} = 3 \text{ gpm/bathroom} \times 2 \text{ bathrooms}$$
$$= 6 \text{ gpm}$$
$$\text{peak time} = 300 \text{ gallons/6 gpm}$$
$$= 50.0 \text{ minutes}$$

Pump Test Design

Well flow (discharge) is a combination of water pumped from the standing column of water in a well (the **well storage contribution**) and water flowing into the well from the aquifer (the **aquifer contribution**). In any well evaluation it is necessary to recognize that the well acts as a water storage area. Water is taken from well storage during peak demand times and gradually replenished from the aquifer during off-peak times.

At the beginning of the two-part pump test, the water in a well is at the static level: the water in the well and aquifer are at the same pressure and there is no net flow into or out of the well. As soon as the pump goes on for the peak demand test, water is removed from the casing and the water level drops. Because the pressure is now lower in the well than in the aquifer, water will flow from the aquifer into the well. Until the water level stops dropping, the discharge pumped from the well includes well storage and aquifer contribution components. In general, though certainly not always, the aquifer contribution will increase as the water level in the well drops.

For the constant head test the water level must be stable or nearly stable, neither dropping nor rising rapidly. The water level may stabilize during the peak demand test due to increase in aquifer contribution, or it may be stabilized by decreasing the pumping rate. When the water level and pumping rate are stable the well is said to be at equilibrium, the pumping to be at a constant head pumping rate and the water to be at a constant head level.

Peak Demand Test

The peak demand part of the two-part test determines whether or not the volume of water stored in the well plus the volume which will flow from the aquifer to the well during peak time will be sufficient for peak needs. The well is allowed to come to its static level, then is pumped at the peak demand rate for the peak time. A well for which the combined well storage and aquifer contributions are insufficient will fail before the expiration of the peak time.

Constant Head Test

The constant head test determines whether or not the aquifer contribution will meet long-term needs. An accurate measurement of the aquifer contribution can be made when the well is being pumped under constant head conditions. If a well is being pumped but the water level is not changing, the volume of water stored in the well is not changing. The well storage contribution is therefore zero and all water flowing from the well is coming from the aquifer; the aquifer contribution is equal to the measured pumping rate. If the aquifer contribution rate is less than the flow required for total daily needs (see tables 3 and 4), the well fails this portion of the test.

Test Results

If the well passes the constant head test but fails the peak demand test, the aquifer can supply enough water on a daily basis, but additional storage is required for peak demand needs. Storage may be provided in either the well or a surface storage tank.

If a well fails the constant head test it will not supply enough water on a daily average to meet household needs regardless of whether or not it passed the peak demand test. Aquifer contribution must be increased by developing, deepening or relocating the well.

Depth Required for Adequate Storage

If, for a well which has passed the constant head test but failed the peak demand test, storage is to be provided by deepening the well, the necessary well depth can be calculated from results of the constant head test. Two assumptions are necessary. The first is that there is no aquifer contribution until the drawdown in the well reaches the level measured during the constant head test. This is a conservative assumption. There is indeed aquifer contribution before the water level falls this far, but the rate is not measured during the test and is thus unknown. The second assumption is that as soon as the drawdown in the well reaches the level measured during the constant head test, the aquifer contribution begins at the rate measured at the conclusion of the constant head test and does not increase as the drawdown increases. This, also, is a conservative assumption, but is reasonable in that in a bedrock aquifer the most significant water-bearing zones are commonly associated with weathered fractures within several tens of feet of the soil/rock interface. Additional drawdown below the fractured or weathered zone may not induce much more water to flow into the well.

The volume of water which will enter the well from the aquifer during peak demand periods can be estimated using these assumptions. Subtracting this volume from the peak load gives the total volume of storage needed. Conversion of storage volume to additional depth required for drawdown is discussed under *Additional Drawdown for Wells Without Adequate Storage* in the *Implementation* section, below.

Surface Storage Tanks

The effect of surface storage of water on the well depth required for reliable peak supply can be taken into account by subtracting the available volume in the storage vessel from the peak demand. This gives the volume which must come from the well during each peak demand period. Dividing this lower volume by the peak demand rate gives the length of time the pump must operate during the peak demand period. The calculation of the necessary volume of well storage then proceeds as discussed above. The peak demand test should be carried out using the lower value for pumping time. The surface storage tank must, of course, be refilled, but if the well has passed the constant head test it should be possible to fill between peak demand periods.

Normally a domestic water supply system includes a hydropneumatic tank. A conventional hydropneumatic tank is intended primarily for maintenance of water pressure and contributes little to available water storage. Only that volume of water which drains from the tank before declining pressure causes the well pump to switch on contributes to available storage. This can be referred to as the available storage volume of the tank. An additional tank, dedicated to water storage and equipped as necessary to deliver water to the plumbing system of the house at the required pressure, could conceivably be installed.

Total Well Depth and Pump Placement

The pump must be placed in a well so as to allow for the maximum drawdown measured during the peak demand test. Pump size must be based on the required water pressure in the plumbing and the anticipated drawdown. Too deep of a pump setting can be as undesirable as too shallow a setting if the pump cannot deliver water at the required pressure. A balance must be struck between obtaining the storage advantage of maximum drawdown and ensuring adequate water pressure. This report attempts to prevent well failure caused by setting the pump at too shallow a depth.

IMPLEMENTATION

Testing of domestic wells is not usually conducted in a manner that establishes long-term performance capability. In fact, estimates of well yield are frequently made during drilling. In particular this is true with air rotary drilling when estimates of yield are based on the quantity of water lifted from the well with an air compressor. For an accurate test a pump with a discharge rate control is necessary; this might include the use of valves or a throttle on a generator used to power a pump.

An effective pump test must determine whether the well can supply both peak needs and total daily needs. In the method presented here, this is done using a two-part pumping test. The first part is the peak demand test and the second is the constant head test. Both of these must be performed in one continuous testing session. *It is important to note that the well is not considered to be satisfactory until it passes both tests during one continuous session.*

Peak Demand Test

The peak demand test is a drawdown pumping test to determine if the well can supply the water needed by the household during times of peak water demand. In this test the well is pumped at the peak demand rate estimated for the household for a time equal to or greater than the estimated peak time. If pumping can be maintained at this rate for the peak time, then the well should be able to support the peak needs of the household. If this pumping cannot be maintained, storage in the well is insufficient. The constant head test will provide further information as to the nature of the difficulty.

Constant Head Test

The constant head test is to determine if flow from the aquifer to the well can replenish water removed from the well during peak demand periods. In this test the pumping rate is adjusted so that the drawdown stabilizes. When the water in the well is at a constant level, one is certain that all of the discharge is coming from the aquifer, none from well storage. If under this constant head pumping condition the aquifer can supply the total daily household needs, then long-term needs can most probably be met. For the purposes of this report a constant head condition exists when the pumping rate is held steady and the water level changes at a rate of less than 6 inches per hour.

Outline of Testing Procedure

Planning of a pump test and evaluation of the results (figure 2) can be summarized as follows:

1. The well is constructed in accordance with state and local requirements.
2. The **peak demand rate** and **peak time** are calculated from the number of bedrooms and bathrooms using equations 2 and 3 or tables 1 and 2. Unless surface storage is to be taken into account, these are the required discharge rate and duration of the peak demand pump test.
3. The peak demand test is performed. For this test the pump should be positioned so as to take full advantage of the available drawdown in the well. The static water level in the well is measured prior to pumping. Then the well is pumped at the peak demand rate for the peak demand time. If pumping cannot be sustained at this rate the well fails the peak demand pump test. The water level at the completion of the peak demand test must be measured accurately for it is used to measure drawdown during the constant head test and, later, used to establish the pump setting.
4. The **constant head test** is undertaken *immediately* upon completion of the peak demand test regardless of whether or not the well passed the peak demand test.

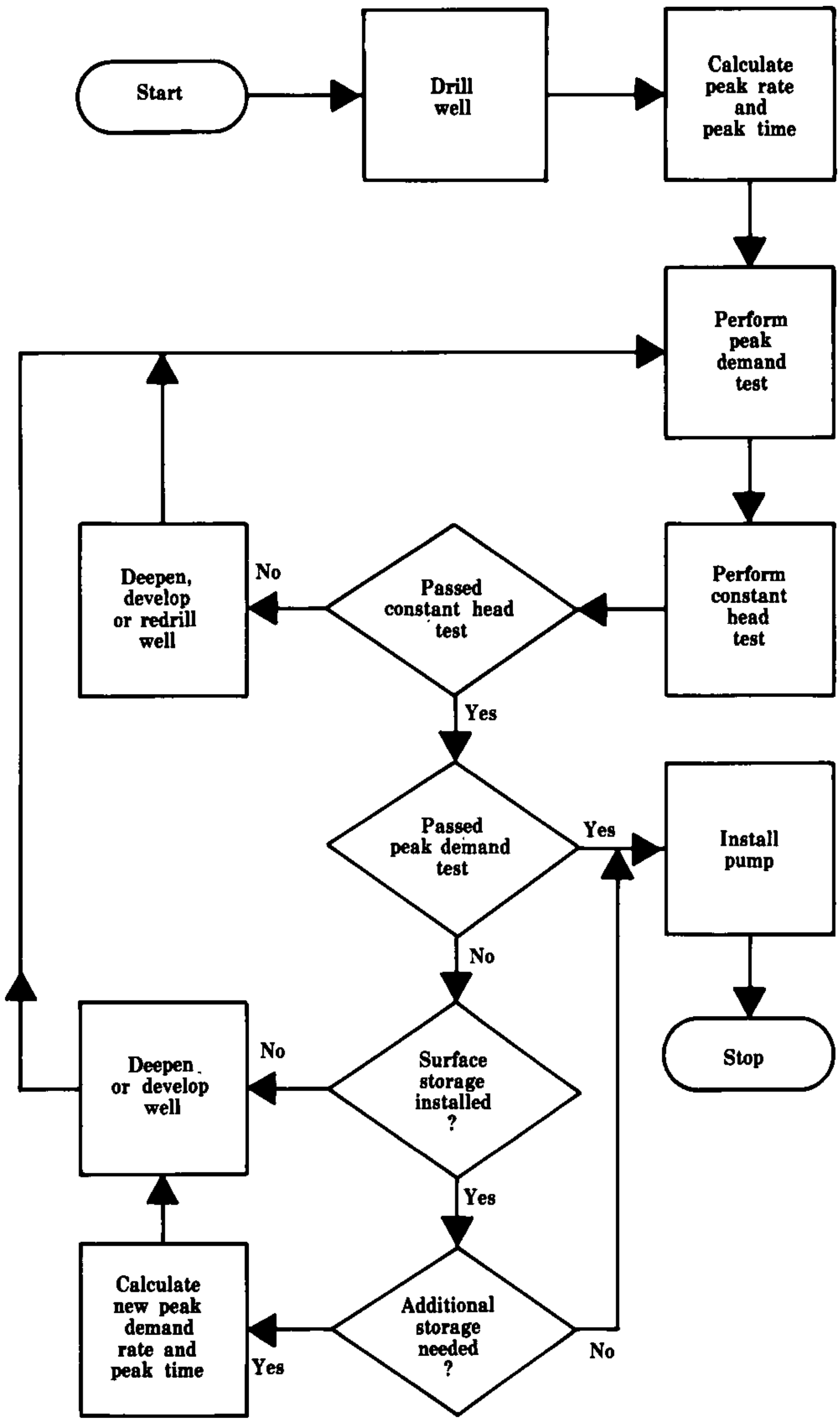

Figure 2. Flow chart of performance and evaluation of pump test.

The well is not allowed to recover from the peak demand test. In the constant head test the pumping rate is lessened, if necessary, to a rate at which the drawdown shows insignificant change with time. A **constant head condition** exists if the head changes at a rate of less than 0.5 feet (6 inches) per hour under a constant pumping rate. The pumping rate which maintains this condition is termed a **constant head pumping rate.** The water level at the constant head pumping rate must be measured accurately. The difference between this level and the static water level is the **constant head drawdown.** The constant head pumping rate should be as close as possible to the peak demand pumping rate, but the main objective is to achieve a stable water level while pumping. Too low a discharge rate will result in underestimation of the capabilities of the aquifer and may lead to overdeepening of the well.

5. The constant head pumping rate is converted to gallons per day (table 3) and compared to the total daily demand of the household. If the discharge rate during the constant head test will provide the total daily water demand, the well passes the constant head test. If not, it fails.

6. The results of the two tests are evaluated. The four possible outcomes are:

   a. Peak demand test—Pass
      Constant head test—Pass

      This well can supply the home with enough water. The pump should be installed as discussed under *Total Well Depth and Pump Placement* below.

   b. Peak demand test—Pass
      Constant head test—Fail

      This well, when full, can supply peak demand needs. However, more water will be withdrawn each day than can be replaced by the aquifer. This well will prove inadequate sooner or later. It must be deepened, developed or redrilled at a new location to provide a larger aquifer contribution. In bedrock aquifers the well may not encounter additional water-bearing zones at greater depth. The aquifer may not provide sufficient supply for domestic needs. If the well is redrilled, developed or deepened it must be retested.

   c. Peak demand test—Fail
      Constant head test—Pass

      This well lacks sufficient water from combined well storage and aquifer flow to meet peak needs. The aquifer contribution is, however, sufficient to meet total daily needs. More storage must be supplied to satisfy short-term peak demands. This can be accomplished by deepening the well and lowering the pump, redrilling to a greater diameter or adding a water storage tank. If the well is to be deepened, a method for calculating additional required depth is described in *Additional Drawdown for Wells Without Adequate Storage,* below. If a water storage tank is installed see *Surface Storage Tanks,* above. If the well is redrilled or developed it must be retested.

   d. Peak demand test—Fail
      Constant head test—Fail

      This well has neither sufficient storage nor sufficient aquifer contribution to ensure an adequate household supply. It must be deepened to encounter additional water-bearing zones, developed to increase flow to the well or a new well drilled elsewhere. Depending on the success of efforts to increase flow from the aquifer, storage may have to be increased. The well must be retested when any of the above procedures are completed.

Additional Drawdown for Wells Without Adequate Storage

A well that fails the peak demand test but passes the constant head test can be made satisfactory by providing additional storage. If additional storage is created by deepening the well, the necessary additional volume of storage and corresponding necessary available drawdown are found by calculating as follows:

A. *Assured volume:* The assured volume of water in the well is the volume in the well between the static water level and the constant head pumping level. Calculate this volume by multiplying the constant head drawdown by the storage capacity per foot of well casing (1.4 gallons per foot for a 6-inch well).

B. *Assured time:* This is the time it will take to pump the assured volume from the well. It is calculated by dividing the assured volume by the peak demand rate.

C. *Shortfall volume:* This is the volume of water which must be supplied after the assured volume has been withdrawn from the well. It is calculated by subtracting the assured volume from the peak load.

D. *Shortfall time:* This is the time within which the well must supply the shortfall volume. It is calculated by subtracting the assured time from the peak time.

E. *Aquifer contribution volume:* This is the volume of water the aquifer is predicted to supply to the well during the shortfall time. During the shortfall time water is assumed to be moving from the aquifer to the well at the aquifer contribution rate measured during the constant head test. Aquifer contribution volume is calculated by multiplying the aquifer contribution rate by the shortfall time.

F. *Additional well storage volume:* This is the volume of water which must be withdrawn from well storage after the assured volume has been pumped. It is calculated by subtracting the aquifer contribution volume from the shortfall volume.

G. *Additional well drawdown:* This is the additional drawdown required beyond the constant head drawdown. It is calculated by dividing the required additional well storage volume by the storage capacity per foot of well casing (1.4 gallons per foot for a 6-inch well).

Equations for this sequence of calculations are:

A. assured volume
   = constant head drawdown X storage capacity per foot of well casing

B. assured time = assured volume/peak demand rate

C. shortfall volume = peak load - assured volume

D. shortfall time = peak time - assured time

E. aquifer contribution volume
= shortfall time X aquifer contribution rate

F. additional well storage volume
= shortfall volume - aquifer contribution volume

G. additional well drawdown
= additional well storage volume/storage capacity per foot of well casing of well

The additional well drawdown is the predicted drawdown below the constant head level at the end of peak time. It is used to calculate the required well depth as shown in *Total Well Depth and Pump Placement*, below. After deepening or redrilling, both parts of the pump test must be redone during a single testing session.

Total Well Depth and Pump Placement

It is recommended that the pump be placed at least 10 feet below the depth to water measured at the end of a successful peak demand pump test. Also, in order to prevent siltation problems, the pump should be placed at least 10 feet above the bottom of the well. An equation for minimum pump depth is:

minimum pump depth
= depth to water at end of successful peak demand pump test + 10 feet

As an additional safety precaution the pump depth can be increased beyond that suggested here, thus allowing for more drawdown than measured during testing. This will require a well deeper than the minimum shown above and may necessitate a more powerful pump.

EXAMPLES

Example 1: Well passes both parts of test

A builder proposes a 3 bedroom, 2 bathroom house. From table 1 the pump test should last for at least 50 minutes. From table 2, the pumping rate should be at least 6 gpm.

A well was drilled, allowed to stand for 12 hours to come to its static water level, then was pumped at 8 gpm for 1 hour. After 1 hour of pumping the drawdown was 22.0 feet. In being pumped at 8 gpm for 1 hour, the well more than met the peak demand requirements and passed the peak demand test.

The constant head test was begun without pause in a second hour of pumping, also at 8 gpm. At the end of the second hour the drawdown was 22.2 feet. Because of this small change in the drawdown the well was properly considered to be at a constant head level. 8 gpm is equvalent to more than 11,000 gallons per day (table 3). A 3 bedroom house will require 600 gallons per day (table 4). The well thus passed the constant head test.

Because the well passed both parts of the pump test the production pump can be set according to the minimum safety allowance at 10 feet lower than the drawdown measured during the peak demand pump test; this is 32 feet below the static water level. Setting the pump deeper would provide an additional margin of safety. The pump should be placed at least 10 feet above the bottom of the well as a precaution against siltation.

Example 2: Well fails peak demand test

A 5 bedroom, 3 bathroom house is proposed. A 6-inch well 250 feet deep has been drilled and allowed to stand for 12 hours to come to its static water level.

From table 4, the daily household water demand will be 1000 gallons and the peak load 500 gallons. From tables 1 and 2 the peak demand pump test should last at least 55.5 minutes and the discharge rate should be at least 9 gpm.

Before pumping, the static water level was measured at 25 feet below the ground surface. At a pumping rate of 9 gpm the well failed after 33 minutes. The driller therefore proceeded directly to the constant head test. After some trial and error, the driller determined that 2 gpm was the maximum rate at which a constant head could be maintained. At the end of the constant head test the water level in the well was 230 feet below the top of the casing.

An aquifer contribution of 2 gpm is equivalent to 2,880 gallons per day (table 3) and will satisfy long-term needs. The well passed the constant head test. It failed, however, the peak demand test. The problem therefore lies in an inadequate volume of storage. The driller decided to deepen the well to provide additional storage in the borehole and calculated the additional required drawdown as outlined in *Depth Required For Adequate Storage* and below:

The constant head drawdown at a 2 gpm pumping rate is the constant head pumping level of 230 feet minus the static water level of 25 feet. This comes to 205 feet.

The assured volume (the volume of water stored in the well between the static water level and the level measured in the constant head test) is 205 feet of drawdown times 1.4 gallons per foot of casing. This comes to 287 gallons.

The assured time (the time it will take to pump out the assured volume) is 287 gallons divided by the peak demand rate of 9 gpm, or 31.9 minutes.

The shortfall time is 55.5 minutes (the peak time) minus 31.9 minutes (the assured time), or 23.6 minutes.

The shortfall volume is 500 gallons (the peak load) minus 287 gallons (the assured volume), or 213 gallons.

During the shortfall time the aquifer contribution is constant at 2 gpm. The total aquifer contribution volume is thus 2 gpm times 23.6 minutes, or 47.2 gallons.

The volume of water which must be stored in the well below the constant head level is 213 gallons (the shortfall volume) minus 47.2 gallons (the aquifer contribution volume during peak time). This comes to 165 gallons.

The additional required drawdown is calculated by dividing the shortfall volume of 165 gallons by the storage capacity of 1.4 gallons per foot of well casing. This comes to 118 feet.

The maximum predicted drawdown is 205 feet (the maximum drawdown during the constant head test) plus 118 feet (the additional drawdown for peak needs calculated above) plus 10 feet (the minimum safety allowance). This comes to 323 feet below the static water level.

The total well depth then should be at least 25 feet (the static water level) plus 323 feet (the maximum predicted drawdown below the static level) plus 10 feet (pump placement above well bottom). This comes to a total of 368 feet.

The well must therefore be deepened to a minimum depth of 368 feet, then retested.

ADDITIONAL CONSIDERATIONS

The two-part pump test is a means of evaluating the capability of a well to supply domestic needs. The interpretation of test results is mathematical and may not take into account all the physical factors that affect a particular well. Some additional considerations are listed below:

1. *Seasonal recharge variations:* Pump tests performed during times of seasonally high ground water may not accurately predict performance during times of reduced water availability. A well that passes a pumping test in the spring, during high water-table conditions, may not be able to provide an adequate supply in summer or during drought periods when the water table is lower. Tests performed between June and October are more reliable than those performed in the rest of the year in determining if a well will satisfy household water demands.

2. *Low aquifer contribution:* The aquifer contribution as defined in this report is the volume of water that flows from the aquifer to the well during pumping. Table 4 shows that a one-bedroom house requires 200 gallons per day, which is equivalent to 0.14 gallons per minute. This is an extremely low aquifer contribution value. Experience has shown that a well with an aquifer contribution of less than 0.5 gpm (720 gpd) is a marginally dependable source of water for domestic use. It is recommended that a minimum cut-off of 0.5 gpm be established for the aquifer contribution.

3. *Addition or withdrawal of water during drilling:* During drilling water may be added to the aquifer or withdrawn depending upon the drilling method used. Immediately after completion of drilling the heads in the aquifer near the well may not be at static (unstressed) levels. The pump test should be conducted after any stresses induced by the drilling process have dissipated. A 12-hour recovery period is recommended between completion of drilling and performance of the pump test.

4. *Storage capacity:* Chapter 199 of NJAC 7:10-3.85 specifies minimum hydropneumatic tank sizes. These tanks maintain pressure in household water systems. They provide some storage, but this is not their primary purpose. They never empty completely, so the available storage in these tanks is less than their total volume. The presence of tanks specified in the regulations, or larger tanks dedicated solely to water storage, may be taken into account when calculating peak demand volumes.

5. *Large households:* The assumptions that relate dwelling size to household water demand may not be applicable to large dwellings that are not fully occupied. For homes with more than 5 bedrooms or 3 bathrooms it may prove advisable to use a different method to predict peak demand time, peak load and peak demand rate.

6. *Pump discharge:* In areas of vertical fracturing and thin or permeable overburden, water discharged at the surface may quickly infiltrate to the water table. If a pump test is conducted at such a site and the water pumped from the well is discharged at the well head, the water may return to the well as artificial recharge. Because this recharge will not be present during normal operation of the well, aquifer contribution will be overestimated. Water should be discharged at a distance from the well head in order to minimize this possibility.

7. *Drawdown safety factor:* A drawdown safety factor of 10 feet was recommended above. That is, the pump is to be set 10 feet below the drawdown level measured during the peak demand pump test. This level may be increased if a well is drilled in an aquifer known for large water level fluctuations.

8. *Well diameter:* Normally, domestic wells drilled in rock aquifers have a diameter of 6 inches. This provides approximately 1.4 gallons of storage per foot of drawdown in the casing. Increasing the well diameter will increase the storage per foot of well depth. The increased storage can be accounted for by using the appropriate value for the storage capacity per foot of drawdown.

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TABLES

Table 1: Duration of **peak time** in minutes as a function of the numbers of bedrooms and bathrooms in a dwelling.

		Number of Bathrooms				
		1	**1½**	**2**	**2½**	**3**
Number of Bedrooms	1	33.3	22.2	16.7	13.3	11.1
	2	66.7	44.4	33.3	26.7	22.2
	3	100.0	66.7	50.0	40.0	33.3
	4	133.3	88.8	66.7	53.3	44.4
	5	166.7	111.1	83.3	66.7	55.5

Table 2: **Peak demand rate** as a function of the number of bathrooms in a dwelling.

Number of Bathrooms	**Peak Demand Rate (gpm)**
1	3
1½	4.5
2	6
2½	7.5
3	9

Table 3: **Flow volumes** in gallons per minute corresponding to flow volumes in gallons per day.

Flow Volume (gpm)	**Flow Volume (gpd)**
0.01	14.4
0.02	28.8
0.05	72.0
0.1	144.0
0.2	288.0
0.3	432.0
0.4	576.0
0.5	720.0
0.6	864.0
0.7	1,008.0
0.8	1,152.0
0.9	1,296.0
1.0	1,440.0
2.0	2,880.0
5.0	7,200.0
10.0	14,400.0

Table 4: **Daily demand volume** and **peak load** as a function of the number of bedrooms in a dwelling.

Number of Bedrooms	**Daily Demand Volume (gallons)**	**Peak Load (gallons)**
1	200	100
2	400	200
3	600	300
4	800	400
5	1,000	500

DOMESTIC WELL WORKSHEET FOR TWO-PART PUMP TEST

PUMP TEST

Test Design

Preliminary Well Summary

1. Depth of well .... ______ feet
2. Static water level (depth to water from top of casing) .... ______ feet
3. Number of hours between well completion and measurement of static water level .... ______ hours

Dwelling Summary

4. Number of bedrooms .... ______
5. Number of bathrooms .... ______

Peak Demand Test Requirements

6. Peak time (required minimum duration of test, from table 1) .. ______ minutes
7. Peak demand rate (required minimum discharge rate from pump during test, from table 2) .... ______ gpm
8. Peak load (from table 4) .... ______ gallons

Test Measurements

Peak Demand Test

9. Depth to water at beginning of test (static water level) .... ______ feet
10. Depth to pump at end of test ...... ______ feet
11. Discharge rate measured during test (use minimum observed) .... ______ gpm
12. Duration of test .... ______ minutes
13. Depth to water at end of test ...... ______ feet
14. Drawdown at end of peak demand test .... line 13—line 9 = ______ feet

Constant Head Test

15. Constant head pumping rate .... ______ gpm
16. Duration of pumping at constant head rate .... ______ minutes
17. Depth to water at end of test ...... ______ feet
18. Drawdown at end of constant head test .... line 17—line 9 = ______ feet

Evaluation of Results

19. Peak demand test duration. If line 12 is less than line 6 then well fails peak demand test ...... ______ pass or fail
20. Peak demand pump test rate. If line 11 is less than line 7 then well fails peak demand test ...... ______ pass or fail
21. Calculate aquifer contribution (multiply line 15 by 1440 or use table 3) .... ______ gpd
22. Daily home water demand (from table 4) .... ______ gpd
23. Aquifer contribution rate. If line 21 is less than line 22 then well fails constant head pump test ... ______ pass or fail

DOMESTIC WELL WORKSHEET FOR TWO-PART PUMP TEST

Actions Based on Test Results

Peak demand test	Constant head test	Action
24. pass	pass	Go to *Pump Placement and Minimum Well Depth* (lines 35-37).
25. fail	pass	The well must be developed to increase yield, deepened to increase storage or surface storage installed. If the well is deepened or developed, it must be retested. Go to lines 28-34 (*Additional Drawdown for a 6-inch Well With Insufficient Storage*)
26. pass	fail	The well must be developed, deepened or redrilled at a new location to increase yield. It must then be retested.
27. fail	fail	The well must be developed, deepened or redrilled at a new location to increase yield. It must then be retested.

ADDITIONAL DRAWDOWN FOR A 6-INCH DIAMETER WELL WITH INSUFFICIENT STORAGE

28. Assured volume .... line 18 X 1.4 gallons/foot = ______ gallons
29. Assured time .... line 28/line 7 = ______ minutes
30. Shortfall volume .... line 8 - line 28 = ______ gallons
31. Shortfall time .... line 6 - line 29 = ______ minute
32. Aquifer contribution volume .... line 15 X line 31 = ______ gallons
33. Required additional storage .... line 30 - line 32 = ______ gallons
34. Additional drawdown needed in well .... line 33/1.4 gal/ft. = ______ feet

TOTAL WELL DEPTH AND PUMP PLACEMENT

35. Minimum total drawdown needed .... line 14 + 10 feet = ______ feet
36. Depth below top of casing to place pump .... line 9 + line 35 = ______ feet
37. Minimum total depth of well .... line 36 + 10 feet = ______ feet

GLOSSARY

Aquifer contribution: the proportion of the well flow at any given time which comes directly from the aquifer.

Aquifer contribution rate: the maximum rate at which water can flow from an aquifer to a well. Here assumed to equal the pumping rate measured in the constant head test.

Aquifer contribution volume: the total volume of water which flows from the aquifer to the well during the shortfall time.

Assured time: the time it will take to pump the assured volume from the well at the peak demand rate.

Assured volume: the volume of water in a well below the static level and above the constant head level.

Constant head: a stable water level attained under a constant pumping rate. For this report a rate of change of less than 0.5 feet (6 inches) per hour is taken as stable.

Constant head drawdown: the drawdown in a well when a constant head condition has been attained. Here measured from the static water level at the end of the constant head test.

Constant head level: the water level in a well at the end of the constant head test. Measured from the top of the casing.

Constant head pumping rate: a constant pumping rate at which a stable water level is attained. The pumping rate during the constant head test.

Constant head test: a pumping test in which pumping rate and drawdown are kept constant with time. For this report a rate of change of less than 0.5 feet (6 inches) per hour is taken as constant.

Drawdown: the decline in the water level in a well during pumping. Measured from the static water level prior to pumping.

Hydropneumatic tank: a tank which uses compressed air to maintain pressure in a water supply system. It is only secondarily a water storage tank.

Peak demand rate: the average rate of water use by a household during peak demand periods.

Peak demand test: a pumping test conducted to evaluate the capability of a well to supply peak demand needs of a household. The test is conducted at a rate equal to or greater than the peak demand rate for the peak time.

Peak load: the volume of water required by a household during each peak demand period. In this report, the peak load is assumed to be half the estimated total daily household water consumption.

Peak time: the length in minutes of each of two daily peak demand periods.

Shortfall time: the time needed to pump the shortfall volume from a well at the peak demand pumping rate.

Shortfall volume: the volume of water needed in addition to the assured volume to make up the peak load.

Static level: the water level in a well before a pumping test when all effects of drilling and previous pumping on the aquifer have dissipated and the well is in equilibrium with atmospheric pressure.

Storage contribution: the proportion of the well flow at any given time which comes from storage in the well.

Well flow: the flow rate of water from a well at a given time. It is the sum of the aquifer contribution and the well storage contribution.

Well storage: the volume of water stored within a well which is available for pumping.

UNITS OF MEASUREMENT

Foot-pound-second (english) units of measurement are used in this report. These can be converted to International Standard (SI) units as follows:

Multiply	by	to obtain
inches	2.54	centimeters
feet	0.305	meters
gallons	3.79×10^{-3}	cubic meters
gallons/minute	6.31×10^{-2}	liters/second
gallons/day	3.79×10^{-3}	cubic meters/day

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