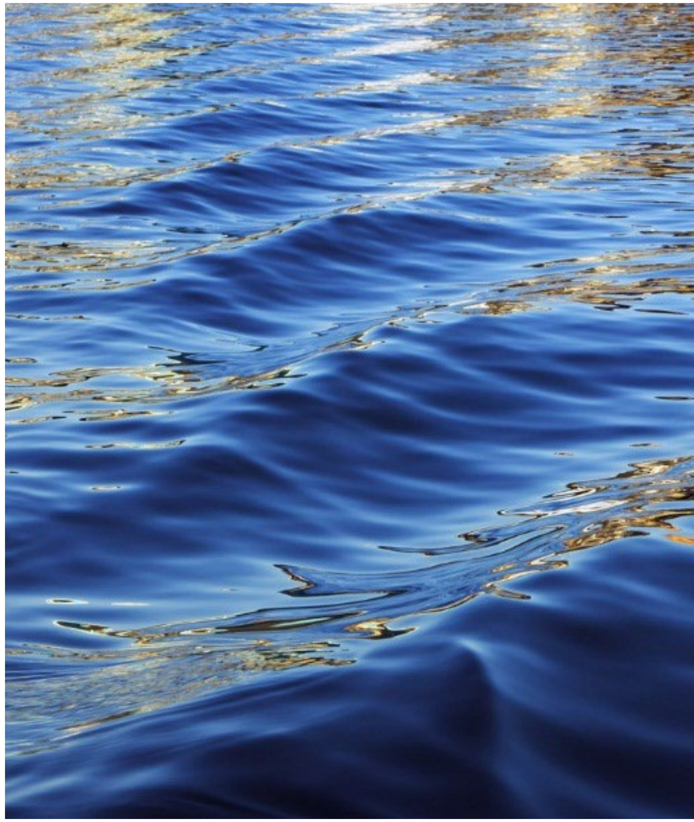
Planning, Designing, and Installing Shallow Wells

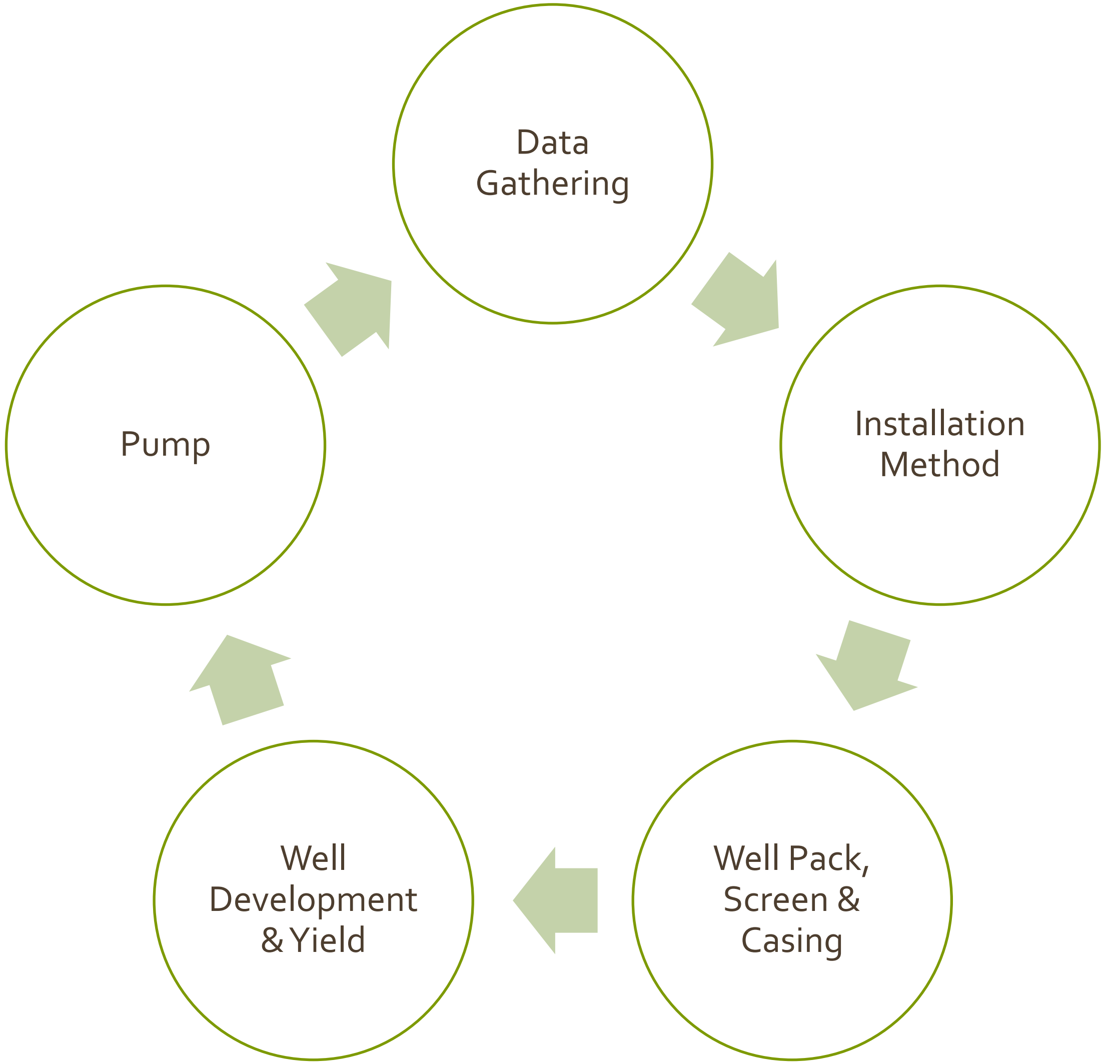
Identify an efficient shallow well system suitable for existing saturated soil and saturated granular surficial geology conditions.



Joseph Ayotte, Supervisory Hydrologist, USGS New England Water Science Center, Pembroke, NH
Manuel Diaz, Agricultural Engineer, USDA NRCS, Amherst, MA

A simplified process of: Planning, Designing, and Installing Shallow Wells

- Data gathering
  - Soil, watershed, surficial geology, neighboring wells, and aquifer material sampling and analysis.
- Installation method
  - Excavator, hand auger, hydraulic auger, drill.
- Well pack, screen and casing
  - Natural or artificial well filter pack.
  - Concrete, HDPE, PVC or stainless-steel screen and/or casing.
  - Well diameter.
- Well development and well yield
  - Over pumping, backwashing, mechanical surging, pressurized air, water/air jetting.
- Pump
  - Surface or submersible.



Introduction: Saturated soil

Test pit after 3 minutes

Test pit after 3 hours

We typically call soil the material in the top 5 ft from the surface. Underlaying saturated conditions can bring water up to otherwise unsaturated layers. The opposite also can apply.

Introduction: Saturated granular surficial geology

Water table located in glacial till, about 14 ft under the soil surface.

Hydraulic auger hit confined aquifer under dense layer.

Surficial geology is typically referred to the unconsolidated material that lay between 5 ft under the surface and the depth to bedrock.

A novel shallow well technology to provide safe, sustainable drinking and irrigation water

Joseph Ayotte, Hydrologist
USGS New England Water Science Center

2022 USDA Science and Technology Training Library Webinar
November 22, 2022

What this talk will cover

1. The increasing need for clean, reliable water supplies for domestic and agricultural use
2. Dug wells, historical design, and problems
3. A novel shallow well design that is drought resilient
4. A pilot study to assess well performance

New dug well in upland setting

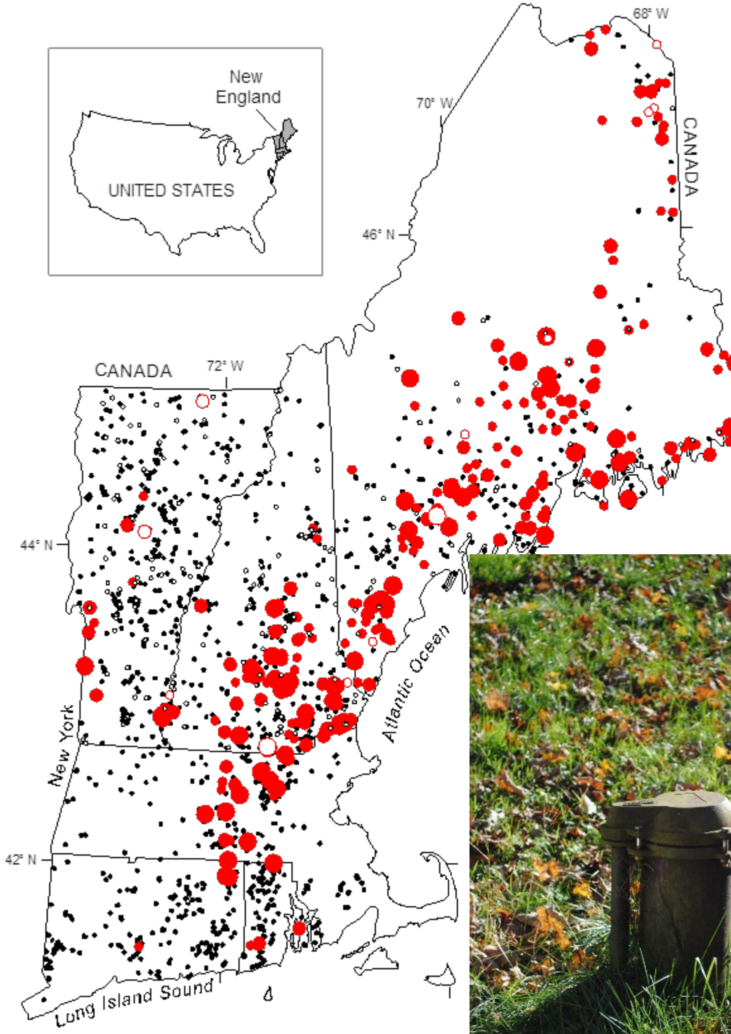
USGS

Impetus for a new dug well

1. Arsenic is a common contaminant in bedrock aquifer wells in eastern New England (20 to 50% of wells).

2. Arsenic in glacial aquifers in New England is *low* due to **acidic pH** and **oxic water**.

Are there alternatives to drilling new wells into rocks that consistently contain high-arsenic water?



doi:10.1021/es026211g

The need for water

The potential for drought conditions has increased interest in water for irrigation in New England.

1. Bedrock wells comprise nearly 100% of all new private supply wells, but are costly and lack storage.

2. A new well design, developed to reduce exposure to arsenic, also is drought resilient and can be used to meet small-scale agricultural needs due, in part, to large storage capacity.

The glacial till aquifer

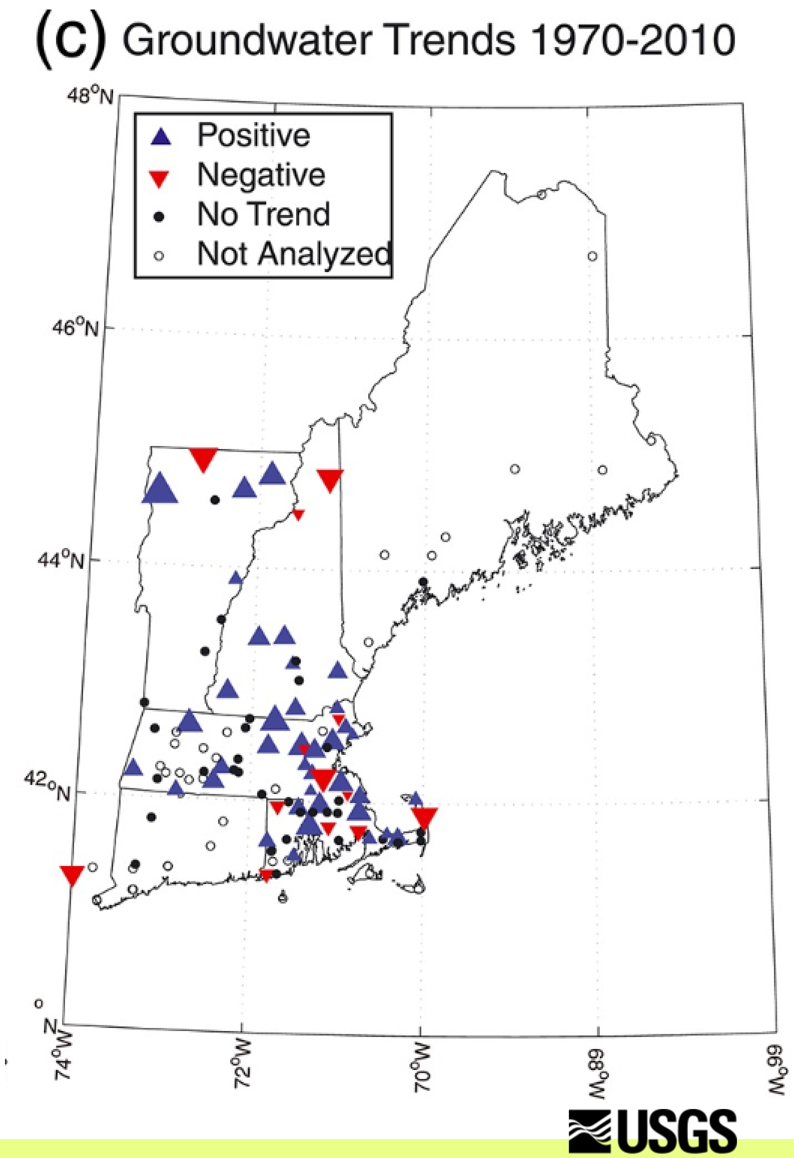
Hydrological Processes

RESEARCH ARTICLE | Full Access

Assessing hydrogeologic controls on dynamic groundwater storage using long-term instrumental records of water table levels

David F. Boutt

First published: 30 December 2016 | https://doi.org/10.1002/hyp.11119 | Cited by: 1



Till aquifers have 70% of the active groundwater storage…
…connected bedrock aquifers have less storage than the till.

<u>HOWEVER</u>:

1. Till aquifers can provide sustainable (As-free) water supply.
2. Traditional "dug wells", due to bacteria and yield issues, have obscured this notion.

Drilling Deeper?

MENU

nature sustainability

Analysis | Published: 22 July 2019

Deeper well drilling an unsustainable stopgap to groundwater depletion

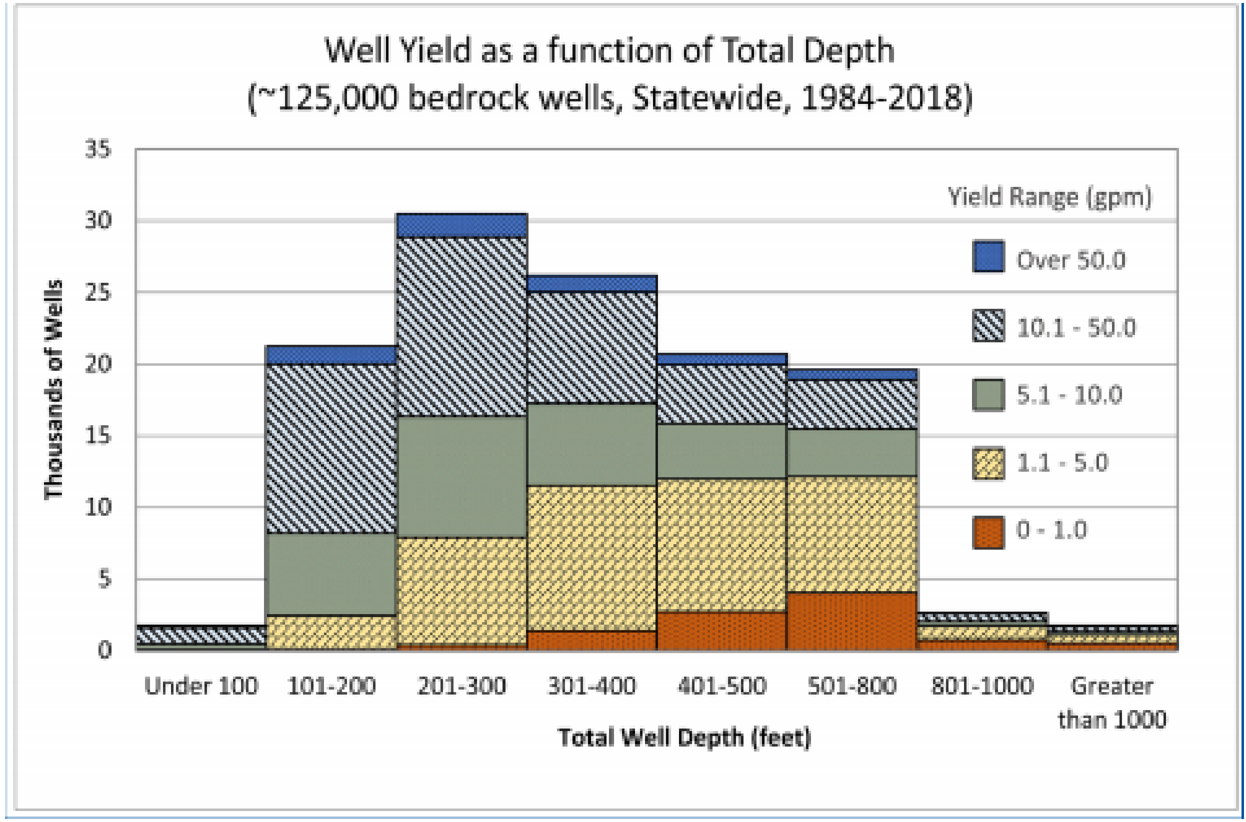
Debra Perrone & Scott Jasechko

Nature Sustainability (2019) | Download Citation

Abstract

Groundwater depletion is causing wells to run dry, affecting food production and domestic water access. Drilling deeper wells may stave off the drying up of wells—for those who can afford it and where hydrogeologic conditions permit it—yet the frequency of deeper drilling is unknown. Here, we compile 11.8 million groundwater-well locations, depths and purposes across the United States. We show that typical wells are being constructed deeper 1.4 to 9.2 times more often than they are being constructed shallower. Well deepening is not ubiquitous

New Hampshire DES Supply Lines with the Source | Fall 2019



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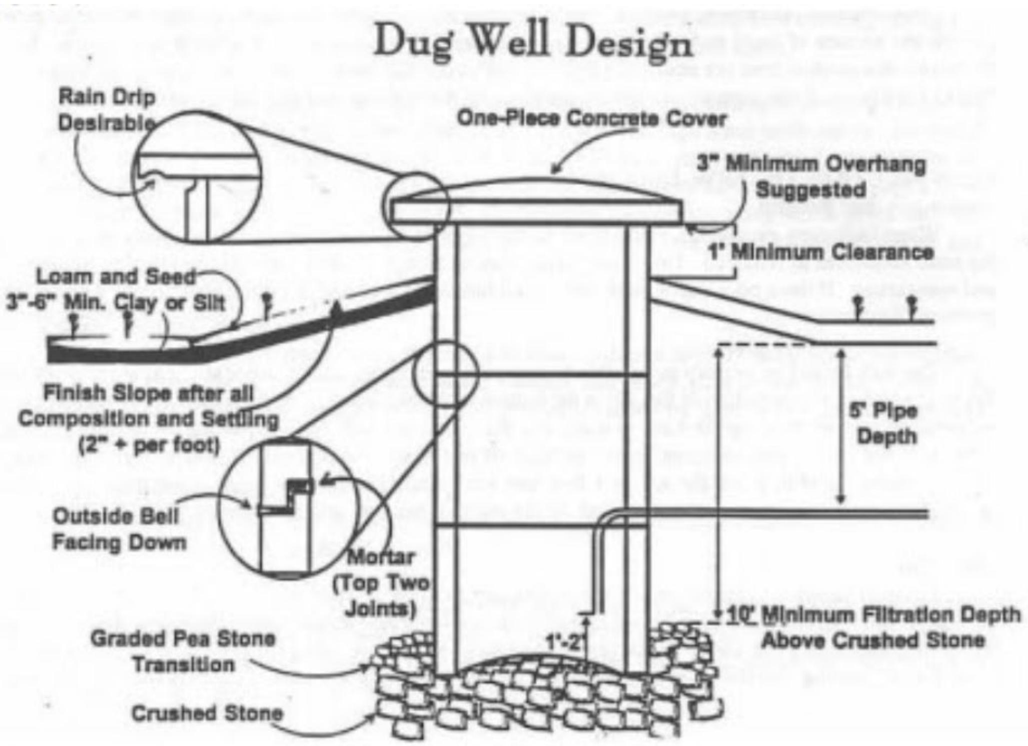
Historical “dug well” design



Historical problems:

- Small inflow area at bottom and sides means low yield and no-water periods.
- Insufficient storage for immediate use while aquifer recharges well.
- Prone to bacteria and animal entry through joints and the concrete cap.

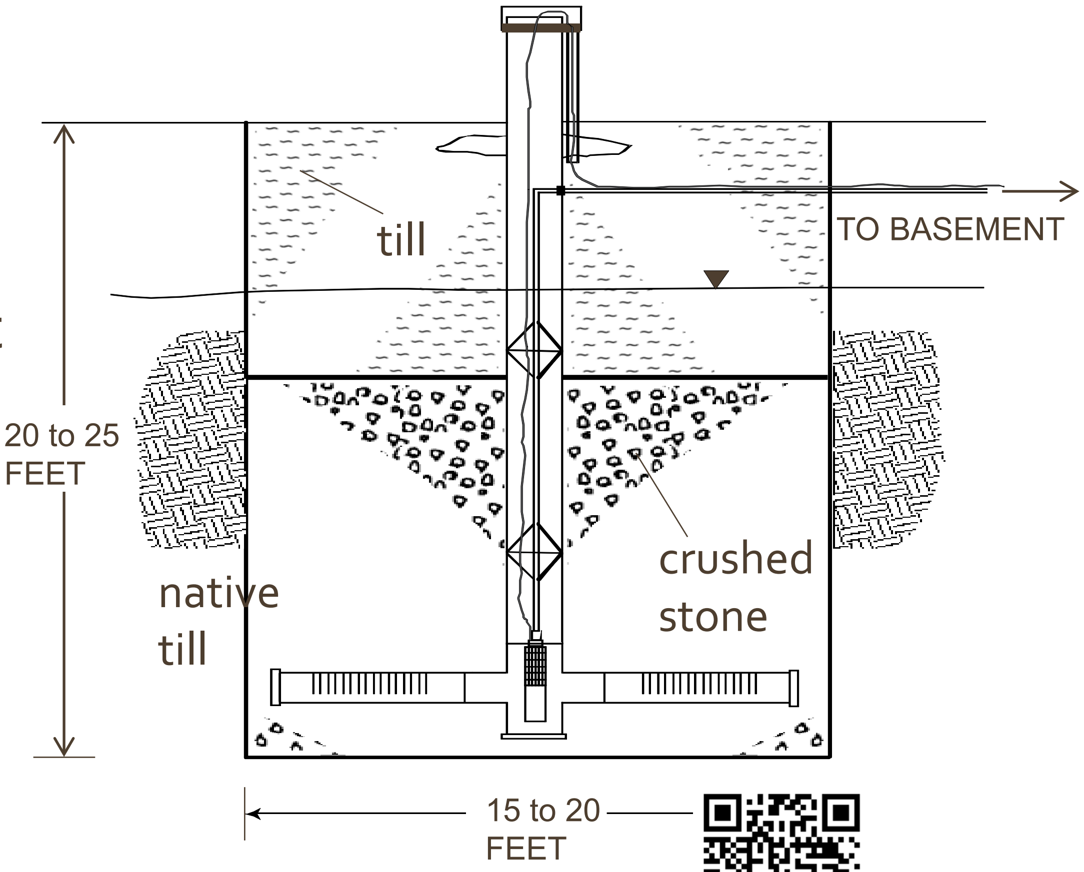
https://www.des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-1-4.pdf

USGS

A new shallow well design

New approach:

- Large inflow area means higher yield and drought resiliency.
- Thousands of gallons of storage for use while aquifer recharges well.
- Resists bacteria and animal entry through single casing and sealed cap.



US Patent 9,689,235 B1
, June 27, 2017

Groundwater

Performance Assessments of a Novel Well Design for Reducing Exposure to Bedrock-Derived Arsenic

by Richard B. Winston[1] and Joseph D. Ayotte[2]

Abstract

Arsenic in groundwater is a serious problem in New England, particularly for domestic well owners drawing water from bedrock aquifers. The overlying glacial aquifer generally has waters with low arsenic concentrations but is less used because of frequent loss of well water during dry periods and the vulnerability to surface-sourced bacterial contamination. An alternative, novel design for shallow wells in glacial aquifers is intended to draw water primarily from unconsolidated glacial deposits, while being resistant to drought conditions and surface contamination. Its use could greatly reduce exposure to arsenic through drinking water for domestic use. Hypothetical numerical models were used to investigate the potential hydraulic performance of the new well design in reducing arsenic exposure. The aquifer system was divided into two parts, an upper section representing the glacial sediments and a lower section representing the bedrock. The location of the well, recharge conditions, and hydraulic properties were systematically varied in a series of simulations and the potential for arsenic contamination was quantified by analyzing groundwater flow paths to the well. The greatest risk of arsenic contamination occurred when the hydraulic conductivity of the bedrock aquifer was high, or where there was upward flow from the bedrock aquifer because of the position of the well in the flow system.

Introduction

Arsenic in groundwater is a problem for domestic well owners both in the United States and worldwide and can be difficult to remediate (Zheng and Ayotte 2015). In New England, more than 10% of domestic wells drilled into fractured crystalline bedrock are at risk for concentrations of arsenic higher than the maximum contaminant level of 10 μg/L (Flanagan et al. 2012). In parts of eastern New England, the percentage can range from 20% to 30%, making arsenic a significant issue for domestic well owners (Ayotte et al. 2003; Yang et al. 2009). There are significant barriers to testing and treating domestic well water to make it safe for human consumption, such as cost, understanding, and optimism bias (Flanagan et al. 2012). As a result, as long as domestic well owners are responsible for testing and treating their well water, there will always be significant exposure to arsenic from groundwater used for drinking water (Zheng and Ayotte 2015).

One potential solution to reducing risk of arsenic exposure would be to manage the sources of well water. In New England, this can be done by increasing the use of glacial aquifers that overlie much of the region for drinking water. Water from the glacial aquifer is generally oxic with a low pH conditions that cause arsenic to adsorb to aquifer materials and be removed from groundwater. In contrast, the bedrock aquifer is generally anoxic with a high pH: conditions that enhance arsenic solubility in the groundwater (Smedley and Kinniburgh 2002; Stollenwerk 2003).

The glacial aquifer is seldom used for domestic drinking water wells today in New England because pumping combined with low water levels during dry periods frequently causes loss of well water. Such wells are also vulnerable to surface-sourced bacterial contamination (New Hampshire Department of Environmental Services 2010). In Bangladesh, concerns for lack of sanitary well conditions drove wells deeper over time, which not unlike New England, resulted in greater exposure to inorganic arsenic in drinking water (Jo … 90% of new wells are curr… ifers (Flanagan et al. 2012… vells installed in glacial ac… well design. For example, … shift

[1]Corresponding author: U.S. Geological Survey, MS 431 12201 Sunrise Valley Drive, Reston, VA 20192; rbwinst@usgs.gov
[2]U.S. Geological Survey, 331 Commerce Way, Pembroke, NH, 03301.

Article impact statement: New dug well design helps homeowners reduce arsenic exposure. The design is drought resistant.

Received September 2016, accepted September 2017.

doi: 10.1111/gwat.12603

USGS

New shallow well study

Well screen details

Well construction – glacial till aquifer

Well construction – casing and stone

Preparing the base

Setting the casing

Filling in around the casing

USGS

Geotextile and backfill

USGS

Pitless adapter and water line

USGS

Construction data for pilot study wells

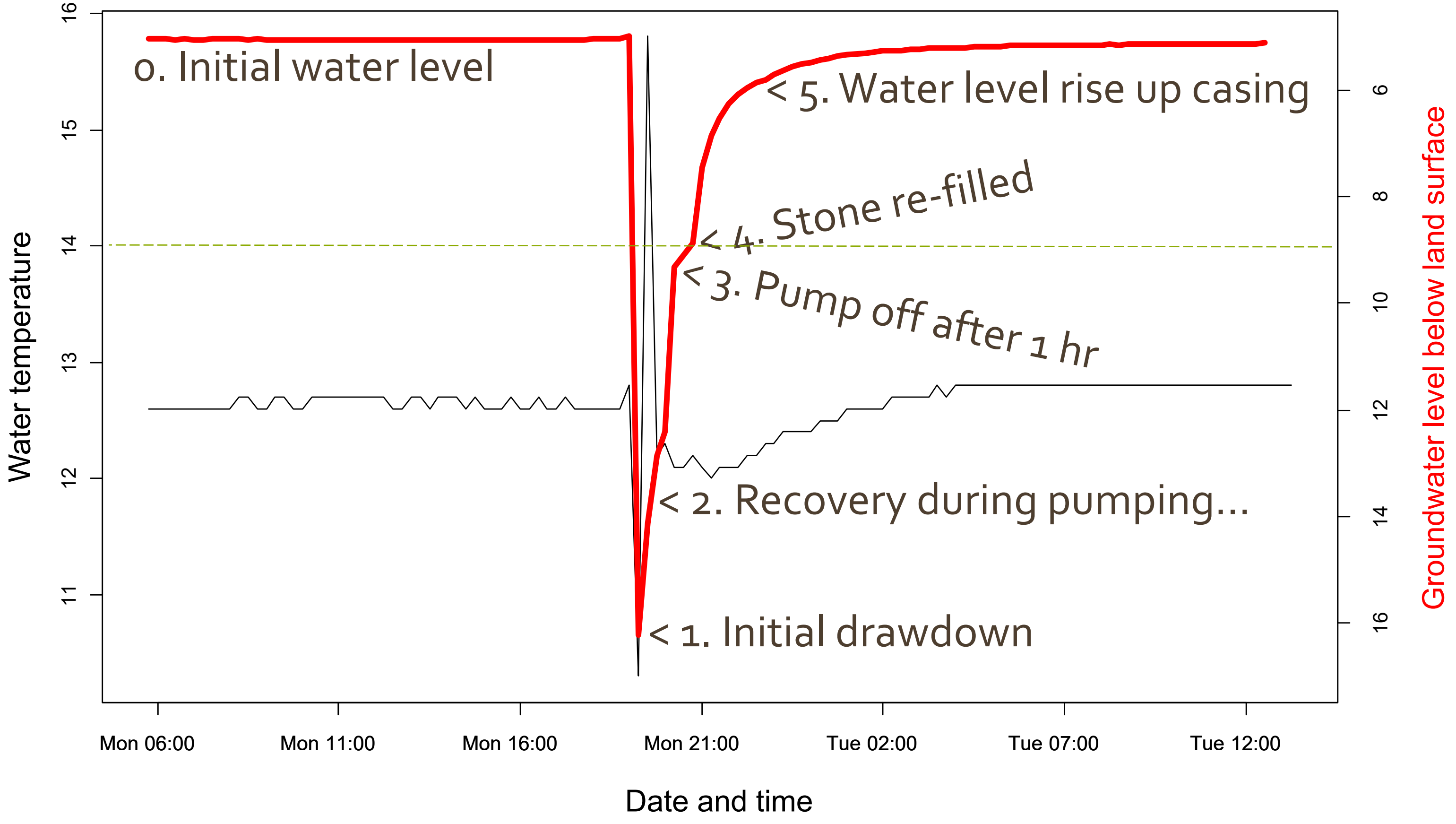
Groundwater discharge area

Area of well = 246.5 ft^2
Volume of water in stone = ~6,600 gal.
Well yield = est. **3.9 gpm**

Groundwater recharge area

Area of well = 321.75 ft^2
Volume of water in stone = ~4,800 gal.
Well yield = est. **0.55 gpm**

Pump test at 8 gpm



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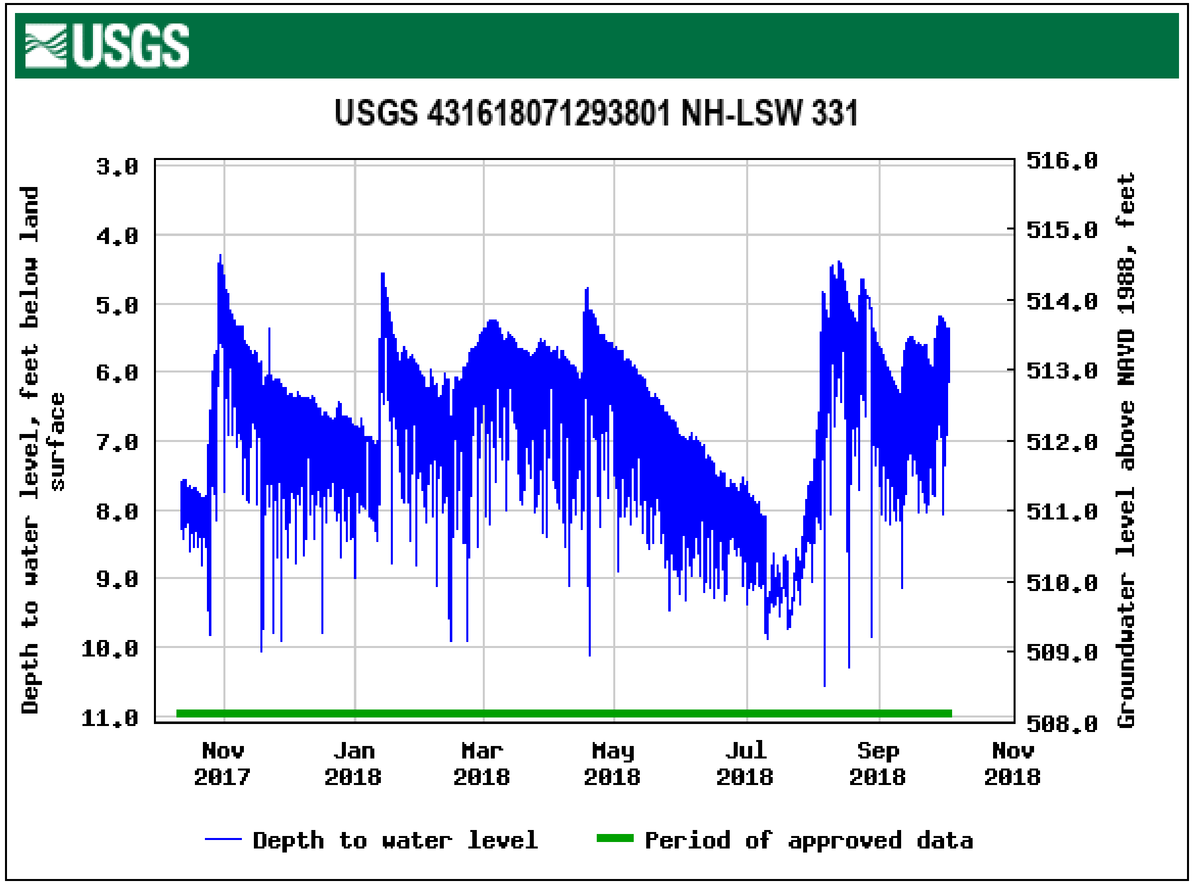
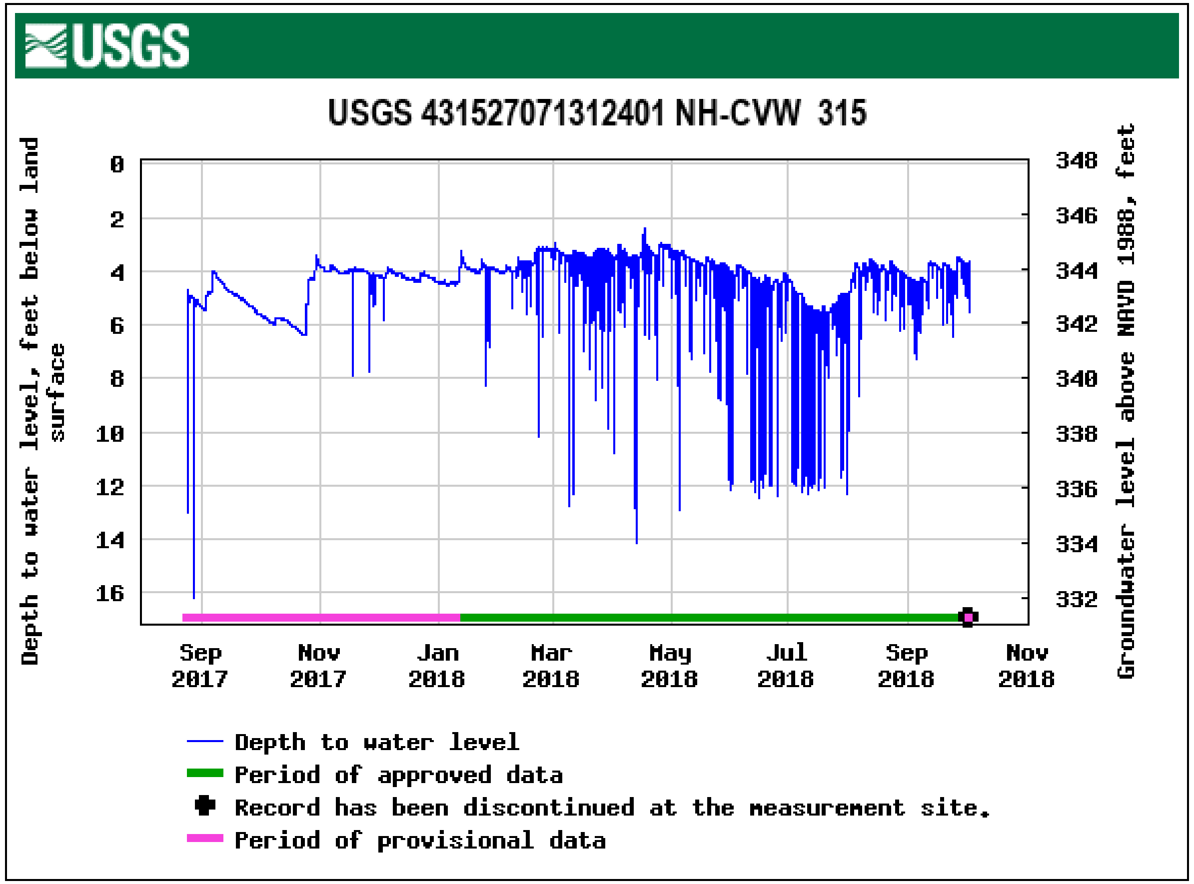
Continuous water level data

Groundwater recharge setting



Groundwater discharge setting

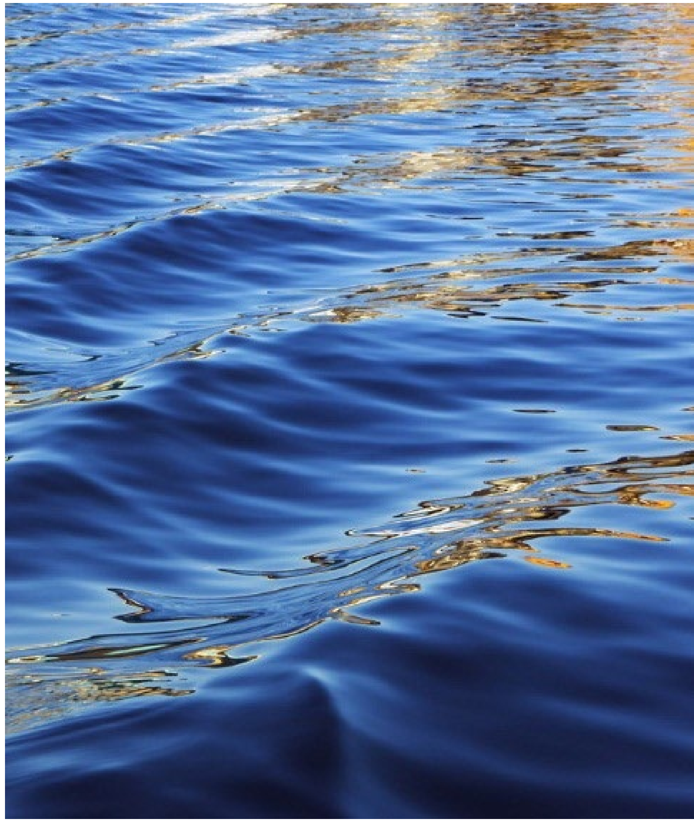


Summary

1. Data indicate wells may be suitable for small-scale agricultural or domestic use.
2. Well "siting" is important (for any well type) for optimal water quality.
3. Acceptance from public, well installers, etc. may be challenging.
4. Concord Monitor article (October, 2018) https://www.concordmonitor.com/arsenic-groundwater-USGS-well-nh-20568786

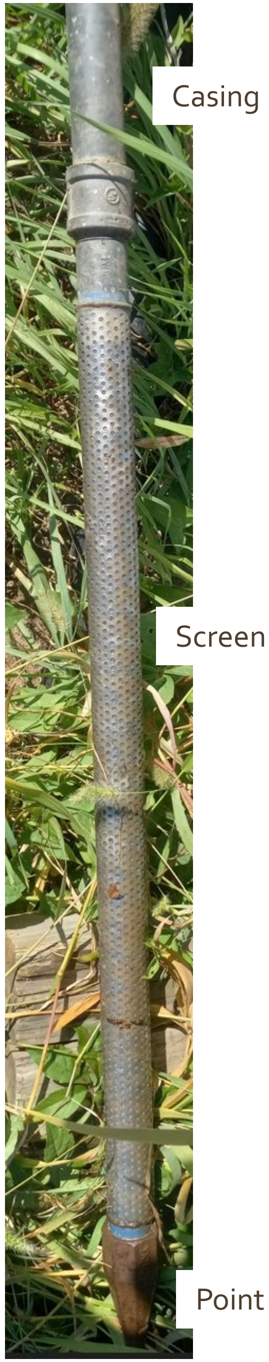
A simplified process of: Planning, Designing, and Installing Shallow Wells

Manuel Diaz, Agricultural Engineer, USDA NRCS, Amherst, MA



Point wells

- Typically, 1-1/4" to 2" diameter and 20 to 40 ft in depth, although under some conditions can go to 80 ft or deeper.
- A surface shallow well pump is often used when the pumping (dynamic) water level is less than 20 ft.
- Jet pumps (and some submersible pumps) are used on 2" diameter wells which pumping water level is deeper than 20 ft.
- Typical flow range from 5 to 80 gpm.
- Point wells are often augered by hand and sleeved and pounded in the ground. Other common installation methods are pounding with a cable tool and using a hydraulic auger.



Point wells are often augered by hand and sleeved and pounded in the ground.

Check local and State regulations on the installation and use of different wells, often states have specific regulations for shallow wells, including point wells.

Drilled wells:
Mud drill and air rotary drill

- Not often used for installing shallow wells because the drill rig is so big and expensive. Probably best if used for wells 6” in diameter or bigger.
- Installation method may require particularly long well development because of the mud that can be created on the borehole.
- Often does not allow for artificial well pack installation, or the installation of artificial well pack is cost prohibitive.
- Often needs a telescoping screen to be sleeved through the casing, resulting on a smaller screen than casing. For instance, a 6” diameter will would need a 5” telescoping screen.

A full-size drill rig can be used for a shallow well installation. Advantages and disadvantages need to be taken into consideration ahead of time.

Augered Wells: Hydraulic auger

- Very handy machine for the installation of shallow wells. Often used for wells 8" in diameter or smaller.
- Smaller machine which can often access locations inaccessible to bigger rigs.
- Allow for artificial well pack (which results in a more efficient well) installation at an affordable cost.
- Mechanical well developing can be achieved which it is often the preferred well developing method.

Both Manuel Diaz and Joseph Ayotte have had the better experience installing and developing small diameter wells using a hydraulic auger than a rotary drill rig.

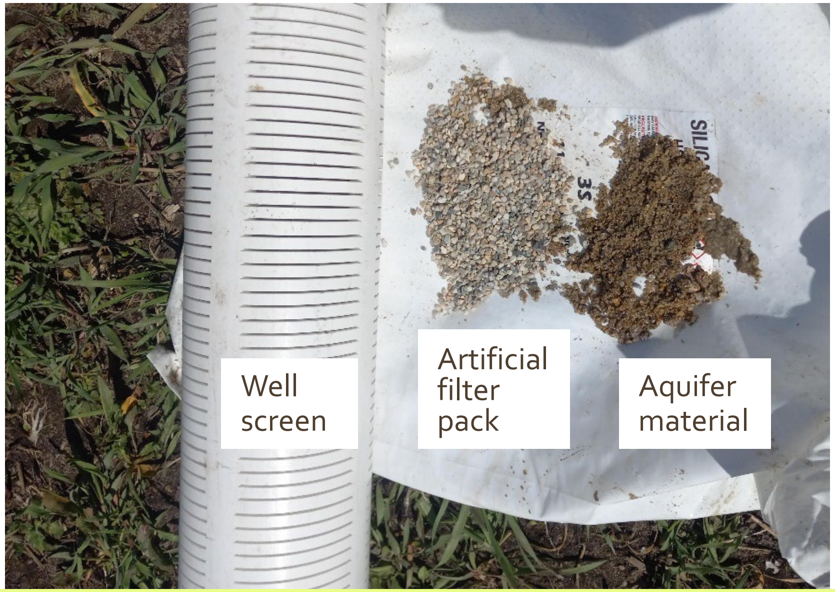
Well filter pack

Natural filter pack:

- The well screen is designed and installed so a well filter pack is created by extracting the finer material from the aquifer and developing the aquifer sand and gravel into the screen filter.

Artificial filter pack

- The well screen is designed and installed along a well filter pack that stabilizes the aquifer material surrounding the screen, allowing for the development of finer material while stabilizing the aquifer sand and gravel.
- It effectively increases the localized permeability of the aquifer, making the well more efficient.



Often, the use of a natural filter pack or an artificial filter pack is determined by the installation method and cost. Hydraulic augers can install artificial packs easily and affordably.

Planning for shallow wells.

Finding a saturated layer which transmissivity satisfy required flow.

- Geologists call the sand, gravel, soils, rocks, and other loose material that lie on top of bedrock surficial deposits.
- Porous, permeable surficial deposits make good aquifers. Some surficial deposits are porous and permeable. Most are not.
- Identifying deposits that are saturated, permeable and have sufficient recharge is the initial goal in shallow well planning.

Transmissivity is the hydraulic conductivity of the encountered saturated media multiplied by the saturated thickness, an indication of potential flow.

Planning for shallow wells. Data gathering: Soils

Look at the soils online

- Web Soil Survey
  - Soil Data Explorer
    - Soil Reports
      - Soil Physical Properties
        - Physical Soil Properties
          - Typical profile
            - Sand, silt, loam, clay
          - Properties and qualities
            - Depth to restrictive feature
            - Drainage class
            - Ksat of the most limiting layer
            - Depth to water table

Soils information by itself rarely lead to shallow well suitability determination, but is one piece of the overall analysis.

Planning for shallow wells. Data gathering: Watershed

Attempt to delineate the watershed

- Many software and online interfaces to do this. One easy to use is:
  - StreamStats
    - Delineate

Watershed information by itself rarely lead to shallow well suitability determination but should be part of the overall analysis.

Planning for shallow wells.
Data gathering: Surficial geology and hydrogeology

Gather local, state and national surficial geology and hydrogeology.

- Maps of:
  - Hydrography
  - Aquifers
  - Surficial deposits
  - Transmissivity
  - Groundwater flow
  - Depth to bedrock
- New and old USGS maps can provide critical information.
- There are multiple online interfaces that provide readily available GIS maps.

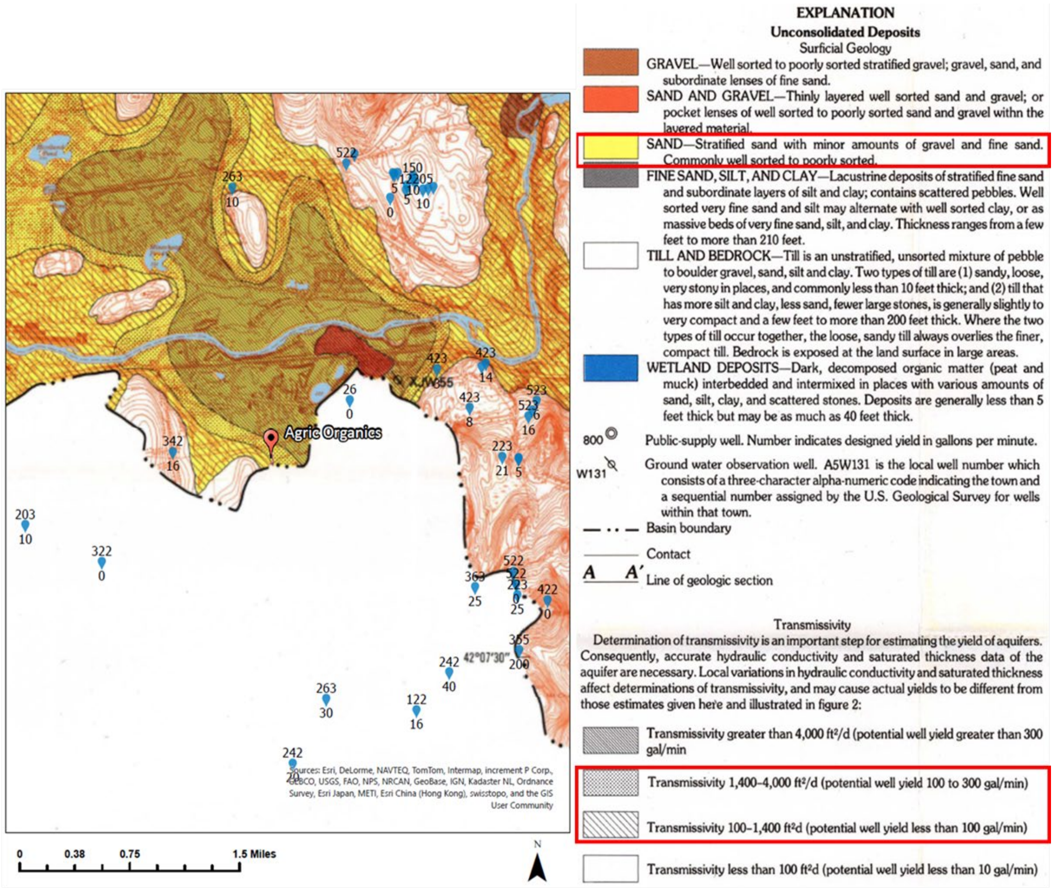


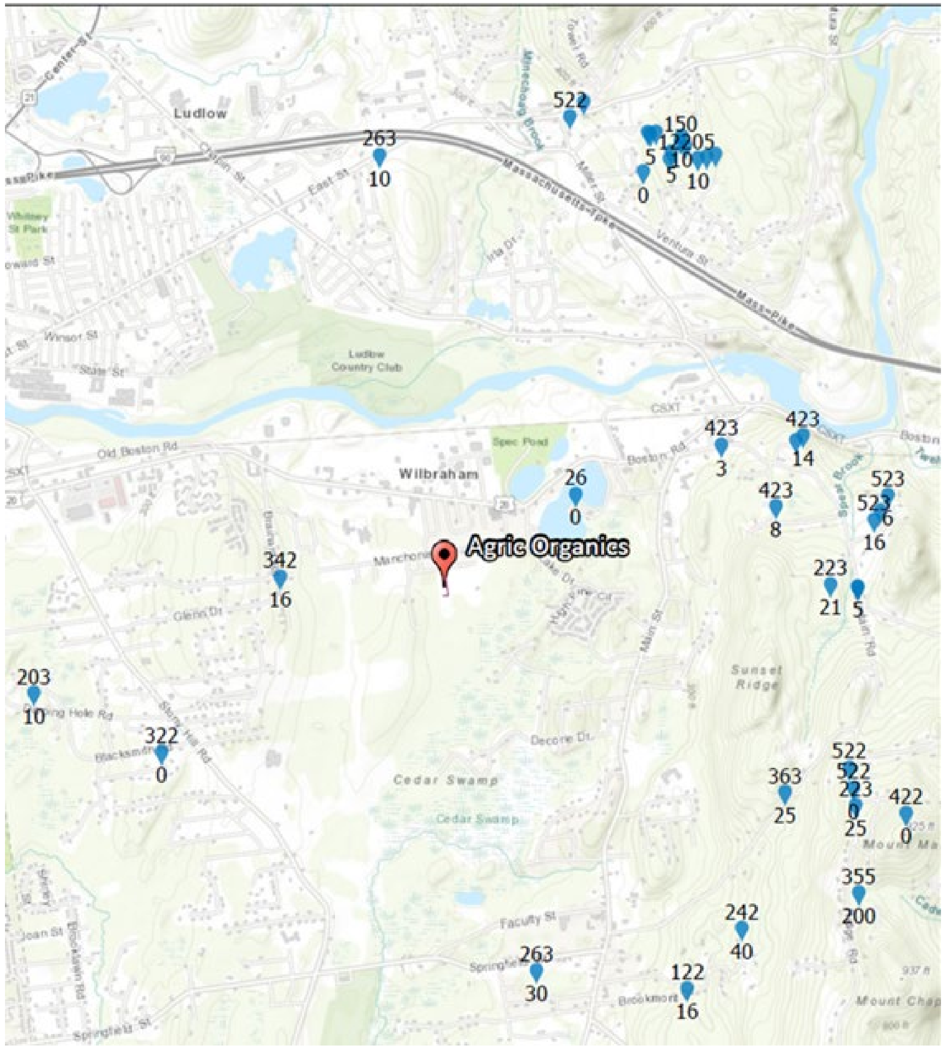
Figure 3. Map showing the availability of ground water in unconsolidated sediments (Krejmas and Maevsky, 1986) plotted with the location of Iron Agric Organics (red placemark), and private water wells (blue placemarks) in the area. Posted on the water wells are the total depth of the well (above) and the reported yield (below). Agric Organics is identified as overlying sand deposits and straddling a transmissivity contour (1,400 – 4,000 ft^2/d. to the northeast and 100 – 1,400 ft^2/d to the southwest).

Surficial geology maps can be a powerful tool in documenting the possible risk for the well installation.

Planning for shallow wells.
Data gathering: Neighboring wells

Characteristics of neighboring wells that can be useful:

- Well type
- Drilling method
- Well depth
- Depth to bedrock
- Screen and casing characteristics
- Filter pack characteristics
- Static and dynamic water level
- Yield
- Recovery time
- Development method
- Lithology

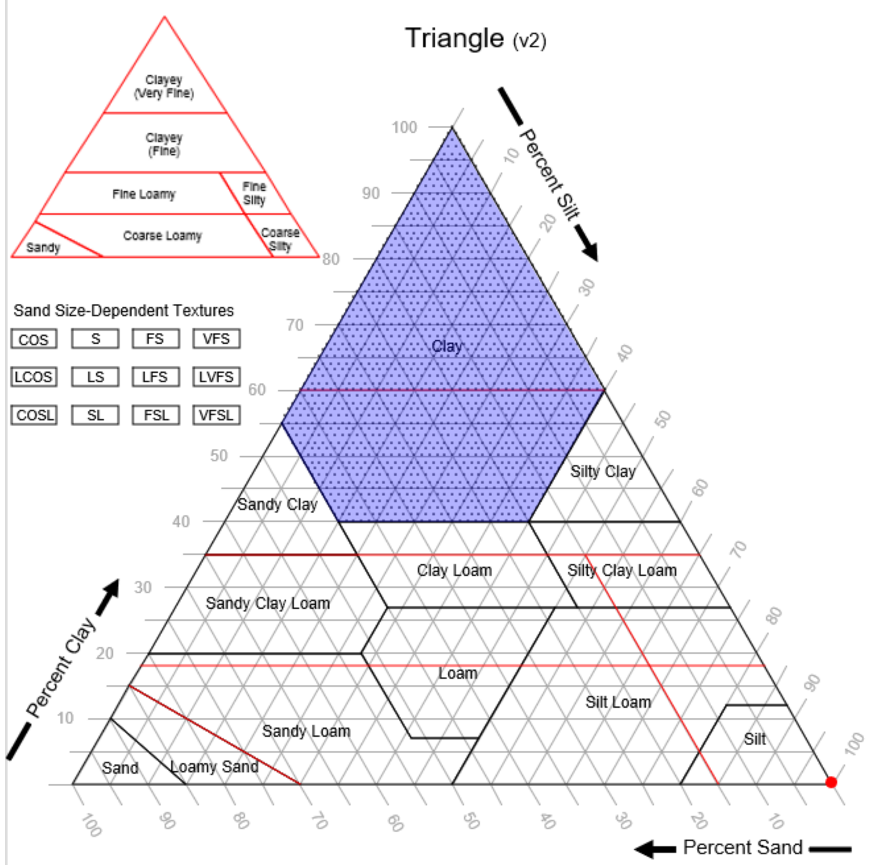


Wells within 1 mile of planning area. Blue drops identify well location, total dept and depth to bedrock.

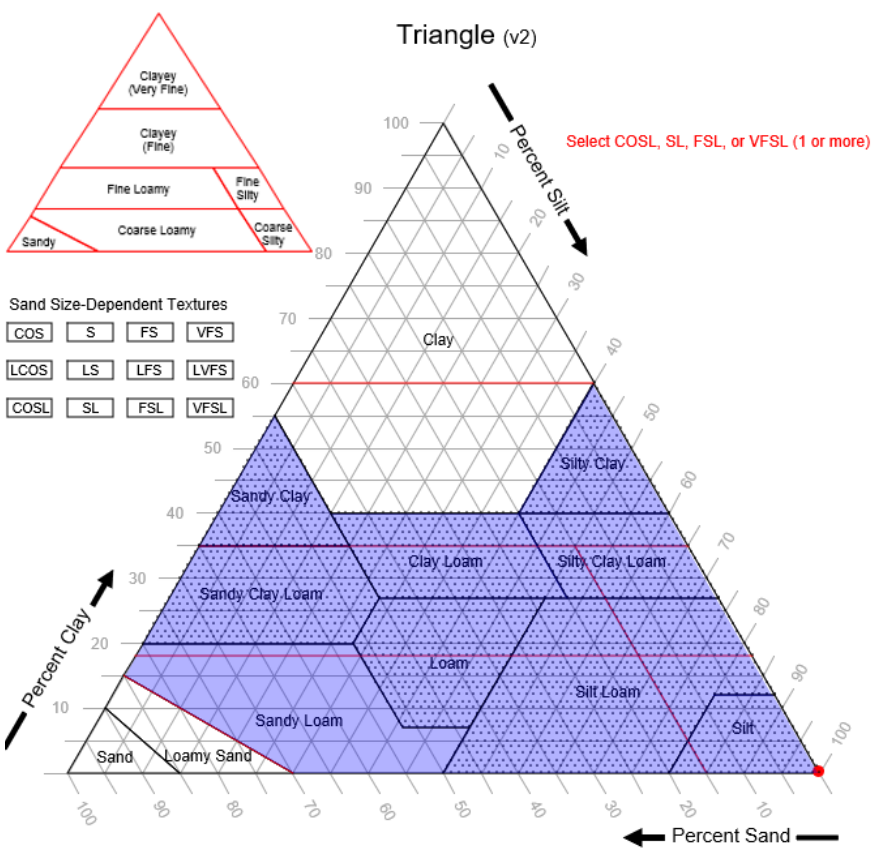
In areas of known high transmissivity, information from neighboring wells can be the main planning factor for new wells.

Planning for shallow wells:
Identification of a suitable shallow well system

Clay soils: No well as hydraulic conductivity is too low.



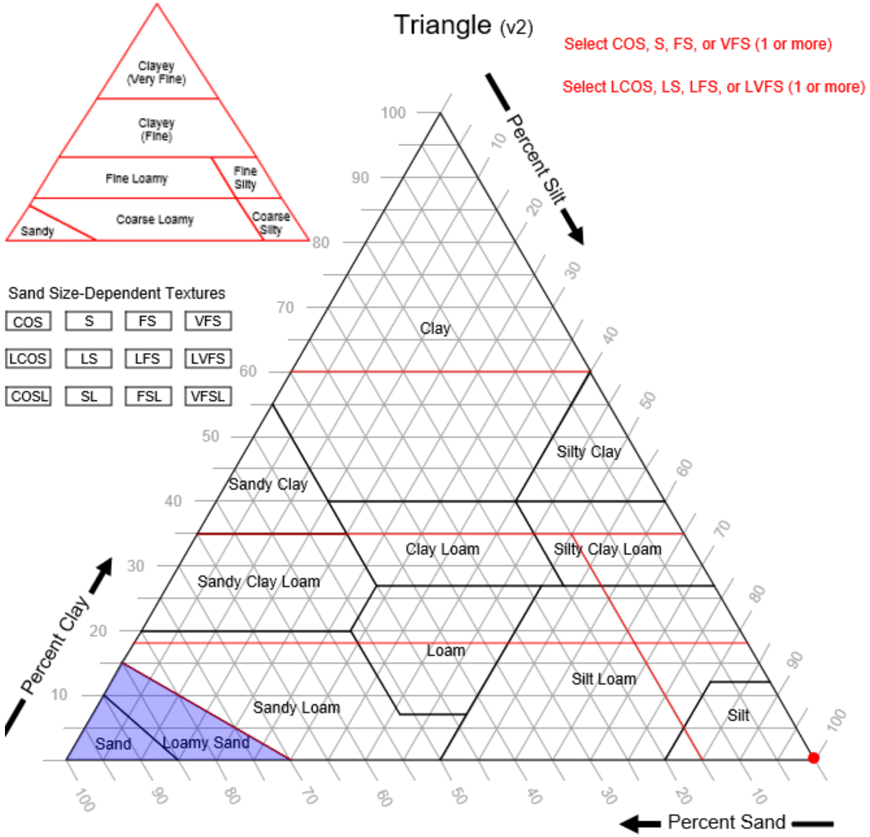
Sandy clay, loamy and silty soils: Consider excavated wells.



There are conditions where loamy and silty soils can yield suitable flow for low demand conditions.

Planning for shallow wells:
Identification of a suitable shallow well system

Soils with high sand and gravel content: Consider point, drilled, augered, pounded, open bottom, or jetted wells.



Split spoon aquifer sample with coarse sand and gravel.

In general, coarse and non-uniform material result in higher yield. Fine and uniform material result in lower yield.

Designing of shallow wells: Aquifer sample collection and analysis

Simplified explanation of the procedure

- Collect aquifer material samples
  - 1 lb minimum of dry material needed
- Dry the samples
  - Oven dry preferred.
- Sieve the samples
  - Shake the dry aquifer samples for at least 10 minutes. The use of a soil shaker is preferred.
- Select the aquifer sample to be used for well and well screen design.
  - Sometimes the selected samples is what feels like a representative sample. Other times is what is perceived as the most limiting sample.

Field sieve of aquifer material

Designing a well system based on actual aquifer samples from the proposed well location is critical for the success of the system.

Designing of shallow wells: Excavated well

- Water table depth
  - Best if within 10 ft from the surface.
- Excavation depth
  - 20 ft deep often makes sense for constructability and storage.
- Excavation width
  - 10 ft minimum recommended for constructability and storage.
- Backfill gravel
  - 5 to 15 vertical feet of ¾" clean crushed stone is widely acceptable.
- Geotextile
  - Nonwoven geotextile should be used to separate gravel initial backfill from final backfill.
- Casing material
  - Concrete tiles or double wall HDPE is popular, perforate or solid depend on surficial geology conditions.

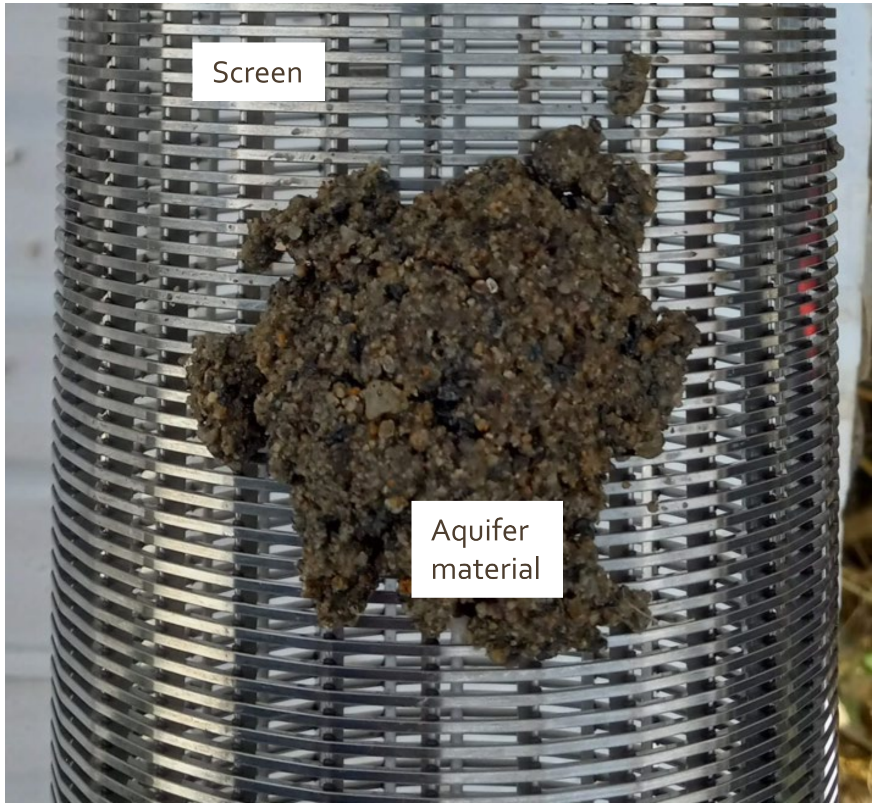
Most often we want the excavated well to fill in from the bottom, taking advantage of the surrounding hydraulic head. The alternative is to have perforated walls.

Designing of shallow wells: Natural filter pack

Two approaches:

- The screen slot size for a naturally developed filter pack in a sand aquifer should be sized so that about 60 percent (D60) of the aquifer material enters the screen (Johnson 1975)
- The U.S. Bureau of Reclamation (USBR) (1964) recommends for a naturally developed filter pack, a slot size equal to half the D85 size of the aquifer material.

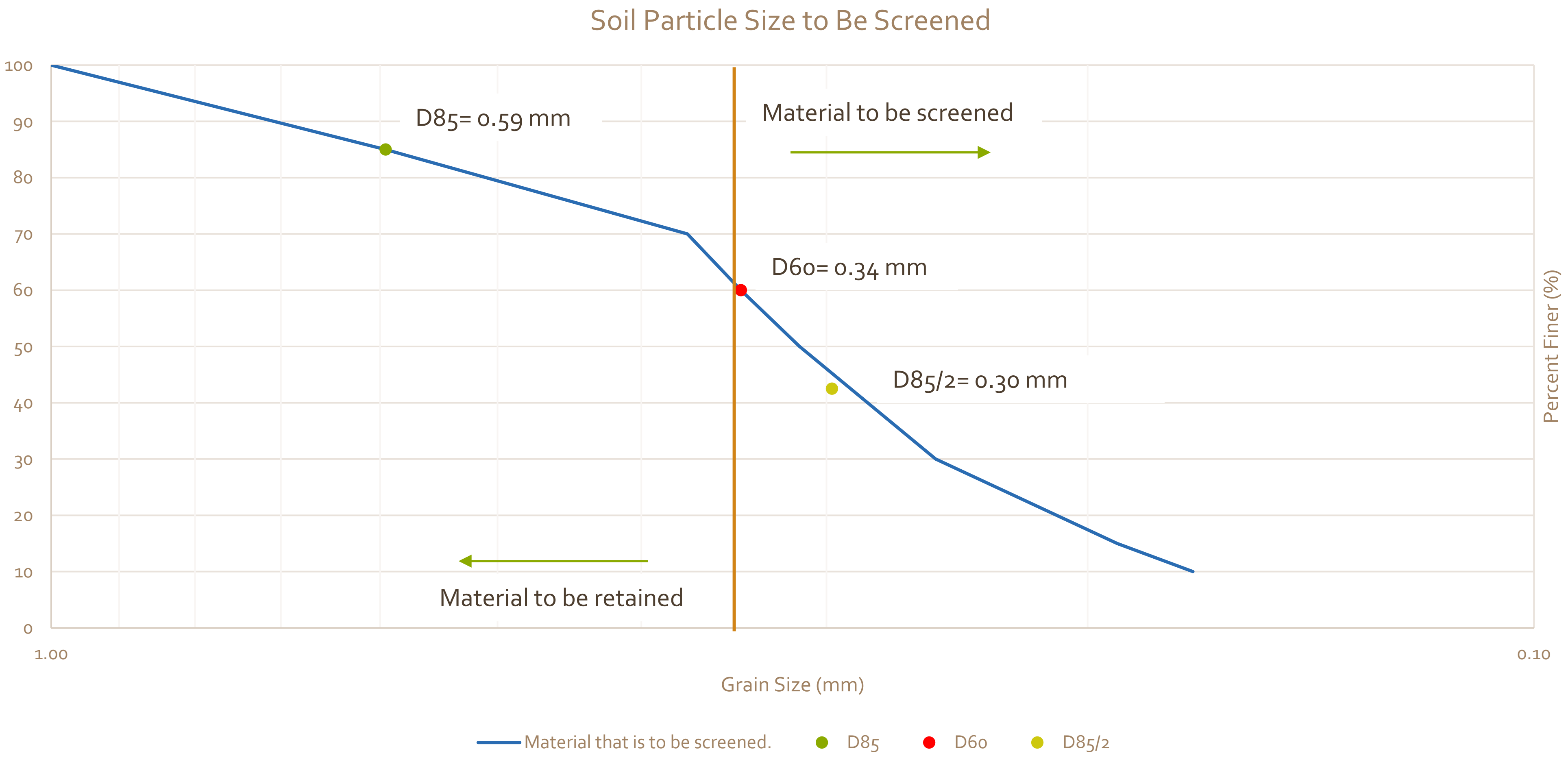
Conceptualization of natural filter pack.



For reference, refer to Part 631 of the NRCS National Engineering Handbook, Chapter 32 Well Design and Spring Development.

During well development the screen allow coarse material to be retained in the aquifer while finer material is extracted, creating the natural filter pack surrounding the screen.

Designing of shallow wells: Natural well pack



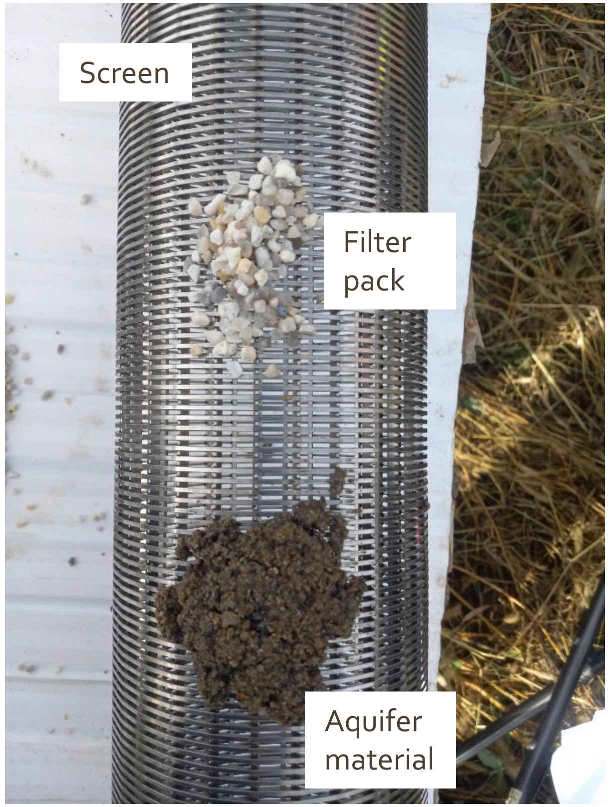
The designer needs to decide what size aquifer material will be allowed to enter the screen, if D60 or D85/2.

Designing Shallow Wells: Artificial well pack

The design of the filter pack is done in the following steps:

- Step 1: Construct a grain size distribution graph of the aquifer material. The filter pack design is based on the gradation of the finest aquifer material that is to be screened.
- Step 2: Multiply the D30 size by a factor of four to nine. A factor of four is used if the formation is fine and uniform (Cu less than 3.0); six if it is coarse and nonuniform; and up to nine if it is highly nonuniform and contains silt.
- Step 3: Plot the point from step 2 on the 30 percent abscissa, and draw a smooth curve with a uniformity coefficient of about 2.5 through it. This is the gradation of the optimum filter pack.
- Step 4: An envelope curve of the permissible limits of the filter pack is drawn, plus or minus eight percent of the optimum curve.
- Step 5: Select well screen slot openings that will retain 90 percent of the filter material.
- Step 6: Gravel or sand for the artificial filter pack should be of washed, well-rounded, hard, and insoluble particles.

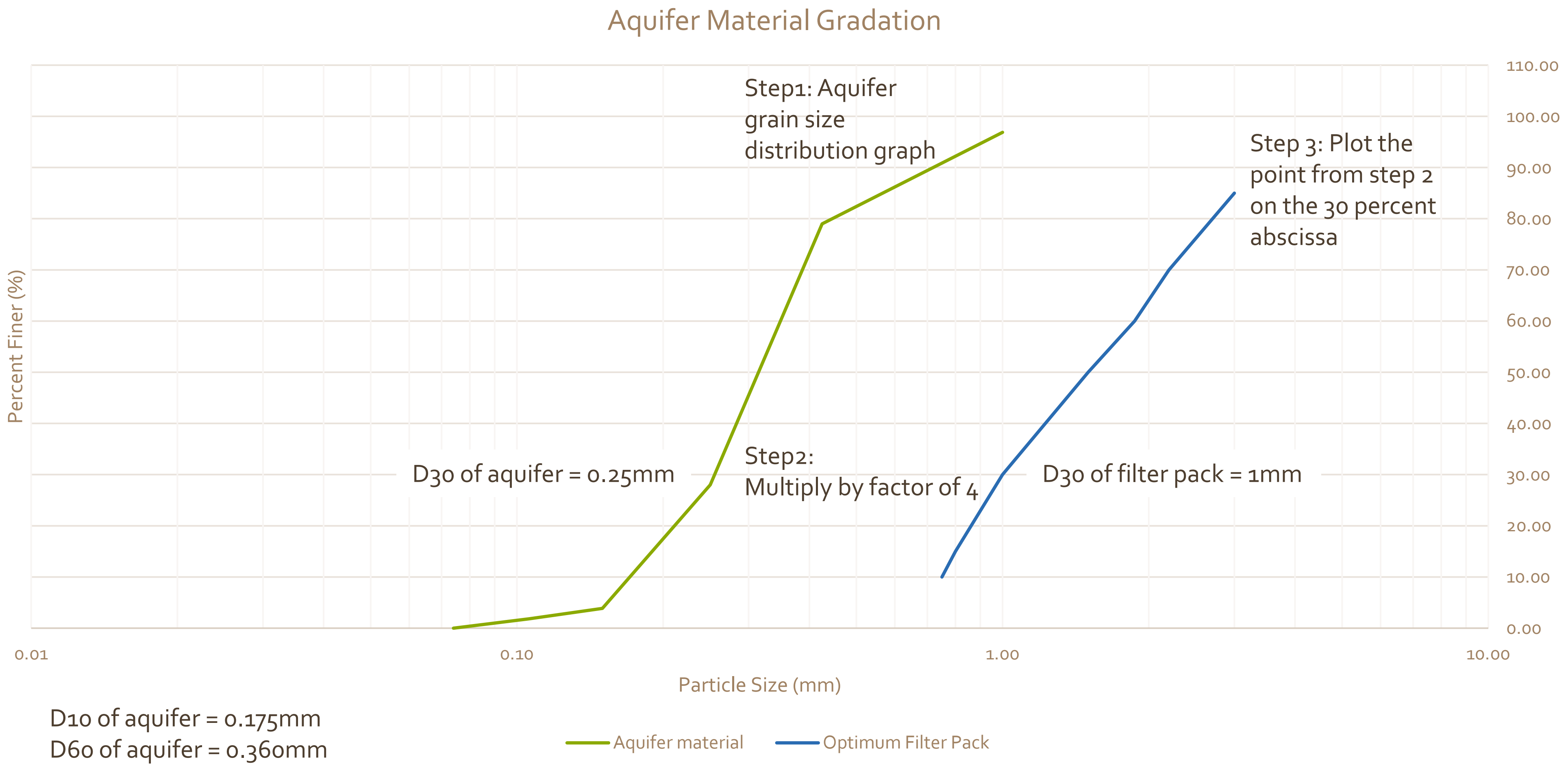
Conceptualization of artificial filter pack.



For reference, refer to Part 631 of the NRCS National Engineering Handbook, Chapter 32 Well Design and Spring Development.

During well development the screen allow artificial pack and native material to be retained in the aquifer while finer material is extracted, creating higher local transmissivity.

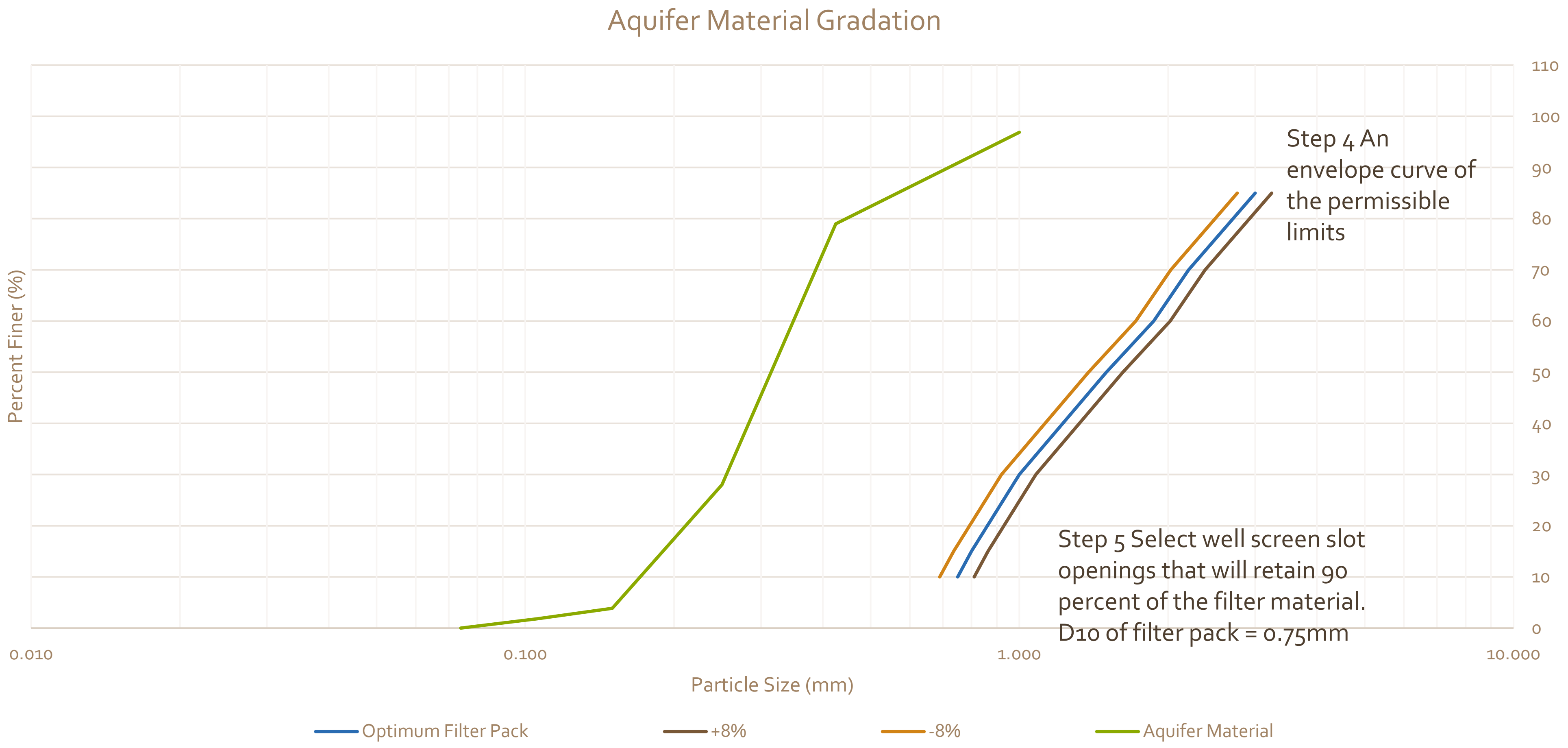
Designing Shallow Wells: Artificial well pack example



D10 of aquifer = 0.175mm
D60 of aquifer = 0.360mm
Cu = 2.06
High uniformity use factor of 4 on Step 2.

Experience will dictate the level of comfort a designer will have when selecting the factor (4 to 9) to multiple D30 in the selection of pack and screen.

Designing Shallow Wells: Artificial well pack example



There is commercially available gravel pack material called 00, 0, 1, 2, 3 or 4 sand which can be matched to the designed gravel pack envelope curve.

Designing Shallow Wells: Well screen

Flow and cost

- There is about 4 to 8 times more slot open area on stainless steel screen than on a PVC screen which translate into a similar flow difference.
  - For instance, 50 slot (0.05" opening) PVC screen has a nominal flow rating of 4.2 gpm per foot of screen while stainless steel is rated at 18.9 gpm per foot of screen.
- Stainless steel screens are generally 2 to 6 times more costly than PVC screens.

Stainless steel vs PVC screen

Stainless steel screen as favorable for high flow conditions.

Designing Shallow Wells: well casing

Steel vs PVC well casing

- PVC casing is far cheaper than steel casing.
- The installation method often dictates determines the need for steel casing over PVC.
  - For example, pounded wells require steel casing.
- The string of well casing pipe–not including the screen- is typically extended to at least the 20-foot depth or to at least 10 feet below the static water level, whichever is the greater depth.

Screen, casing and artificial well pack installation

Screen and casing is sleeved through the hollow auger center part.

Well pack is poured around the screen and 10 ft up the casing.

The use of a tremie pipe is a more efficient and safer method to install gravel pack than pouring it from the surface.

Well development

Effective development procedures should cause reversals of flow through the screen openings that will agitate the surrounding sediment, remove finer fractions, and then rearrange the remaining formation particles (Driscoll, 1986).

- Over pumping
  - Works if the initial aquifer material allow.
- Backwashing
  - Reversal flow through screen.
- Mechanical surging and pumping
  - "Plunging" the well.
- Air development by surging and pumping
- Airlift pumping
- Jetting with air or water

Well development pump

Driscoll, F.G. (1986) Ground Water and Wells. 2nd Edition, Johnson Division, St. Paul. A truly great source for well design and groundwater development.

Well development

Initial well development with mostly sand and gravel coming out of the well.

Initial well development with mostly silty clay coming out of the well.

Initially, large amount of aquifer material will come through the screen. In time, less and less aquifer material will be pumped out, until the well is fully developed.

Well development

Mechanical well development using cable tool or hydraulic system.

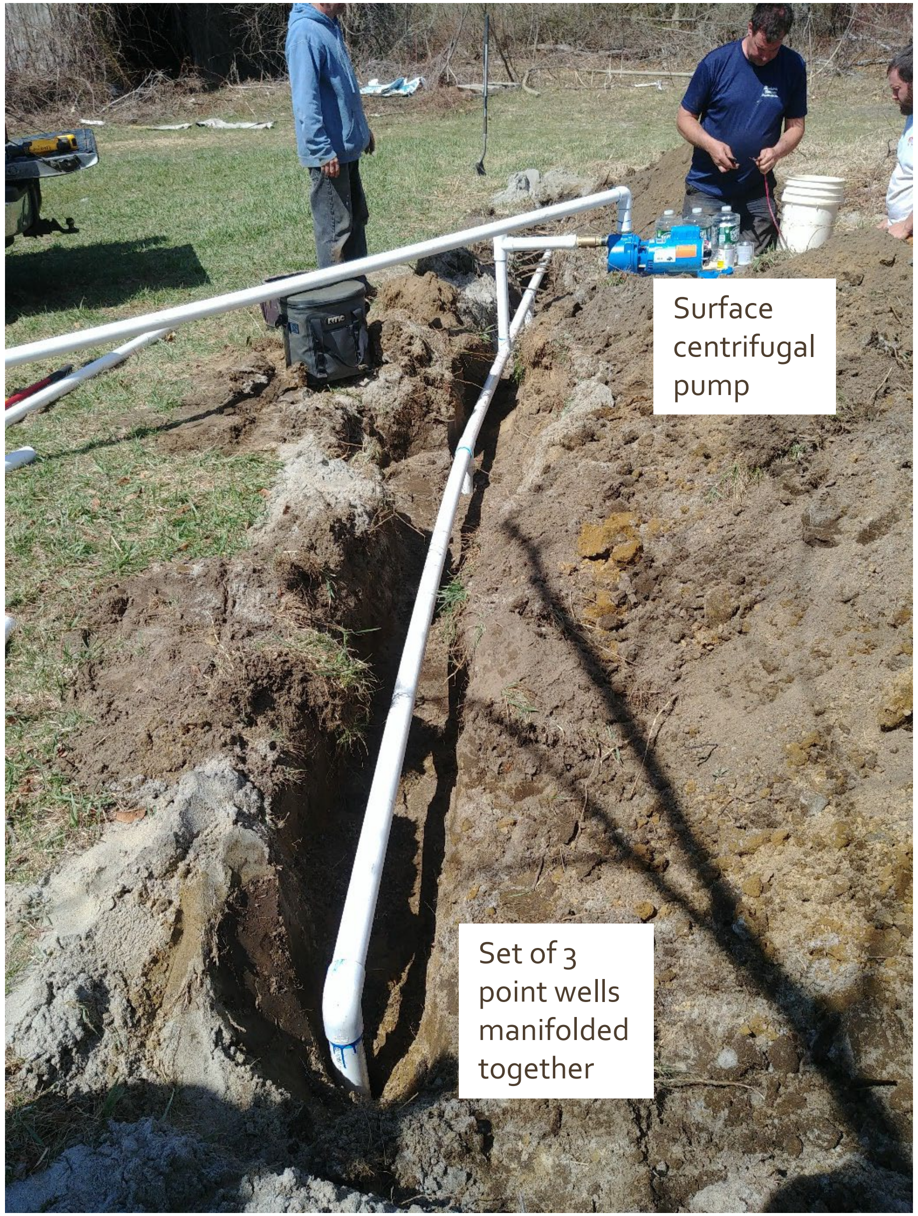
Manual well development

Small diameter wells (4″ or less) can be developed by hand, but it is a lot of work. Mechanical well development is preferred.

Pump selection: Surface pumps

Depth to pumping water elevation (dynamic water level)

- Surface centrifugal shallow well pumps work to about a depth of 20 ft.
  - Atmospheric pressure of about 14.7 pounds per square inch allows a "shallow-well" pump to "pull" water up from a maximum depth of only about 20 feet.
- Surface jet pumps can be used when the pumping water level is deeper than about 20 feet. In this case, a 2" minimum diameter casing must use as it needs to be large enough to accommodate a "packer-jet assembly" to be installed within the casing to enable the pump to "pull" water up from a greater depth.

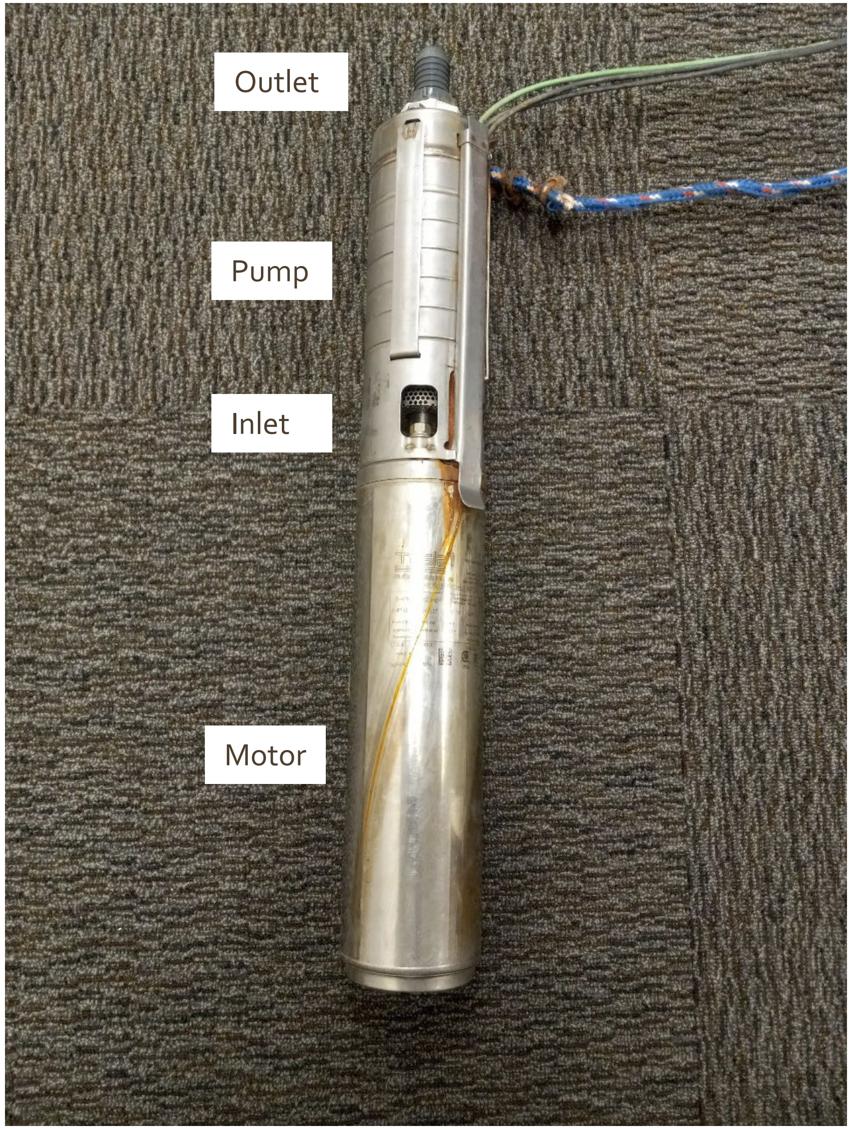


The power source can be an influential factor in the pump selection.

Pump selection: Shallow well

Submersible pumps

- Submersible pumps are used on 4” diameter casing and larger.



Submersible pumps require flow through the motor for cooling. This must be taken into consideration during the design process.

Well maintenance

- Ensure no agricultural chemicals, such as fertilizers and pesticides, are stored or mixed or containers rinsed within a 100 ft. radius of the wellhead.
- The inspection must include conditions that affect well performance as designed for the water use. As a minimum, these conditions include:
  - Declines in discharge, static level, maximum pumping level, and pressure (for artesian wells) that are outside acceptable limits for the well design;
  - Appearance of sediment that may damage the well, pump, or appurtenances;
  - Changes in water quality including odor, color, taste, and chemistry;
  - Presence of algae or iron bacteria.
- Keep a maintenance record that include statements describing identified problems, corrective action taken and date, and specific capacity of well before and after corrective action.

Camera inspection of well screen

A well design, installed and developed well should last 20 to 40 years with minimum maintenance to it.

Successful example

- In 2012, the NRCS planned and contracted a well at Indian Lane Farm in Egremont, MA.
  - The well ended up been over 500 ft deep, cost over $12,000 and it yield less than 2 gpm.
  - The NRCS considered it been a failed practice and did not pay for the well.
- In 2019, Manuel learned about the situation and noted that the area likely had groundwater conditions suitable for shallow wells.
  - In 2022, the NRCS installed one well and did the conservation technical assistance for a second well.
  - The 30 ft deep wells produced a combined flow of 130 gpm once fully developed.

Indian Lane Farm: A sad story with a happy ending

From left to right: Al Thorpe, Manuel Diaz, Elizabeth Keen, Lisa Cusson with the farm dog Luna. Al & Elizabeth own Indian Lane Farm in Egremont, MA

Unsuccessful example

- Manuel planned an excavated shallow well in central Massachusetts.
- Initial testing showed promising conditions, but testing was done sown to 6 ft (too shallow) and during a time of the year where water table was high.
- Bedrock was found at 8 ft under the surface during installation, resulting in a well that was too shallow.
- The water table dropped during a drought summer, resulting on a dry well.

A well installed too shallow.

Excavated wells should approach a depth of 20 ft and have at least 10 ft of saturated conditions around them.

Review: Designing Shallow Wells

Collect samples of the saturated material

Dry, sieve and analyze the samples to design the gravel pack and screen

Experience with local wells is the best indicator for how to design natural and artificial filter packs.

Q&A

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Well development

Get the well developer in the casing

Add pipe and lower the well developer into the casing

Perform a continuous upward and downward movement creating a "plunging" effect.

"Plunge" along and above the well screen

Experience will tell how long will take a well to fully develop. During the initial well planning, at least 10 hours should be allocated to well development, mechanical or manual.

Well development

Set a pump in the well

Pump until there is a clear flow of water

Repeat the process until the "plunging effect" no longer creates a difference in the quality of pumped water. Well development can take as little as 2 hours and as long as weeks of work.

Excavated wells

Vintage stone lined hand-dug well

Typical concrete tile excavated well

Refer to Joseph Ayotte's "A novel shallow well technology to provide safe, sustainable drinking and irrigation water" section for more on excavated wells.