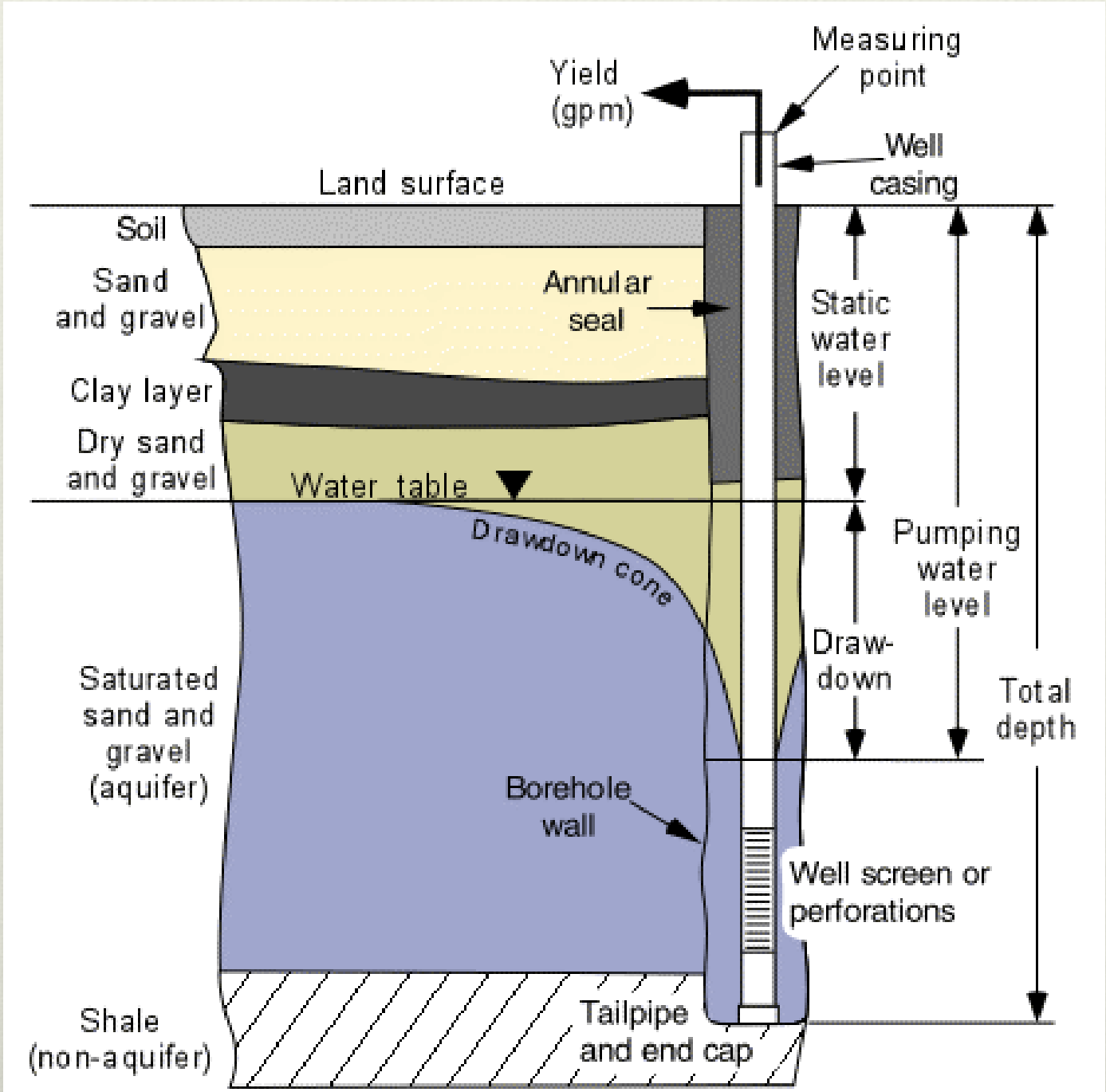
Overview

- Water Well Design
  - Important terms
  - Design Considerations
  - Steps of Water well design


Yield
(gpm)
Measuring
point
Well
casing
Land surface
Soil
Sand
and gravel
Annular
seal
Static
water
level
Clay layer
Dry sand
and gravel
Water table
Drawdown cone
Pumping
water
level
Draw-
down
Saturated
sand and
gravel
(aquifer)
Total
depth
Borehole
wall
Well screen or
perforations
Shale
(non-aquifer)
Tailpipe
and end cap

Important terms

- Annular seal
- Aquifer
- Borehole
- Casing
- Drawdown
- Cone of depression
- Measuring point
- Pumping water level
- Screen or perforations
- Static water level
- Tailpipe and end cap
- Water table
- Total depth
- Yield

Design

- Length of screen
- Diameter of screen
- Slot openings of the screen
- Strainer size
- Gravel pack material
- Yield of Tubewell

Depth of well

Generally a well should be completed to the bottom of the aquifer because:

1. More of the aquifer thickness can be utilized as intake portion of the well, resulting in, greater higher specific capacity.

2. More drawdown can be made available permitting greater well yield.

3. Sufficient drawdown can be made available to maintain well yield ever during periods of severe drought or over pumping.

Depth of well

Exceptions:

1. The well screen is centered between the top and bottom of a uniform confined aquifer.
2. In extremely thick aquifer, it may not be economical to drill to the bottom of the aquifer.
3. When poor-quality of water found in part of an aquifer, the well should be completed to a depth that will avoid the undesirable water.

Well Screen Length

- Optimum length based on
  - thickness of the aquifer
  - available drawdown and
  - nature of the stratification of the aquifer

Most Productive Aquifer

The intake portion of the well must be placed in those zones having the highest hydraulic conductivity which is determined using following technique:

- Aquifer materials at definite intervals undergo sieve analysis
- Particle size distribution curve is prepared
- **effective size(D_{10} or d_{10}) and uniformity coefficient($C_U = d_{60}/ d_{10}$)**
- The aquifer materials having high effective size and low uniformity coefficient will have high hydraulic conductivity
- The best aquifer for screening is determined by comparison of the grain size analysis curve of the materials along the depth of the borehole

The effective size(D_{10})

- That sieve size through which 10% of the particles shall pass and 90% are retained. 90% of the particles in the aquifer are thus coarser than this size and hence retained on a sieve of this size

The Uniformity Coefficient (Cu)

- Defined as the ratio of the sieve passing 60% of the aquifer material, to the sieve size passing 10% of the aquifer material. In other words:

$$C_U = D_{60}\,(40\%\text{retained}) / D_{10}\ (90\%\ \text{retained})$$

- This ratio is proposed by Hazen(1893) to be a quantitative expression of the degree of assortment of water bearing sand, as an indicator of porosity,

- Generally, a material is classified as uniform, if the uniformity coefficient C_U is less than and equal to 2.0

Well Screen Slot openings

- Oversized slots will pump finer materials indefinitely and become difficult to obtain clear water. Undersized slots will provide more resistance to flow of ground water into the well, resulting in more head loss and corrosion.
- Screen slot openings for the same formation can be different depending on whether the well is naturally developed or filter packed.
- Coarse- grained non homogeneous material can be developed naturally, whether fine-grained homogeneous materials are best developed using a filter pack.

Well Screen Diameter

- Well yield is much more effectively increased by increasing the screen length by proportionately increasing the screen diameter.
- Doubling the screen diameter, for instances , will only result in increasing 10 to 15 percent in the yield. On the other hand, doubling the screen length will result in the yield being almost doubled.
- It is much more better to **use screen length as a controlling factor** on well rather than screen diameter in thick aquifer.
- enough open area must be provide so that the entrance velocity of water generally does not exceed the design standard of 0.1 ft/s

Filter Pack Design

- Filter pack materials should be well sorted to assure good porosity and hydraulic conductivity of the materials near the screen.

Filter packing is required when:

- The sediments are highly uniform and fine grained(D_{10} < 0.25 mm).
- The sediments are highly laminated.
- The borehole diameter may be much larger than required for the installation of a screen.

Selecting a screen slot size that will retain 90% or more of the filter pack material. The thickness of the filter pack should be within 3 to 8 inches.

Entrance Velocity

- Fields experience and laboratory tests show that the average entrance velocity of water moving into the screen should not exceed 0.1 ft/sec.
- At this velocity, the friction losses in the screen openings will be negligible and the rates of incrustation and corrosion will be minimal.

Screen Transmission Capacity

The transmitting capacity of a well is given by,

$Q = \pi D L(0.01p) v_c$

Where, Q= screen transmitting capacity

D= diameter of the screen

L= length of the screen

p= percent opening area of the screen

v_c= permissible entrance velocity

The discharge of a tubewell should not exceed the transmitting velocity.

Steps for well design

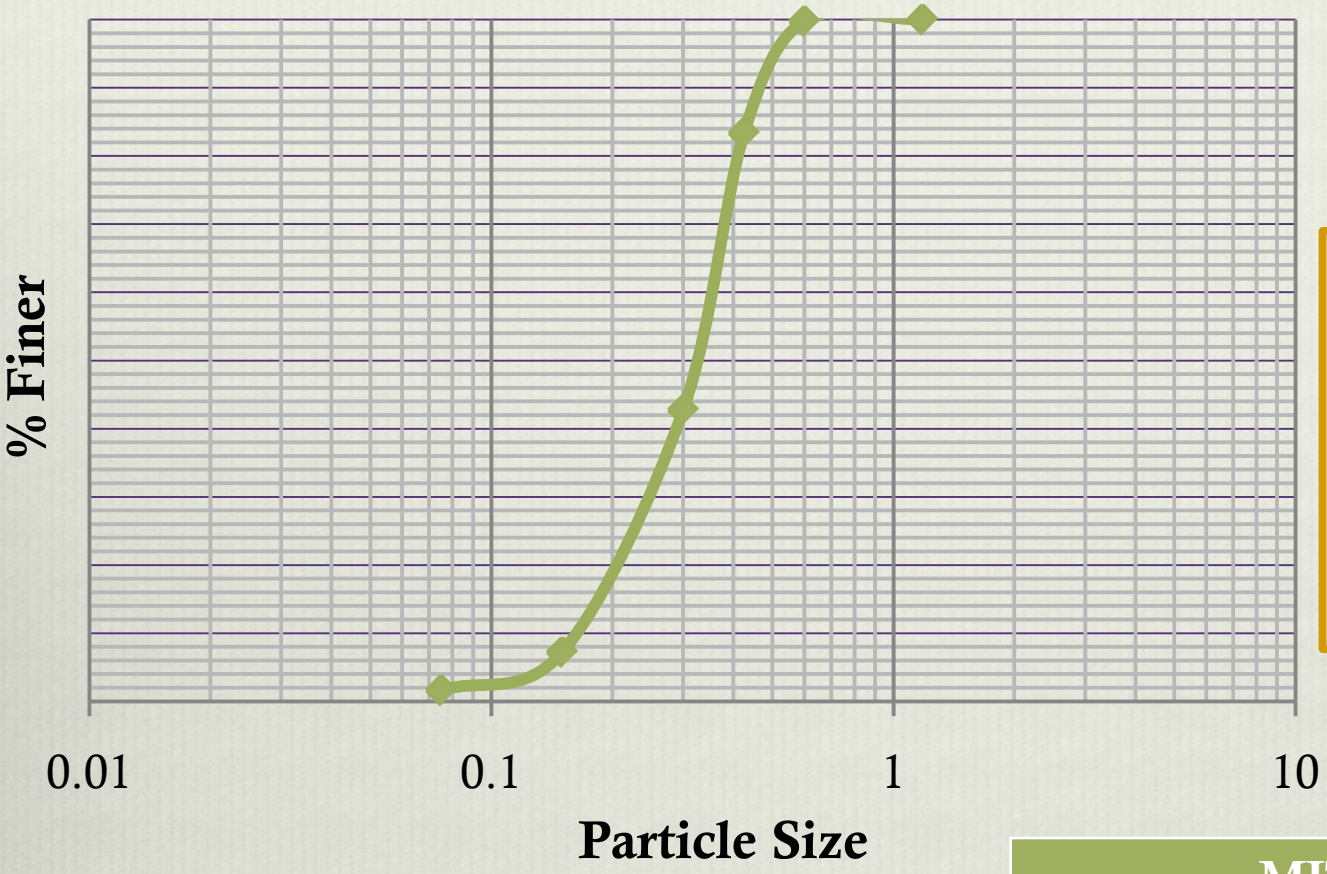
1. Grain size distribution for different soil layers
2. Locating the aquifer and water bearing strata
3. Determination of strainer length and position
4. Design of gravel pack material
5. Selection of strainer size
6. Yield of well

1. Grain size distribution for different soil layers

Sample Calculation

Sieve No	Seive Size (mm)	Material Retained	% Retained	Cumulative % Retained	% Finer	FM
16	1.18	0	0	0	100	
30	0.6	0.2	0.2	0.2	99.8	
40	0.425	16.4	16.47	16.67	83.33	
50	0.3	40.4	40.56	57.23	42.77	1.5
100	0.15	35.4	35.54	92.77	7.23	
200	0.075	5.6	5.62	98.39	1.61	
Pan	0.0001	1.6	1.61	100	0	
Total		99.6				

- FM= $\frac{\sum(\text{Cumulative \% retained of standard sieves})}{100}$



Fine Sand 20%
Medium Sand 79%
Course Sand 1%

MIT Classification	
Silt/Clay	< 0.06 mm
Fine Sand	0.06 – 0.20 mm
Medium Sand	0.20 – 0.60 mm
Course Sand	0.60 – 2.00 mm
Fine Gravel	> 2.00 mm

1. Locating the aquifer and water bearing strata

Summary of Grain Size Distribution

Sample Depth (ft)	D_{10}	D_{30}	D_{60}	U = D_{60} / D_{10}	FM	% Coarse Sand	% Medium Sand	% Fine Sand
130-170	0.15	0.195	0.27	1.80	1.18	1	66	33
170-210	0.12	0.195	0.3	2.50	1.26	3	67	30
210-220	0.15	0.21	0.33	2.20	1.41	4	70	26
220-270	0.17	0.28	0.3	1.76	**1.63**	**6**	**77**	17
270-310	0.17	0.28	0.31	1.82	**1.69**	**11**	**72**	17
310-370	0.17	0.24	0.38	2.24	**1.5**	**5**	**75**	20
370-410	0.17	0.29	0.395	2.32	**1.63**	**5**	**80**	15
410-430	0.15	0.22	0.37	2.47	1.47	5	71	24

***Higher % of coarse and medium sand**
***Higher FM means bigger particle**

Location of water bearing soil layer 220’ to 410’

3. **Determination of strainer length and position**

Primary factors:

1. Length of casing pipe must be selected first
2. Casing pipe must be sufficient enough so that submersible pump always remain below water

Length of the casing pipe is the summation of four lengths:

1. Static water level at present
2. Assumed drawdown of 10’ to 15’ while pumping each time
3. Average rate of water level declination (per year) x Design life
4. Safety distance of 10’ to 15’

- After the length of the casing pipe and depth of the submersible pump being ensured, we can think about strainer position
- Limitation of strainer length

Aquifer Thickness	Recommended Screening
< 25’	70% Screening
25’ – 50’	75% Screening
> 50’	80% Screening

- As it is very difficult to maintain the vertical alignment of a long strainer, it will not be practical to go beyond 100’ screening
- Strainer should not be extended up to the bottom of the aquifer to allow the upward converging flow of water during pumping

Necessity of a blank pipe

1. Between two strainers of a discontinuous aquifer

2. 10’ blank pipe is placed at the bottom of the strainer to trap particles that may enter into the pipe through upward converging flow

Sample Calculation

Let, the static water level at 230’

Average rate of water level declination (per year) = 2’
Design period= 20 years
Drawdown of 15’ while pumping each time
Safety distance of 15’
So length of the casing pipe= (230+40+15+15)= 300’
Aquifer depth= (410-220) = 190’ which is more than 50’.

So 80% of the aquifer screening can be made which gives the strainer length of = (190 * 0.80) = 152’
But as we know that maximum safe length of the strainer is 100’, so we can choose a strainer of 75’

Failure of Tubewell

A normal tubewell lasts for about 15 to 20 years. It may fail due to (1) incrustation, (2) corrosion.

1. Incrustation: the incrustation of the well occurs due to the deposition of alkali salts (calcium carbonate, calcium and magnesium sulfates and silicates) on the inside wells of the pipe.

2. Corrosion: the well pipe is gradually destroyed by corrosion due to action of acidic waters on the pipe material. When chlorides and sulfates or carbon –di-oxide are present in the water, the well pipe will definitely get corroded.

4. Design of Gravel Pack Material
5. Selection of Strainer Size

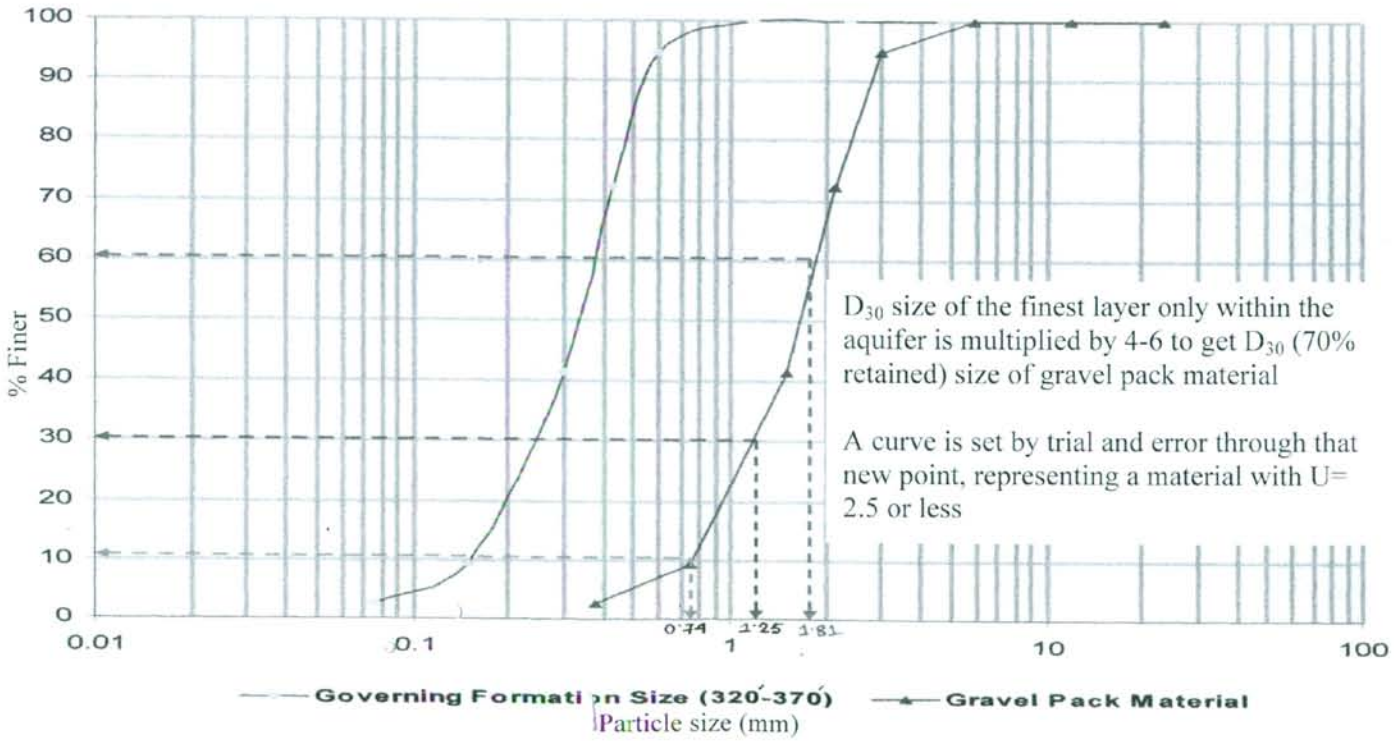
Gravel Pack Material

Sieve No.	Size(mm)	% Finer from Graph	Cumulative % Retained	% reatained	Range of % reatained
4	4.75	98	2	2	0-6
8	2.36	80	20	18	14-22
16	1.18	28	72	54	50-58
30	0.6	5	95	23	19-27
40	0.425	3	97	2	0-6
50	0.3	0	100	3	0-7
100	0.15	0	100	0	-
200	0.075	0	100	0	-

Strainer Size

To retain 90% of gravel pack materials, slot= D_{10} /25.4*1000
=0.74/25.4*1000
=29.13

4-6 inch dia 30 slot strainer is selected having each opening area of 30/1000 inch



D_{30} size of the finest layer only within the aquifer is multiplied by 4-6 to get D_{30} (70% retained) size of gravel pack material

A curve is set by trial and error through that new point, representing a material with U= 2.5 or less

3-8 inch diameter envelop of gravel will surround the entire screen

6. Yield of well

- Well yield is calculated using strainer opening area
- Yield = (area of strainer x flow velocity) / factor of safety
- The factor of safety is considered assuming blockage while operation
- Different slot size have different opening area
- For PVC screen, opening area is considered to be half of the mentioned areas below

Slot size	Assumed opening (Steel screening)
40 slot	20%
30 slot	15%
20 slot	10%

Sample calculation

For 30 slot strainer,

Strainer area= 15% of strainer surface area

= 0.15 x 3.14 x Diameter x Strainer length

Here, Diameter = 6”

Length = 75’

Assume, flow velocity = 0.10 fps

Factor of safety = 2.5

So, Yield of a well = (0.15 x 3.14 x 6/12 x 75 x 0.1) / 2.5

= 0.7065 x $(0.3048)^3$ x 3600 x 1000

= 72, 021 lph

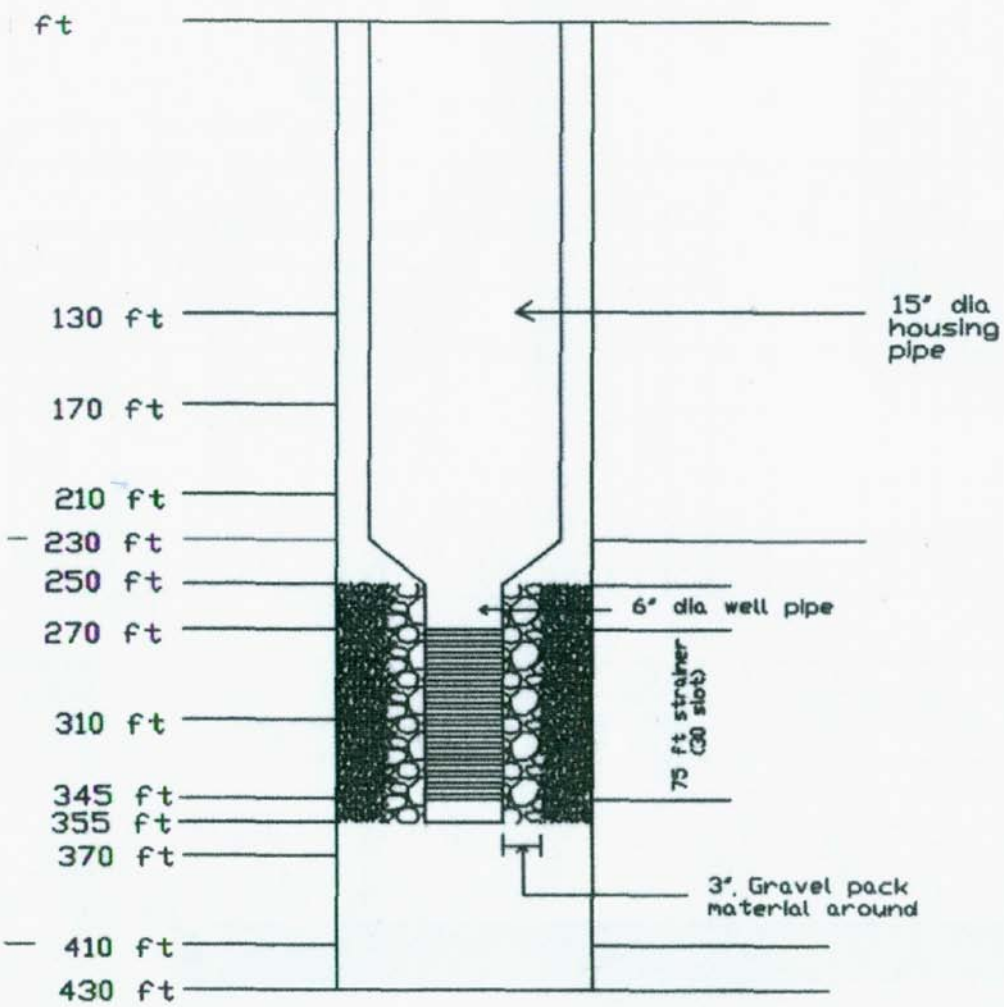
Design considerations:

- For one pump
- In one day
- 8 hour continuous pumping

As pumping is for 8 hour per day, Yield = 72, 921 x 8

= 576, 170 lpd

* More than one well may be required if one well can't meet the demand


ft
130 ft
170 ft
210 ft
230 ft
250 ft
270 ft
310 ft
345 ft
355 ft
370 ft
410 ft
430 ft
15" dia housing pipe
6" dia well pipe
75 ft strainer (30 slot)
3", Gravel pack material around

WELL LOG