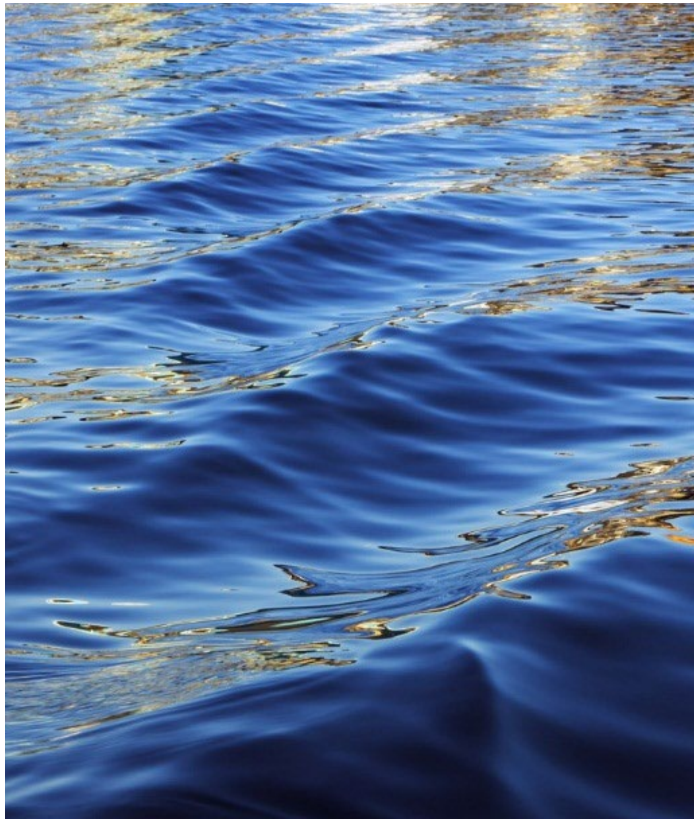
Planning, Designing, and Installing Production Wells

A brief introduction.



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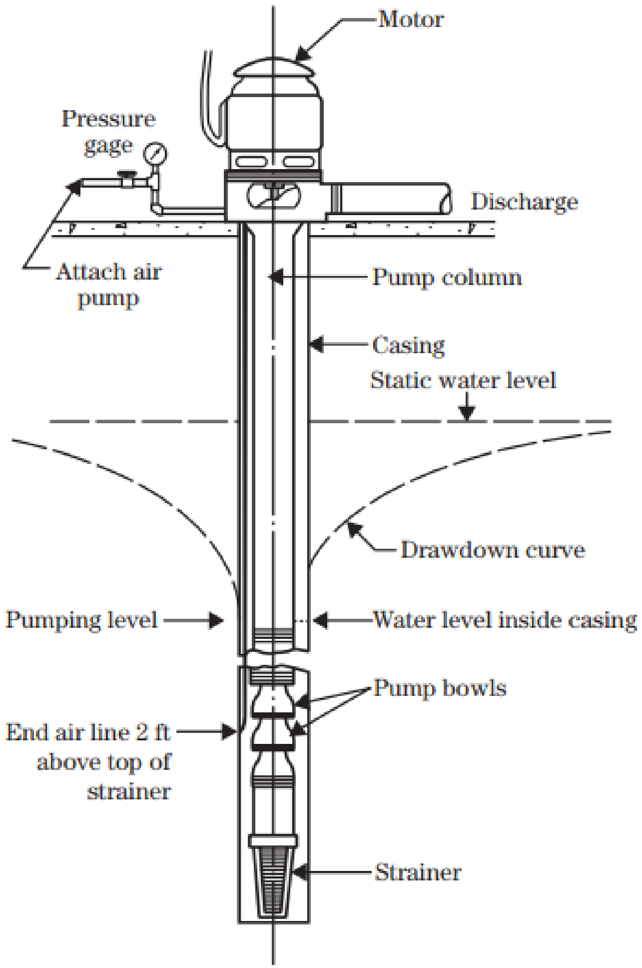
Goals for today:

- Be exposed to some of the planning scenarios under 642 - Water Well.
- Understand the physical properties of the different kind of wells we plan for.
- Get a feeling for what to look for and what to ask when planning for a well.
- Familiarize with the design and installation of production wells.

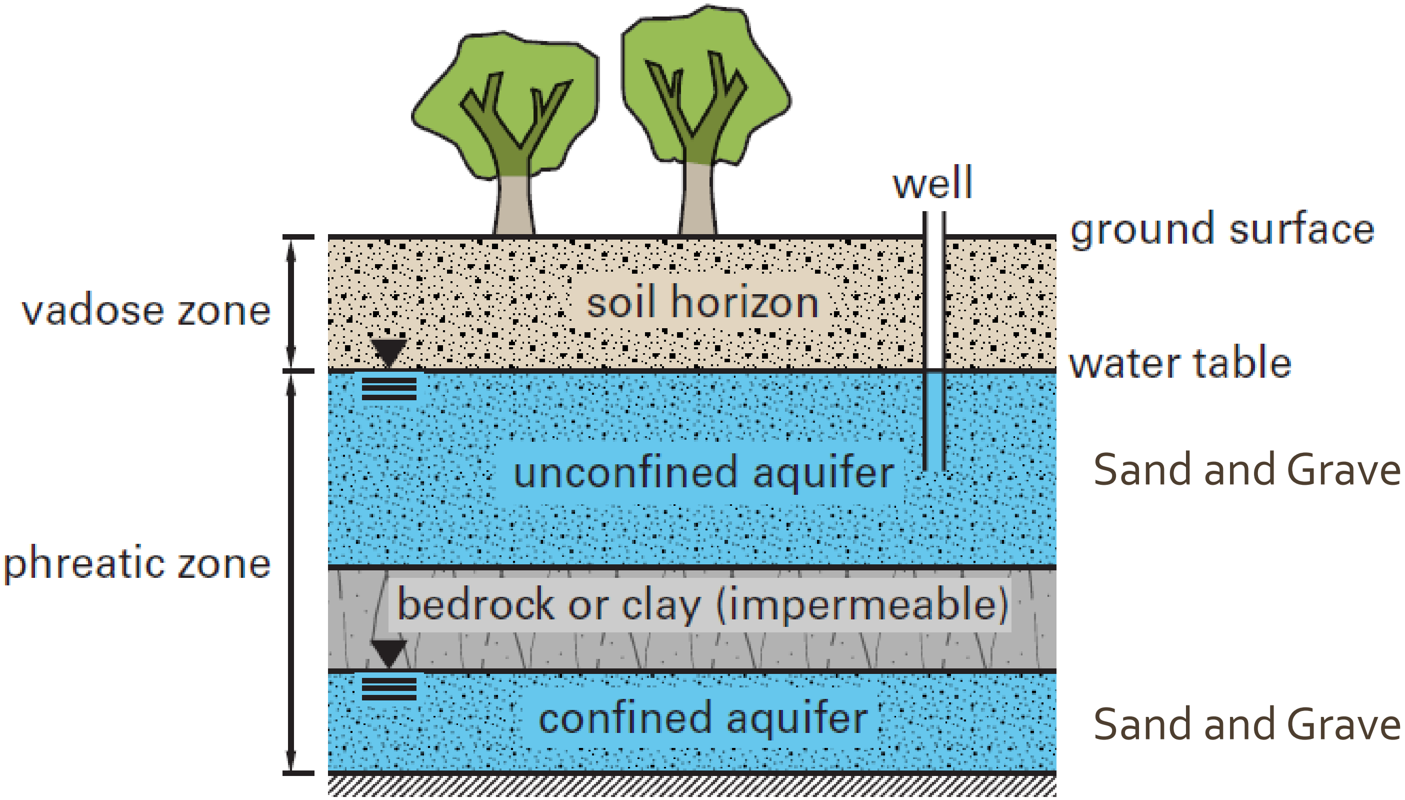


Planning for 642 - Water Well: Summary of scenario description

- ***We select the closest scenario based on the planning conditions. We don't plan or design based on the scenario descriptions.***
- Dug Well – Typically:
  - 4 foot in diameter and
  - 12 feet in depth
  - Excavated using a backhoe/excavator.
- Shallow Well – Typically:
  - 4' in diameter.
  - 100 feet maximum depth.
  - Average depth is 50 feet.
  - The well is drilled, dug, driven, bored, jetted.
- Typical Well – Typically:
  - 6" in diameter
  - 100 - 600 feet depth.
  - Average depth is 400 feet.
  - The well most often drilled to an aquifer for water supply or to bedrock fractures.
- Deep Well – Typically:
  - > 600 feet of the ground surface.
  - 6" or 8" diameter
  - Average well depth is 800 feet.
- Grater flow require greater diameter wells, most often to fit the required pump.

Knowledge of local conditions is an important factor in Planning, Designing, and Installing Production Wells

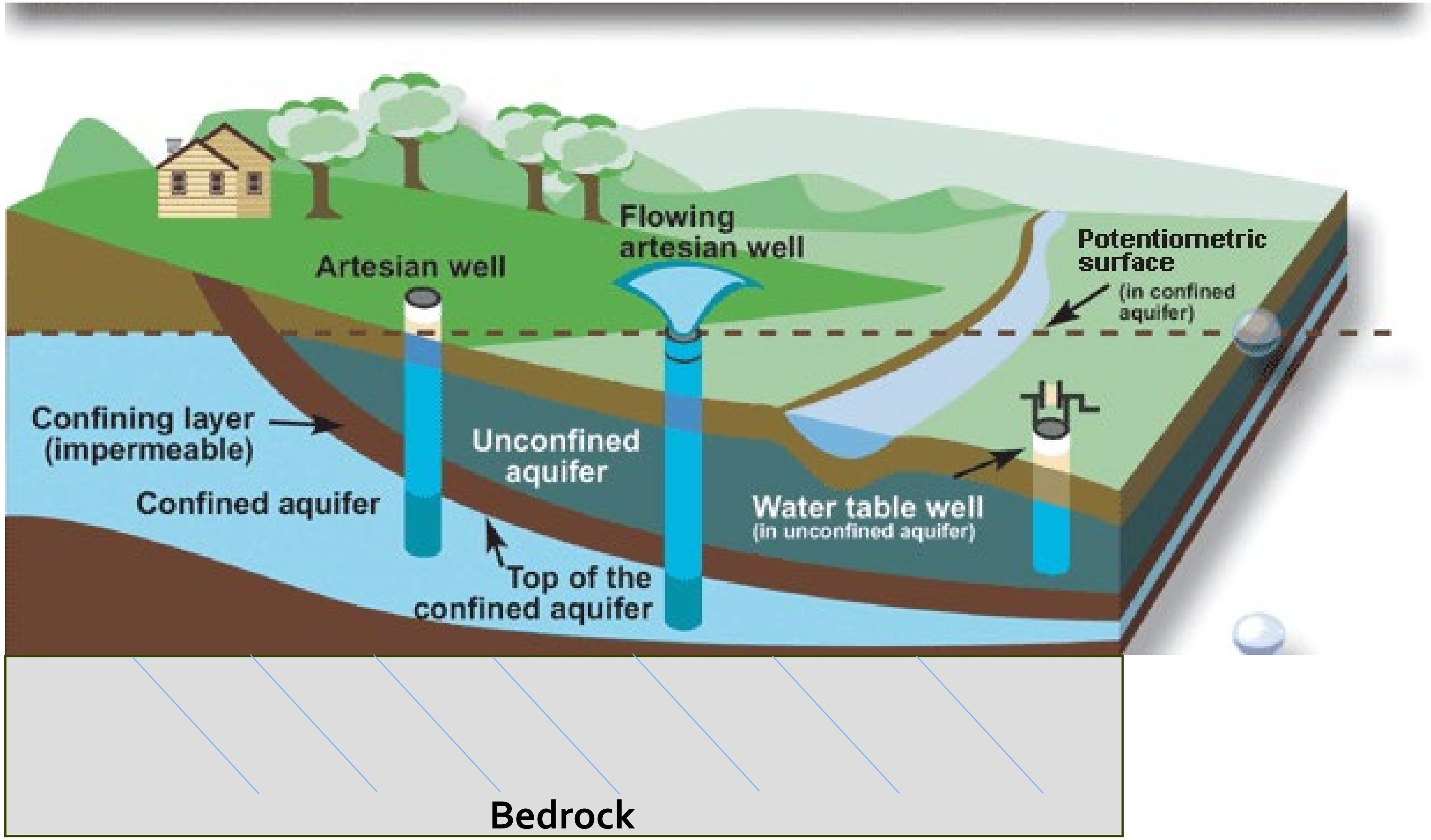
Typical Aquifer Profile



Sand and Gravel material

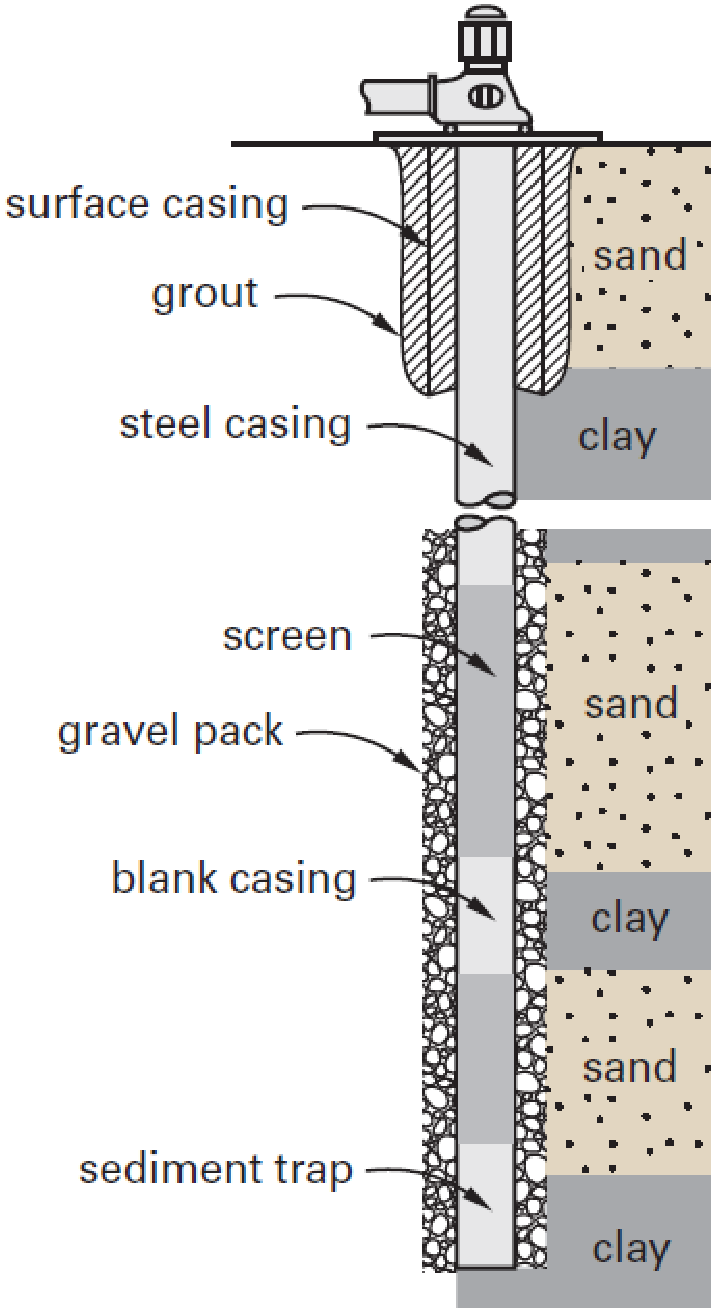
Sand and Gravel material

Wells taping on aquifers



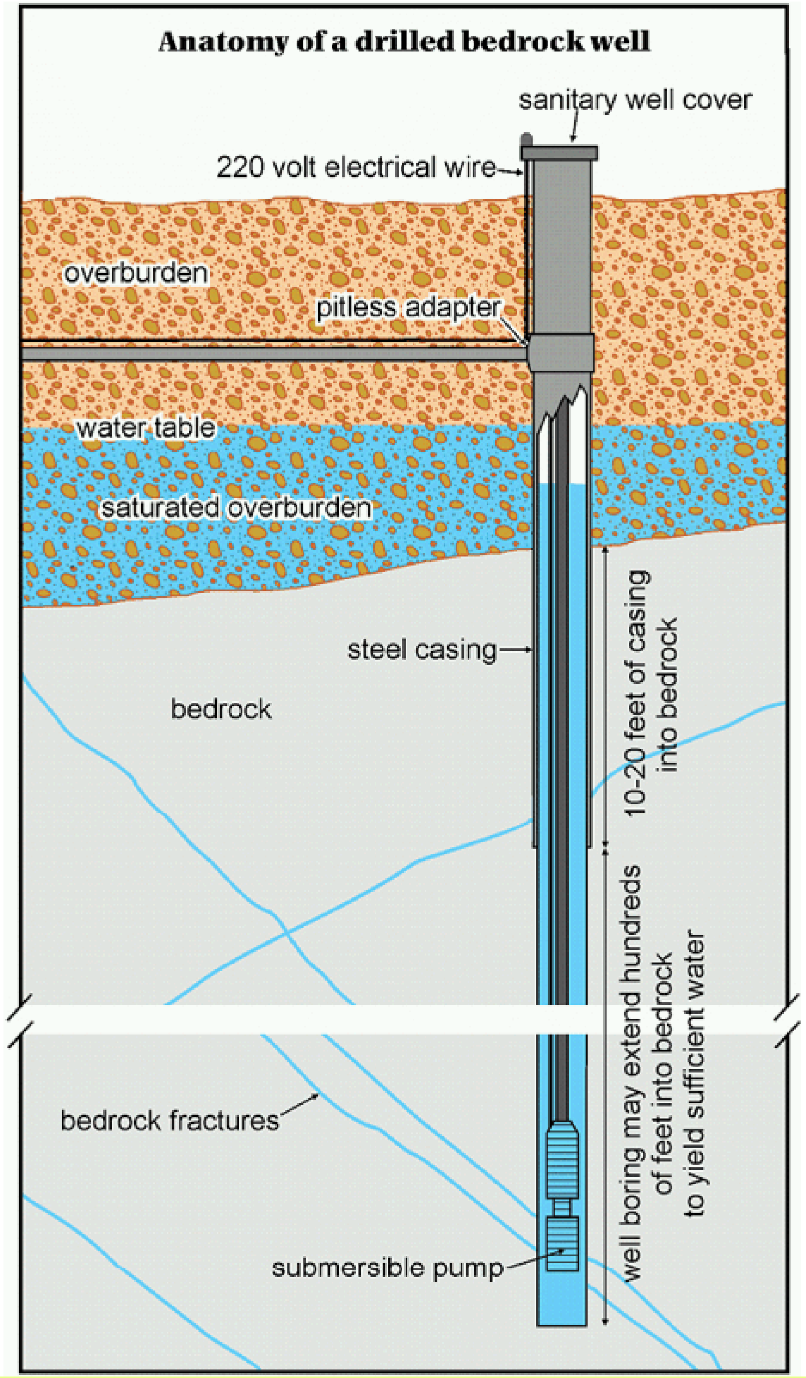
From http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=300688DC-1#sub2, © 2013, Environment and Climate Change Canada.

Wells on aquifers



Wells on bedrock fractures

Generally, we do not consider bedrock fractures as having aquifer conditions, unless there are known large fractures producing high yield making the system behave as an aquifer.



From https://www.maine.gov/dacf/mgs/explore/water/facts/well.htm

Introduction: Saturated granular surficial geology

Water table located in glacial till, about 14 ft under the soil surface.
Good for dug well

Hydraulic auger hit confined aquifer under dense layer at 30 ft.
Good for auger well.

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

Dug wells

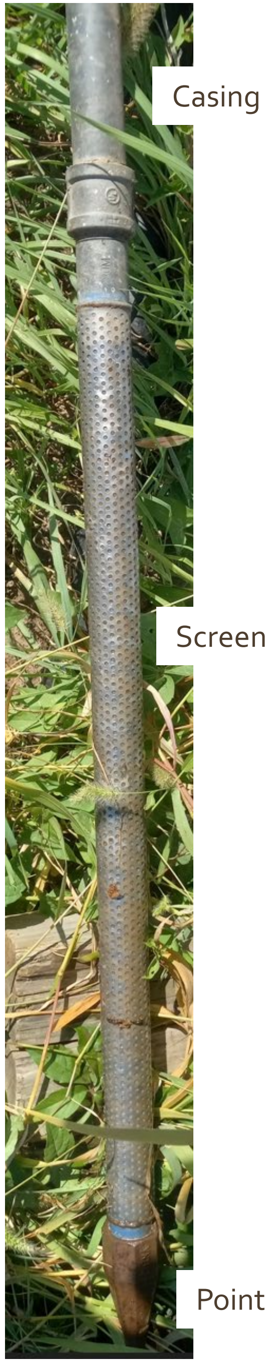
Vintage stone lined hand-dug well

Typical concrete tile dug 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.

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.

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.

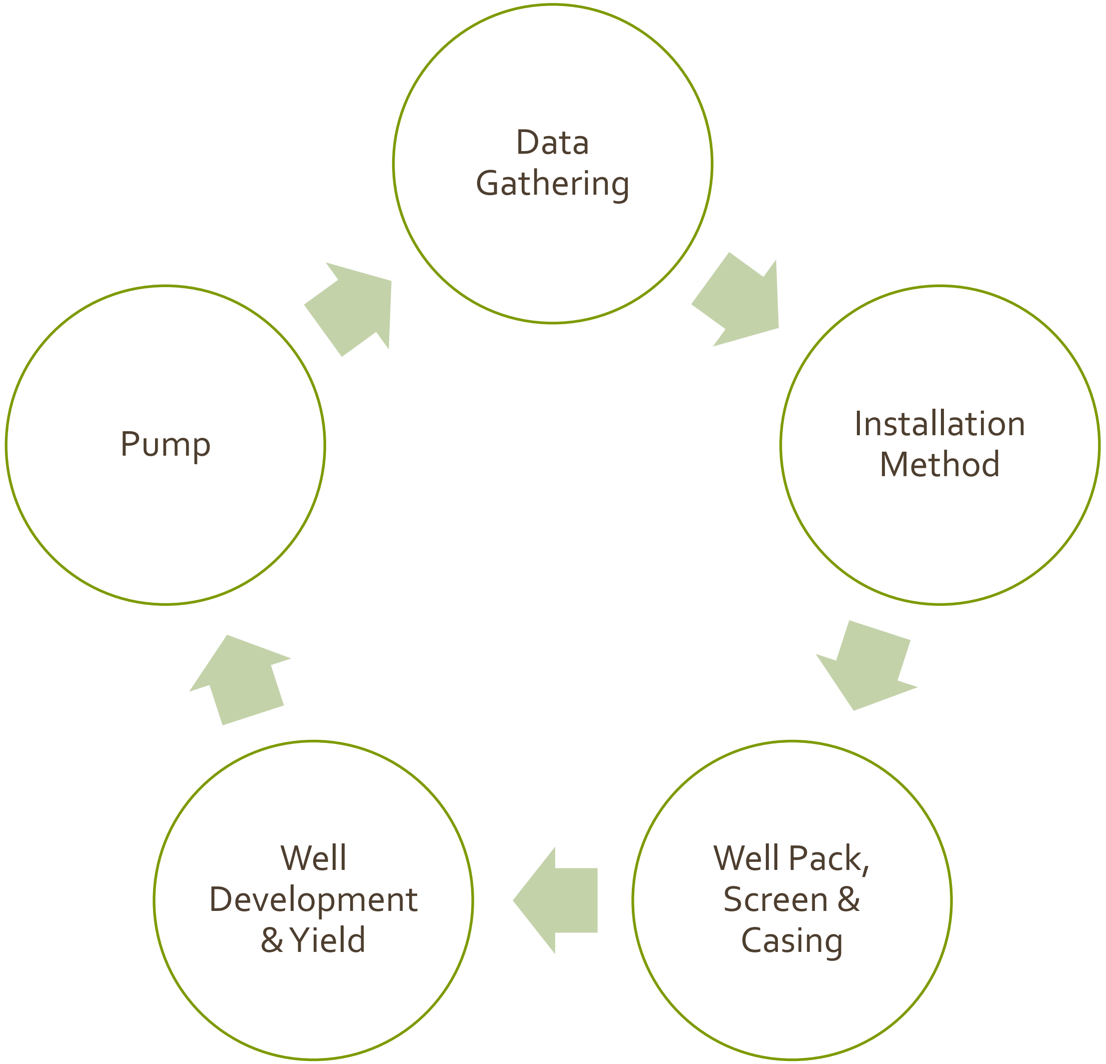
Drilled wells:
Mud drill and air rotary drill

- Used for installing typical and deep wells because the drill rig is so big and expensive. Best if used for wells 6" in diameter or bigger. Almost always used for bedrock wells.
- In aquifer: Installation method may require particularly long well development because of the mud that can be created on the borehole.
- In aquifer: Often does not allow for artificial well pack installation, or the installation of artificial well pack is cost prohibitive.
- In aquifer: 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.

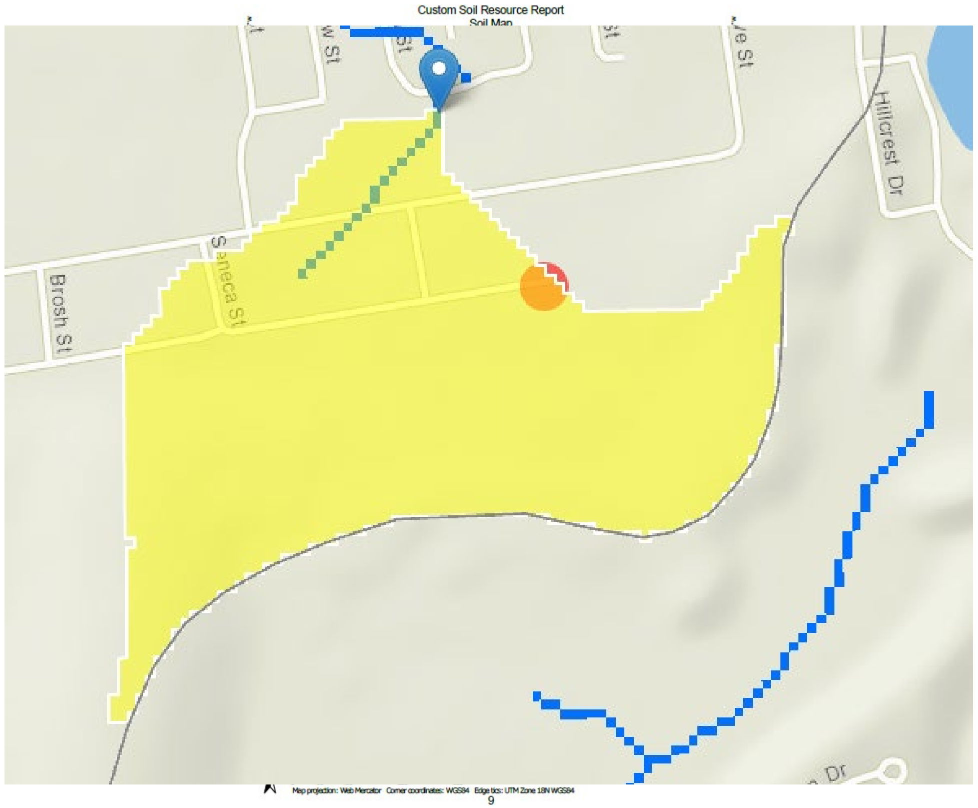
A simplified process of: Planning, Designing, and Installing Wells

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



A lot can go into planning, designing and installing wells. We'll keep the discussion limited to these topics and to non-potable wells installed to a maximum depth of 80 ft.

Data gathering:
Identify Soils and Delineate Watershed



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

Data gathering: Geology and Hydrogeology Maps and Neighboring Wells

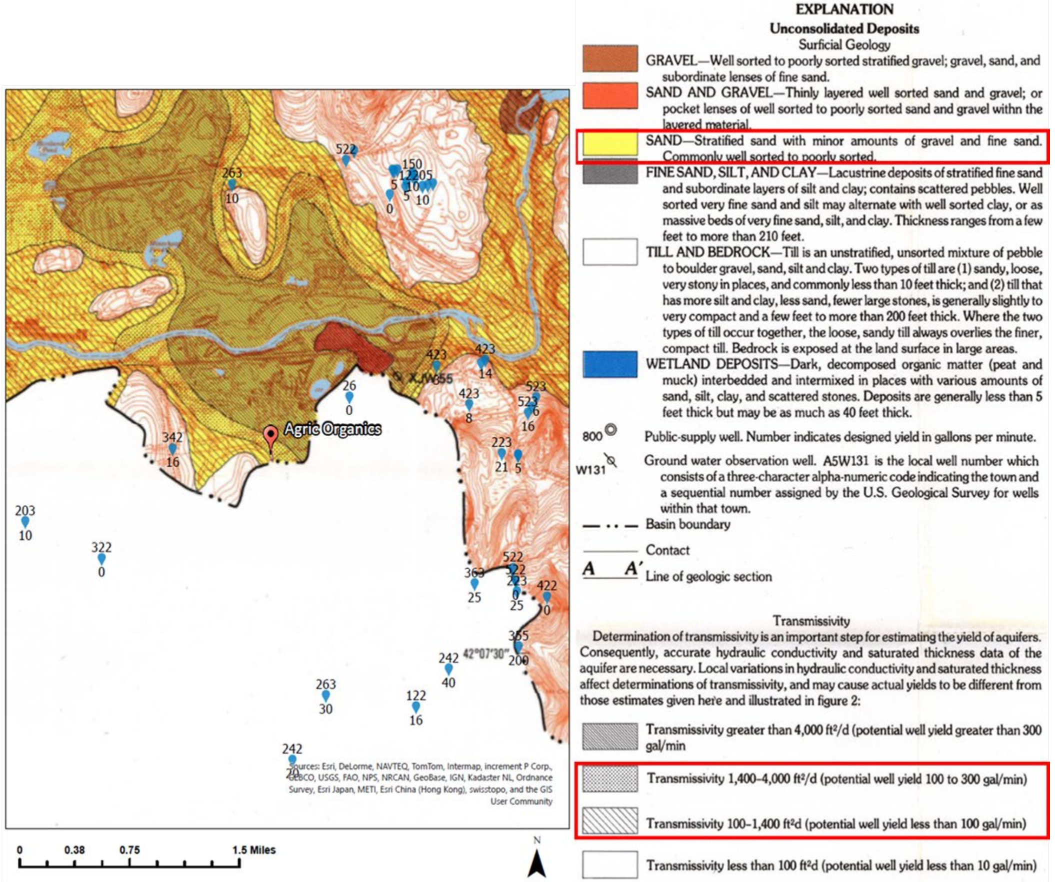
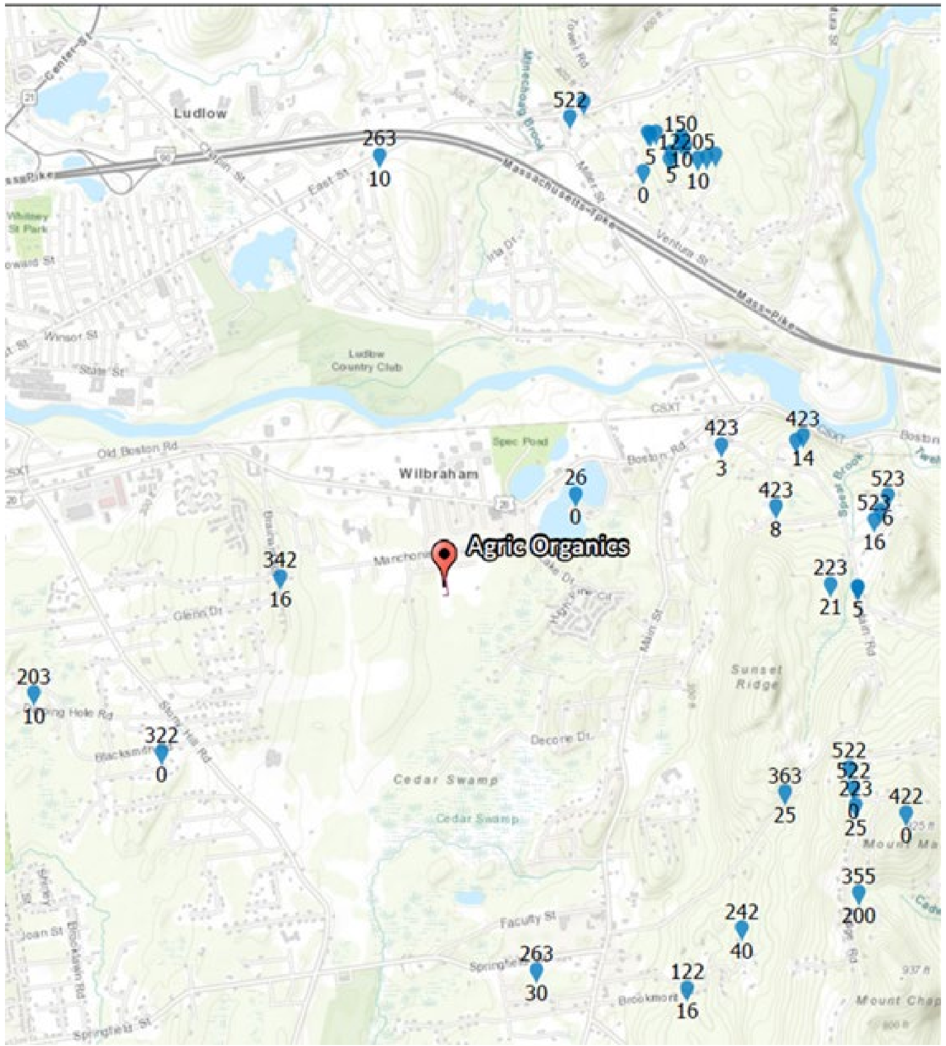


Figure 3. Map showing the availability of ground water in unconsolidated sediments (Krejmas and Maevsky, 1986) plotted with the location of Iron Agric Organics (red placemark), and private water wells (blue placemarks) in the area. Posted on the water wells are the total depth of the well (above) and 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 production wells.

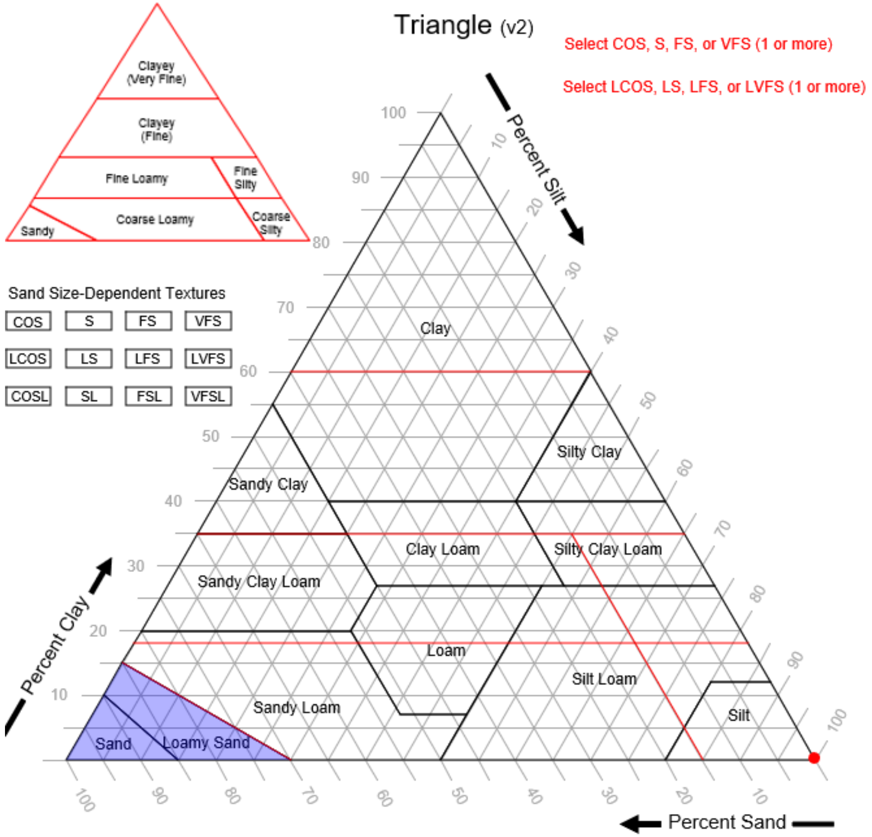
Finding a saturated layer which transmissivity satisfy required flow.

- 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.

Identification of a suitable aquifer material

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.

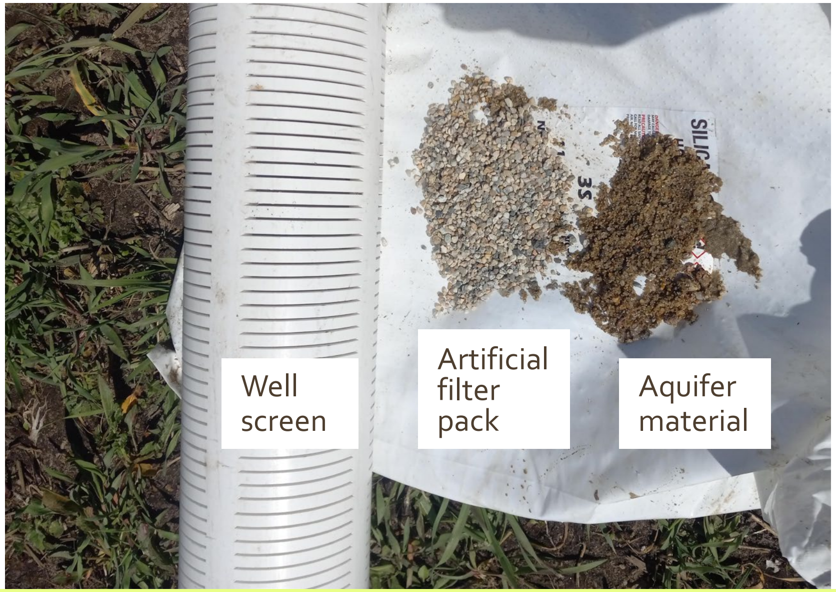
Well filter pack

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.

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.

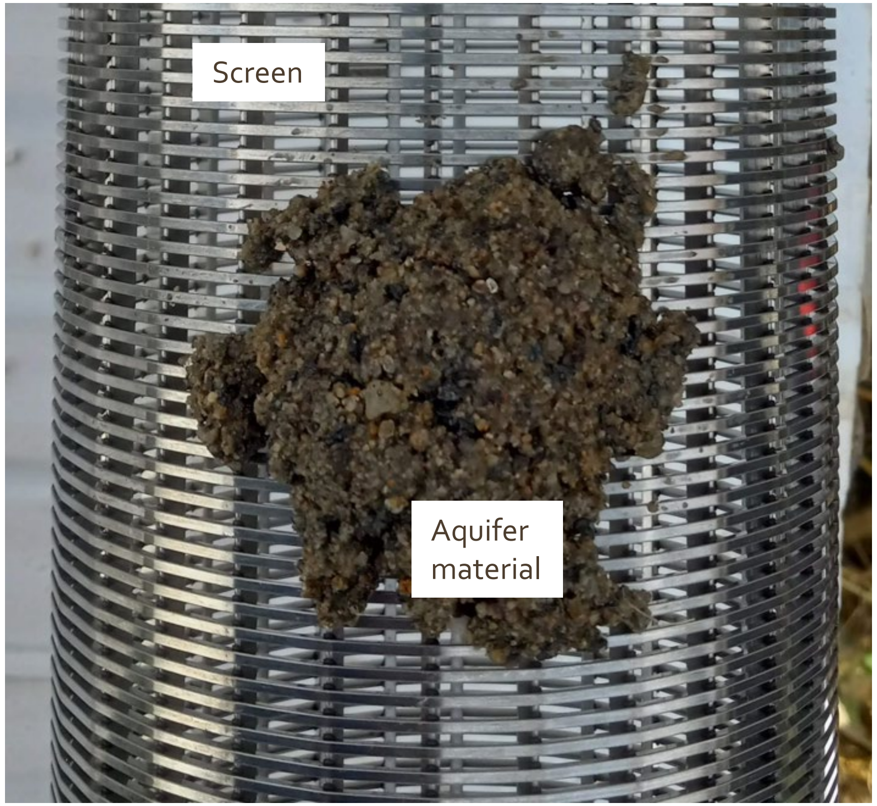
Most often we want the excavated well to fill in from the bottom, taking advantage of the surrounding hydraulic head. The alternative is to have perforated walls.

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.

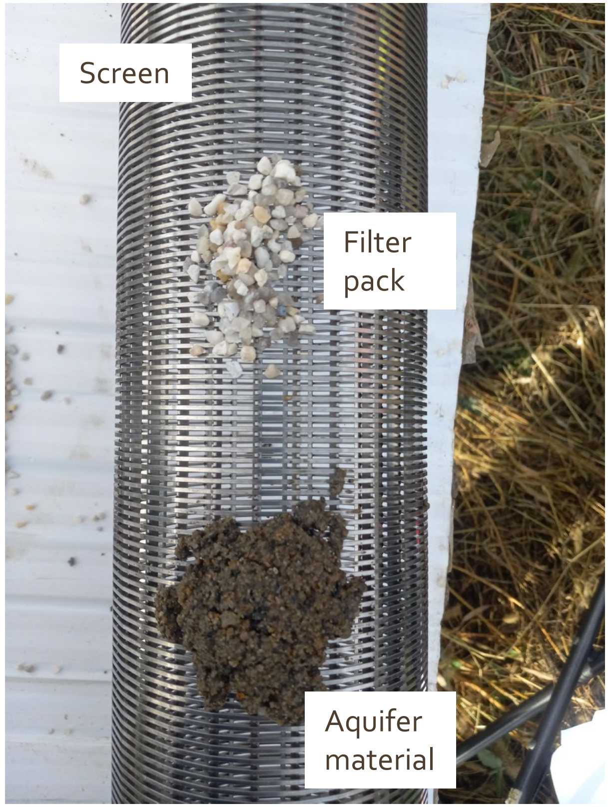
During well development the screen allow coarse material to be retained in the aquifer while finer material is extracted, creating the natural filter pack surrounding the screen.

Designing 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: 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 ~ cleaning the well

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.

Q&A

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Presentation will be available at:

- https://nophnrcse.org/