INSTALLING AN INEXPENSIVE AIR LINE TO MEASURE WATER DEPTHS IN WELLS

Joe Henggeler
Extension Agricultural Engineer-Irrigation

An inexpensive, yet highly accurate, device to measure the depth to water in a well can be fabricated from plastic tubing, a pressure gage, a bicycle valve, and a three-way fitting that joins the components together. All of these items can be found in local home supply or auto parts stores. This well sounder, called an *air line*, provides a valuable service to the irrigator or water district manager. The air line's purpose is to measure the water level in a well. Figure 2 (page 3) shows a diagram of an air line installed in a well.

The materials for the home-made air line discussed in this fact sheet costs only about $30. Commercial units, which have gauges displaying feet of water on their gauge face rather than PSI units (Fig. 2) cost about $200.
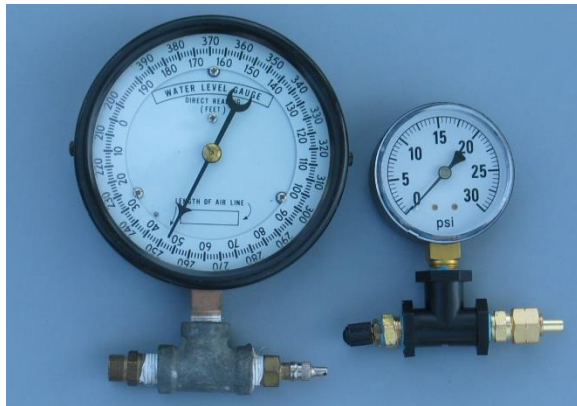

Fig. 1. A home-made air line unit (right) versus a commercially produced one (left).

Normally, an air line needs to be installed as the pump and column pipe are being lowered into the well. Being able to install an air line after the fact, depends on (1) how much space there is between the well casing and column pipe collars and (2) the availability of an access hole.

Although this fact sheet targets the relatively shallow (≈ 100-150 feet) irrigation wells commonly found in alluvial aquifers along the Mississippi and Missouri rivers, for the most part it is applicable to deeper wells, too. Part 1 of this fact sheet focuses on how to correctly install an air line. Part 2 explains how to use measured water levels for a variety of purposeful things.

How an Air Line Works

An air line is based on a law of physics where 1.0 pound per square inch (PSI) of pressure displaces water 2.31 feet. This physical fact allows air lines to be used in measuring the depth to water. First, the air line tubing in the well automatically fills to exactly the same level that the water in the well casing is at. When pressure is introduced to the air line from the surface by using a bicycle pump, the water inside the tubing is displaced. By observing the pressure gauge, one knows the pressure that was required to cause this displacement, and thus how many feet of water were displaced (by multiplying the PSI reading by 2.31). Subtracting this amount of feet of displacement from the length of the air line gives the depth to water.

It does not matter if the measurement is being taken while the water table is at its static level (SWL) or if pumping is taking place, thus lowering the water table (PWL) – it remains accurate under both conditions, responding quickly to changes.[1] Air line readings are not influenced by cascading ground water, as are e-lines. Even pump lubricant oil floating on the water surface doesn't affect the air line's accuracy. The displacement of this oil, which may be dozens of feet deep on top of the water surface and also has a lower specific gravity than water, automatically becomes the equivalent feet of water. Thus pumping plant evaluations are more accurate.

The equation for the water level is:

$$WL = L - (P * 2.31) \qquad \text{Eq. 1}$$

---

[1] Changes in a recovering water table (water level going up) are automatic; a dropping water level requires pumping up again.

Where:

WL = water level, in feet
L = length of air line, in feet
P = pressure on gauge, in PSI

EXAMPLE

- Length of air line (L) = 80 feet
- Pressure gauge reading (P) = 16 psi

What is the water level ?

$$WL = L - (P * 2.31)$$
$$WL = 80 - (16 * 2.31)$$
$$WL = 80 - (37.0)$$

$$WL = 43.0 \text{ feet}$$

Part 1: Installing an Air Line

Materials Needed

1. Plastic tubing.[2]
2. One pressure gage.
3. One 3-way Tee.
4. One tank valve.[3]
5. Pipe dope.
6. Duct tape.
7. Tape measure.
8. Electrical tape.
9. Plastic zip tie.

   Optional Materials

1. One large hose clamp (big enough for the column pipe being used) to strap tubing to column pipe.
2. Children's bubbles (to look for air leaks).
3. Automobile air gauge (to double check readings).

---

[2] Three-eighths inch of continuous polyethylene tubing equivalent in length to the distance from the pump to the ground surface, plus a few additional feet.
[3] Also called a bicycle or Schrader valve; these come with 1/8th-inch MIP thread and can be found in auto parts stores.

Pressure Gauge

Pressure gauges generally come in sizes of 15-, 30-, 60-, 100- and 200-PSI. Since their accuracy level is about 2% of scale maximum, it is best to use the smallest possible pressure size that accommodates the "extreme situation" encountered in your well. The highest possible PSI reading on an air line occurs during *static water level* (SWL) conditions when no pumping is going on. The maximum value for the air line gauge, in terms of feet, becomes the depth the pump is set (D_p) minus the SWL.

$$Feet_{Max} = (D_p - SWL) \qquad \text{Eq. 2}$$

Where:

$Feet_{Max}$ = maximum feet for gauge, feet

Table 1 shows the size and accuracy range of pressure gauges based on the difference between pump depth and SWL. To choose a pressure gauge, calculate the difference between the D_p – SWL in your situation and compare it to the value ranges of column one of Table 1.

Table 1. Size and Accuracy of Pressure Gauge to Use Based on Difference between Pump Depth and Static Water Level

Maximum Difference between Pump Depth and SWL (feet)	Gauge Size (PSI)	Accuracy (± feet)
< 35	15	1
35 – 70	30	1
70 – 140	60	3
140 – 230	100	5
230 – 460	200	9

EXAMPLE

- Pump setting depth (D_p) = 110 feet
- Static Water Level (SWL) = 12 feet

What pressure gauge should be used ?

$$Feet_{Max} = (D_p - SWL)$$
$$Feet_{Max} = (110 - 12)$$
$$Feet_{Max} = 98 \text{ feet}$$

Using Column 1 of Table 1, chose the 60-PSI gauge.

Reference
Benchmark Level

Δ Benchmark
& Ground Level

Static Water Level

Pumping Water Level

Drawdown

Pressure gauge

Tank air valve

3/8-inch tubing

3-way fitting

3/8-inch tubing

Duct tape

Well casing

Column Pipe

Pump

Displaced water

Begin tubing about 2 feet
above suction inlet; fasten with hose clamp.
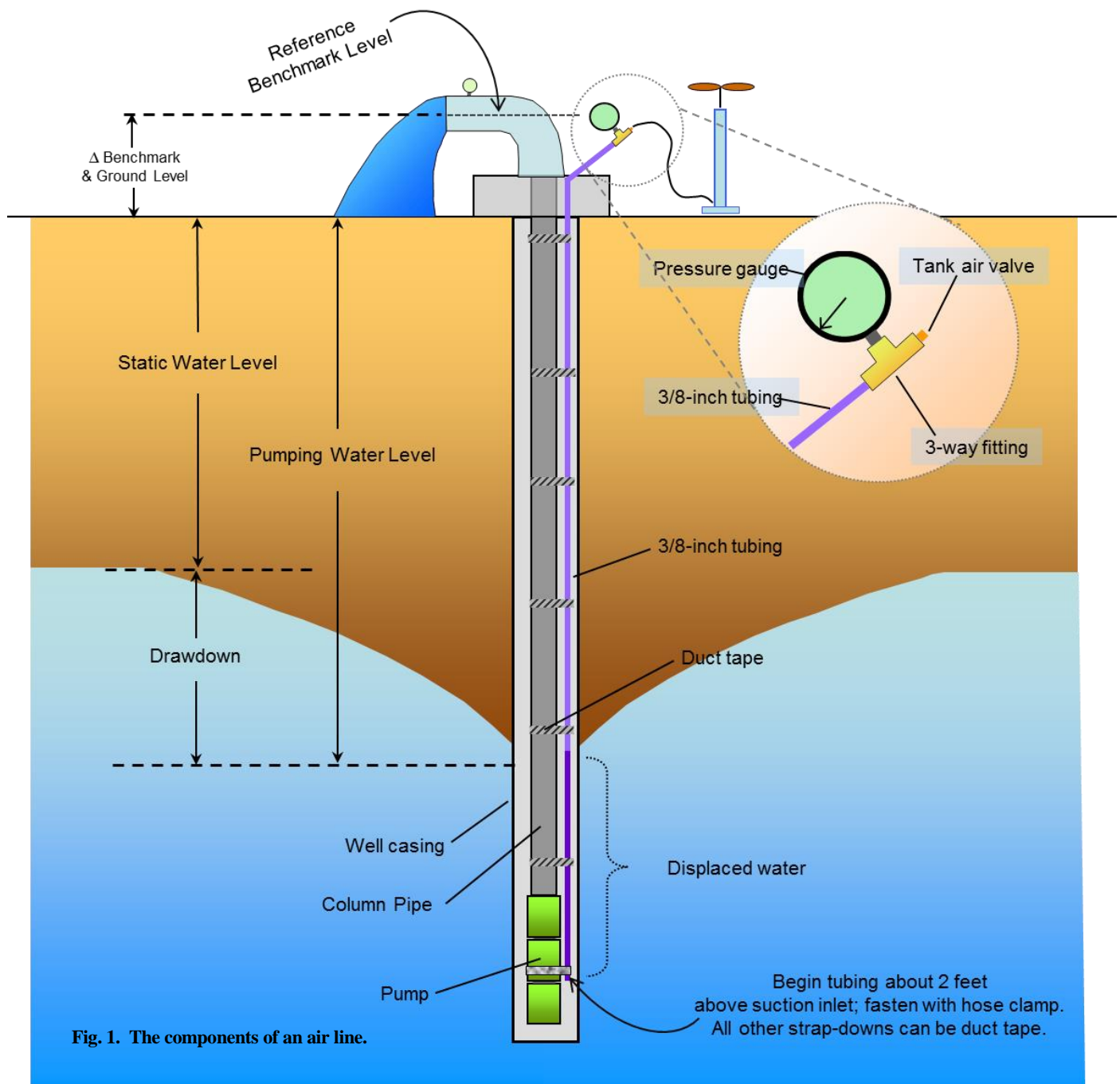All other strap-downs can be duct tape.

Fig. 1. The components of an air line.

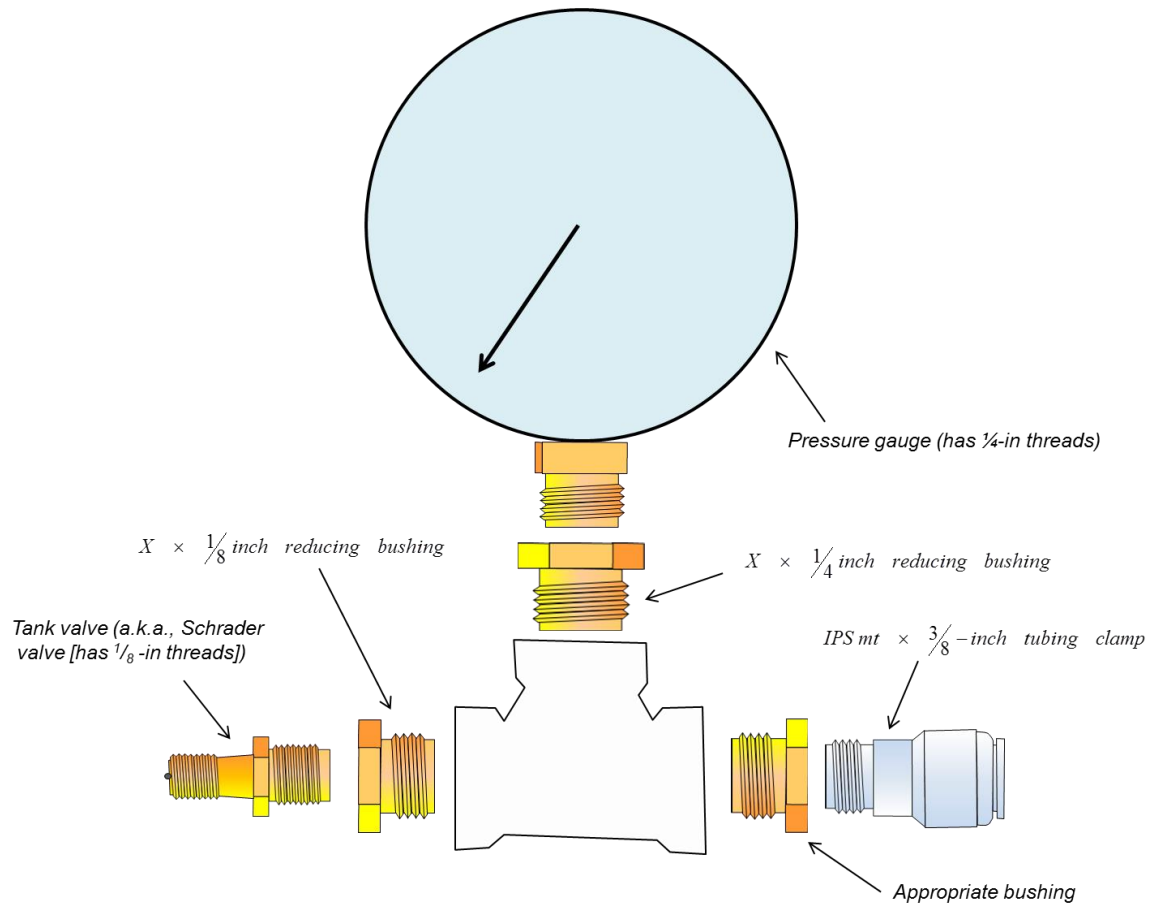**Figure 2. Diagram of the above-ground and below-ground components of an air line.**

Fig. 3. The components of an air line are joined together at the tee. Numerous tee configurations are possible, but inevitably connecting the pressure gauge will require an end with ¼ inch IPS female threads and connecting the tank valve will require an end with 1/8 inch IPS female threads. The fitting that connects to the hose can be bezel type, quick connect, etc.

Tee Connecting Components

Figure 3 shows the components of the Tee. The ways to configure the 3-way Tee are almost endless. The manner you do it will depend on the types of fittings found at your local stores. However, what will almost always be true is that the termination of:

- One of the ends of the tee must have ¼-inch IPS female threads (for the pressure gauge)
- Another of the ends of the tee must have $\frac{1}{8}$-inch IPS female threads (for the tank valve).

It doesn't matter what is connected where; that choice should be made when finally tying it all together at the pump stand, and should be dictated as to facilitate ease of management.

Tubing

The recommendation of using $\frac{3}{8}$-inch PE tubing stems from its relatively low cost and availability of fittings. The ¼ inch tubing also has these traits, but it probably doesn't have the same level of durability as $\frac{3}{8}$-inch does.

Clear PE tubing will not have the UV protection that black tubing does, so be sure and wrap the part of the air line exposed to the sun with black electrical tape.

Wells that Can and Cannot be Sounded

Air lines can almost always be installed as a pump is being set. [4] However, post pump installation, it is a harder task to perform. Air lines are located in the space between the well casing and the column pipe. If there is not ample clearance between the casing and the column pipe (including its collars) there may not be enough room to drop an air line. Even should one be dropped, worries would linger regarding if stretching, coiling, or looping had occurred. However, it might be possible to snake ½-inch CPCV pipe down an access port in the well base gluing the joints together as it drops to serve as an airline.

Also, in the southeast Missouri area, air lines (or, for that matter, even e-lines) cannot be used when centrifugal pumps draw ground water up directly from the aquifer since the well casing also serves as the column pipe. In both instances, a small 2-inch observation well can be jetted in near to the irrigation well to serve as observation wells to take measurements on the water table (Fig. 4).

Fig. 4. A monitor well being installed near an irrigation well which lacks enough space between well casing and column pipe for an air line.

---

[4] One item that sometimes is troublesome is getting the end of the air line outside of the casing at the top of the well.

Information Regarding SWL

While hooking up the air line, it is important to try and get a second-source reading of water table depth so that the integrity of the air line being installed (in particular, the pressure gauge) can be validated. Don't be fooled into thinking that an expensive glycerin-filled gauge is *de facto* correct –check it out. This is easiest done just prior to the pump being set. An e-line, weighted string, or chalked tape line can be used. Less accurately, the level to water can also be estimated by dropping a small stone into the well and timing how long it takes to hit the water, listening to make sure it doesn't ping against the side. Table 2 shows water depth based on time to reach the water.

Table 2. Depth Based on Time It Takes to Strike Water Surface

Time (s)	Depth (ft)	Time (s)	Depth (ft)
0.5	8	1.8	29
0.6	10	1.9	31
0.7	11	2.0	32
0.8	13	2.5	40
0.9	14	3.0	48
1.0	16	3.5	56
1.1	18	4.0	64
1.2	19	4.5	72
1.3	21	5.0	80
1.4	23	5.5	88
1.5	24	6.0	97
1.6	26	6.5	105
1.7	27	7.0	113

The SWL on an installed pump can be measured with an e-line dropped down any of the ports around the base of the pump (Fig. 5).

Also, previously installed air lines can be double-checked for their current accuracy using an automobile tire gauge to take a measurement at the 3-way Tee's Schrader valve (with the pump being either on or off).

Fig. 5. Sounding SWL by dropping e-line into the column pipe after removing an air relief valve while the pump is off.

Installing an Air Line

Starting Installation

The 3-way Tee gauge unit (Fig. 6) can be pre-assembled ahead of time. It must be air tight; use cement to secure PVC to PVC components. Also, use threading paste rather than Teflon tape for metal components.
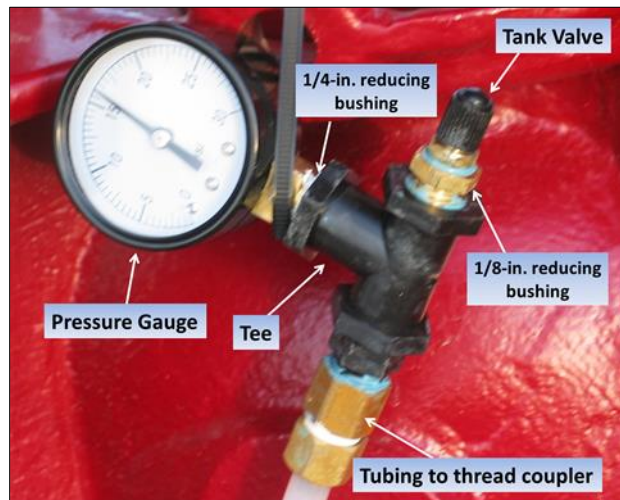

Fig. 6. The components of the 3-way Tee gauge unit.

Cut off a set length of tubing about 10 feet > than the pump depth setting; it should be a rounded number. For example, if the pump is to be set at 60 feet, <u>measure</u> and cut off 70 feet. Instead of trying to measure the length of tubing as the pump is set down the hole, it is easier to measure the residual amount that was finally trimmed away when the tubing was tied into the Tee.

Installation

The end of the tubing is secured to the outside of the column pipe 2 feet above the pump intake with duct tape or a hose clamp (Fig.7). As the pump is lowered secure the air line every 10 feet.

Fig. 7. The distance from the end of the tubing to the top of the pump being measured. Make sure that the end of the tubing is at least 2 feet from intake of the pump.

Once the pump valve head is threaded onto the column pipe, remove one of its access hole plugs and insert the end of the tubing through this port as seen in Figure 8.

Fig. 8. The air line is secured to the column pipe with a final wrap of duct tape. The tubing is run through the bottom end of the pump stand access hole. (NOTE: Both figs 7 and 8 show duct tape being used to secure the tubing to the column pipe. Current recommendations are to use plastic zip ties or large hose clamps instead).

Note: Twelve- and 14-inch well casings are probably big enough so that a pump stand access hole will end up lying somewhere above the space between the casing and the column pipe, providing access to bring the tubing out. In other cases, a hole will need to be carefully cut into the well casing for the tubing to exit out through to outside.

Now trim the exposed tubing back, attach it to the air gauge unit, and secure it somewhere on the pump valve stand with a zip tie so it won't flop around, yet remain accessible to take future readings. Don't forget to record the length trimmed off so that it can be subtracted from the originally measured off length of tubing. Also, write down the air line's length in the panel box or paint it on the pump stand itself.

Figure 9 shows the air gauge unit secured to the well stand with a zip tie. Also, note that the exposed plastic tubing has been wrapped with

electrical tape to keep the sun's ultraviolet rays from damaging it.

When precise measurements are called for, remember that the length of the air line (*L* in Equation 1) is referenced to where the tubing was cut off to attach it to the Tee. If a reading of aquifer depth is desired, the vertical distance from the ground surface to the Tee (Fig. 10) should be subtracted from the results of Equation 1. Similarly, if the exact value for PWL is desired, then the vertical distance from the Tee to the center of the pump discharge pipe is added to the results of Equation 1.

Fig. 9. The air gauge unit attached to pump stand with a zip tie and exposed tubing wrapped with electrical tape to shield the tubing from the sun's UV light.

Fig. 10. The length of the air line tubing, *L*, terminates at where it attaches to the gauge unit, dictating that the measured water surface is measured relative to that point. If the actual distance of water table to some other reference, say ground surface or pump discharge pipe is desired then the vertical distance of these points to the 3-way Tee must be factored in..

Note: Experienced well installer Tim Hutton determined that for the relatively shallow wells found in the Missouri Bootheel region (≈ 100 feet) air line installation is easier if the complete pump, from bowl assemblies up to pump stand, was first threaded together and dropped into the well as normally done, then it is hoisted back up. As it is being dropped back down, the plastic tubing is taped to the column pipe and finally inserted through the pump stand and joined to the 3-way Tee.

Taking a Reading with an Air Line

To use an air line, connect a bicycle pump, or source of compressed air[5], to the Schrader valve and fill the air line up. You will see the pressure gauge begin to increase. Continue on until it no longer increases. Any excess pressure in the air line quickly comes to equilibrium by bubbling out of the bottom of the tube.

---

[5] I've seen farmers in Texas use a hose from their tanks on propane-powered pickups be used.

After you stop pumping air into the air line, the gauge reading should be stable. If the pressure gauge reading slowly drops then there is an air leak somewhere in the Tee. Brush on some children's play bubbles or liquid detergent to find the source and tighten up the loose fittings.

Once a stable pressure is held on the gauge, use Equation 1 to calculate depth to water.

Fig. 11. Using a bicycle pump to air up an air line.

Part 2: Ways Air Lines are Utilized

Measuring the depth to water in a well with an air line (or any other method) provides a number of good management tools for the irrigator. Some of these include:

- Calculating pump efficiency.
- Determining if the well screen is clogging up over time by performing annual specific capacity tests.
- Estimating if the well might be able to produce additional water.
- Monitoring against "pumping off."
- Determining aquifer characteristics.
- Determining the flow rate on electric pumps.

Appendix I
Quick Guide to Installing an Air Line

|	
Pre-assemble gauge unit.	• Using a ½-inch PVC threaded Tee, bush down to 1/8th-inch on one side and ¼-inch on another side. If PVC to PVC, glue bushings to ensure air-tight seal. If metal fittings, use threading compound rather than Teflon tape. • Tighten in pressure gauge on ¼-inch side and tank valve on the 1/8th-inch side. Use threading compound for these connections. • Bush the third side according to connector fitting being used.
Measure out and cut tubing.	• Cut a continuous tubing of length equal to the distance from base of pump stand to intake of pump plus a couple extra feet. ○ Record the original length. After trimming the tubing keep the discarded pieces; subtract the lengths of these from the length of the original tubing length to get air line's length.
Installing tubing in the well.	• Clamp bottom end of tubing 2 feet above the bottom of the pump with a zip tie or a large hose clamp. If an intake tailpipe is being used clamp the end 2 feet above it. • As each joint of pipe is lowered, secure tubing to the pipe.
Bringing the end of the tubing up to the surface.	• If an access port is available through both the bottom of the discharge head valve and the steel plate covering the pipe casing, bring the air line through there (Fig. I). If a port is not available a hole will have to be cut or drilled through the side of the casing.
Securing the end of the tubing.	• Secure the tubing to the three-way Tee. Use zip ties or other method to attach it to the discharge head valve. • Pump up the air line. Coat three-way Tee with children's play bubbles to look for air leaks. Calculate depth to water table and compare that to initial observations. If off replace pressure gauge. • Wrapped exposed tubing in black electrical tape since clear and opaque PE tubing is subject to UV degradation.
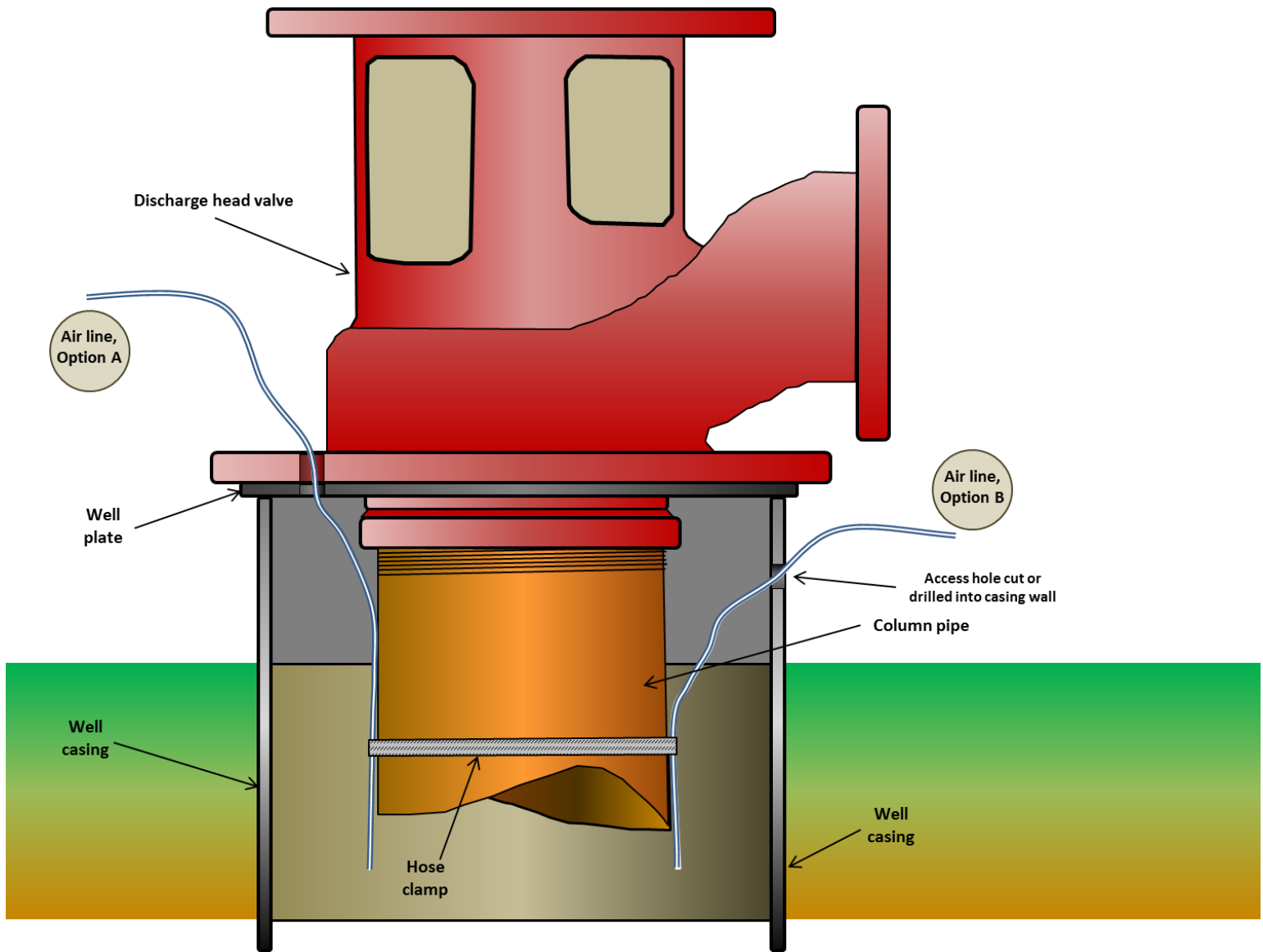
Fig. I. **Option A: Bring air line to outside via ports in discharge head valve and well casing plate if they are there. Option B: Drill or cut access hole in side of well casing and bring air line outside via that entrance.**