Low Pressure Systems Reduce Agricultural Inputs

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By

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Introduction:

Since its introduction in the 1960's, the availability, quality, management and performance of drip irrigation (DI) and subsurface drip irrigation (SSDI) have greatly improved. The uses of DI and SSDI have increased significantly as understanding and benefits of real-time irrigation methods increased and plastic materials availability, manufacturing processes, emitter designs and fertilizers improved. However, the perceived high initial cost of DI and SSDI systems and the energy cost to pressurize the system have slowed down the conversion of gravity irrigation to DI and SSDI.

The low pressure system (LPS) is a systematic development of a low cost DI system. The system is designed to operate at low pressures (2-3psi; 0.14-0.21 kg/cm2) by taking advantage of the slopes graded into furrow irrigated fields. Thus, LPS provides an effective low energy and economical upgrade for furrow irrigation. Furthermore, LPS mitigates environmental issues arising from difficult-to-control surface irrigation, non-point source pollution, deep percolation of soluble salts and pesticides, erosion and sedimentation of watersheds. The introduction of LPS provides an alternative initial low cost, low energy systems with a multiyear life expectancy, displaying a number of advantages associated with permanent DI and SDI systems.

The major objective of LPS is to provide a one-to-five year life span irrigation system with water and fertilizer application advantages of DI and SDI systems but at a lower initial cost. The initial LPS cost is dependent on the sophistication level of the system Conceptually, LPS is designed to: (1) help growers use existing infrastructures such as leveled fields, water sources and pumps, (2) minimize front end investment (3) provide fast return on investment, (4) reduce energy cost for pumping and pressurizing, (5) move and reuse equipment easily and (6) provide low system maintenance and management.

Two additional advantages of LPS could be: (1) low pressure/low flow design suggests that LPS could operate similarly to furrow irrigation by applying water uniformly over 1/4 mile- (400 m)-long rows and thus could potentially replace large Western furrow irrigated acreage and (2) water discharge rates being lower than most soil infiltration rates would not require the use of rigorous high frequency irrigation scheduling (LPS can stay on for longer periods of time without creating runoff and/or deep percolation). It is the purpose of this paper to present and discuss evidence for the applicability of LPS for use in 400 meter long rows and the Agronomic benefits of low pressure/ low flow irrigation. In addition, the economic benefits of low pressure drip irrigation will be discussed.

Components of a Typical LPS System

A typical LPS consists of several specific components. Depending on the size of the system, the topography of the site, the soil characteristics, the crop, the water/fertility requirements, the water source, availability and/or quality or the application considered, LPS may vary considerably in physical layout but generally will basically consist of some of the components shown in Figure 1, although LPS will often be as simple as the system shown in Figure 2. The various components of the system can be added as desired and are divided into: (1) connection to water source, (2) control headworks including a fertigation system, (3) field distribution system, (4) dripper line laterals, (5) accessories and installation tools and (6) optional automation and instrumentation.

Reservoir and Pump--Many farms are storing water in elevated reservoirs to supply water on demand to their irrigation systems and will not required a pump if the reservoir static pressure is at least 7-8 ft. (2.1-2.5 m). In cases where the static pressure from the reservoirs do not meet this minimum pressure requirement, a pump can be used to supply pressurized water for the LPS. Direct Connection to a Pressurized System--Many Irrigation Districts are supplying pressurized water to on-farm turnouts to supply water on-demand for their irrigation clients. In these cases, a pump may not be required if the static pressure from the turnout is at least 7-8 ft. (2.1-2.5 m). In cases where the static pressure from the irrigation district does not meet this minimum pressure requirement, a pump could be used to increase the water pressure for the LPS. Figure 3 shows a basic example of an on-farm low pressure water turnout supplying water for a LPS via a screen filter and a pressure regulating standpipe.

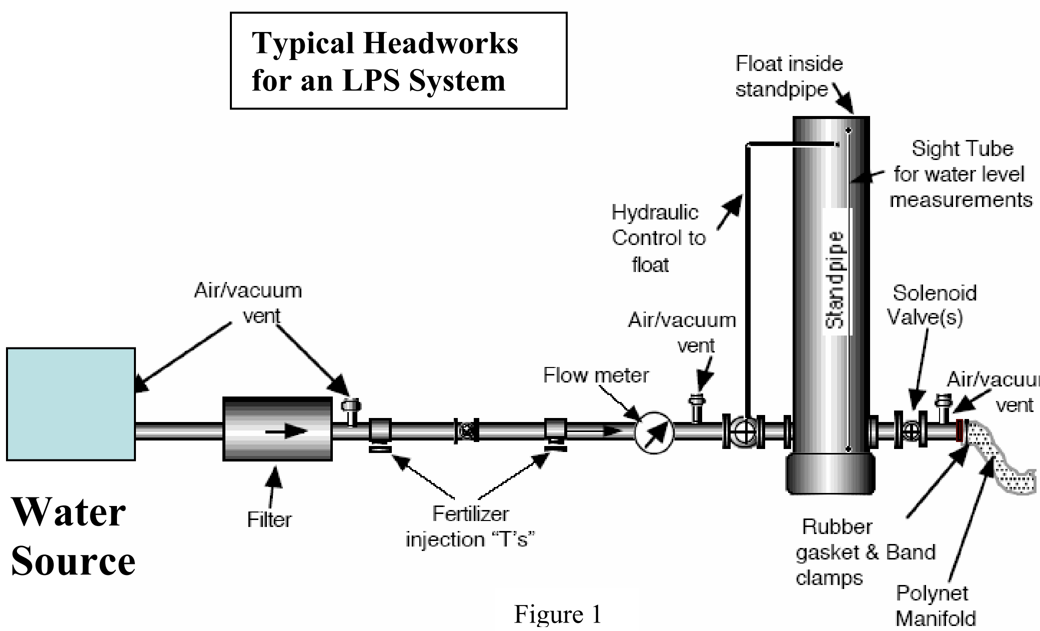

Figure 1

Figure 2

Figure 3

. Control Headworks The headworks of a basic LPS consists of specific components, as shown in Figure 1. Field systems may vary considerably in physical layout but generally will consist of the following or some variations of the following components:

a. Air vents-- Air vents are a critical component of any hydraulic network. If air is not released, air pockets are formed in the distribution lines, reducing the effective diameter of the pipe. The use of air relief valves at all high points of the LPS is the most efficient way to control air. There are three major types of air vents: (1) Air/Vacuum Relief Vents, also known as kinetic air valves. These air vents discharge large volumes of air before a pipeline is pressurized, especially at pipe filling. They admit large quantities of air when the pipe drains and at the appearance of water column separation; (2) Air Release Vents are also known as automatic air valves. These vents continue to discharge air, usually in smaller quantities, after the air vacuum valves close, as the line is pressurized and (3) Combination Air Vents, also known as double orifice air valves, fill the functions of the two types of air vents described above.

b. Filtration--The main purpose of filtration is to keep mainlines, submains, laterals and emitters clean and working properly. Many factors affect the selection of a filtration system. Designers should use the correct equipment for a specific farm water source. With LPS, the choice of a filtration system is further limited by the availability of electrical power and hydraulic pressure. Screen filters, such as shown in Figure 3 and gravity filters (low pressure) have been used successfully with LPS.

c. Flowmeter--Knowing how much water and when it is supplied are critical measurements for correctly operating LPS irrigation. Inline flow meters should record total flow and flow rate.

d. Float Control Valve--The main control valve is regulated by a float, located in the pipe at the preset maximum water level. The valve is hydraulically controlled by the float and opens or closes to maintain a constant water level and head pressure on the downstream LPS system.

e. Standpipe--The main purpose for the standpipe is to accurately control the pressure applied to the LPS dripperlines. Typical standpipes are 10.7 ft. high and 1 to 2.25 ft. diameter with inlet and outlet flanges. Water level and downstream pressure control are achieved by using a float which activates the float control valve shown upstream of the standpipe as in Figure 1. A clear, external water level tube allows the operator to visually determine the water level in the standpipe. Inlet and outlet pipes are connected to the standpipe by bolted flanges. In areas where wind gusts are occurring, the standpipe can be anchored to the ground by three or more steel cable ties.
f. Fertilizer Injector--Fertilizer injection methods range from dripping fertilizers at calculated rates into the standpipe (no available electrical power or necessary pressure) to using fully computerized monitoring and control systems. When electrical power is available, injecting with metering pumps is the most versatile method for injecting chemicals into LPS systems. Automatic time and programmable controllers are usually the best way to control fertilizer injection. When full automation is used, the metering of the fertilizer is programmed for injection during the middle of the irrigation cycle to avoid the line filling time of the irrigation cycle. Injection of chemicals can also be stopped during filter flushing operations. Continuous measurements of pH and EC are also recommended to ensure adequate system performance and to control the pump on or off and/or in the case of accidents and malfunctions.

3. Field Distribution System
The field distribution system consists of (1) automatic or manual valves, (2) Flexible Poly submains/manifolds with lateral connectors, (3) air vents and (4) manual clamps. Figure 4 shows a photograph of a typical manifold and lateral setup (the manual valve for system operation is not visible). Depending on the type of LPS applications, there are several types of thin-wall dripperlines with emitters integrated within the pipe wall that are available for LPS. The available types of LPS dripperlines are based on life expectancy (1-5 years) and types of tillage application. Emitters with different flow path configurations, discharge rates and operating pressure range are presently being used in LPS applications.

Figure 4

Full automation of LPS is available, although strictly an option. Because LPS applies water at a rate usually lower than the soil infiltration rate, high frequency irrigation management is not necessary to prevent runoff and/or deep percolation. Hence irrigation scheduling is typically less complicated and intense than for DI and SDI. However, although optional, instrumentation to measure weather and soil water conditions or access to a system that does (State Weather Network) can help meet the rapidly changing evapotranspiration demand of the crop and improve water use efficiency.

LPS Design Considerations.

The first step in designing LPS systems is to measure the flow rates of drippers at low pressures to ensure that they correspond to the theoretical rates. Table 5 gives comparative results for theoretical flow rates based on K and X values and those measured using a manometer (only the theoretical values are plotted). The values closely match. Such a measurement is not trivial as the flow rates at low pressures are very low and the pressure must be absolutely constant. A manometer is the best way to produce constant low pressures but maintaining the reservoir height requires careful experimental technique. In these experiments a large reservoir was used so that the manometer height would change little over the course of the experiment.

875ID - Typhoon 0.4 gph	K	X		Pressure (psi)										
				0	1	2	3	4	5	6	7	8	9	10
	0.128	0.45	Flow (gph)	0.000	0.128	0.175	0.210	0.239	0.264	0.287	0.307	0.326	0.344	0.361
measured flow rates			Flow (gph)	0.000	0.130	0.179	0.217	0.248	0.276					

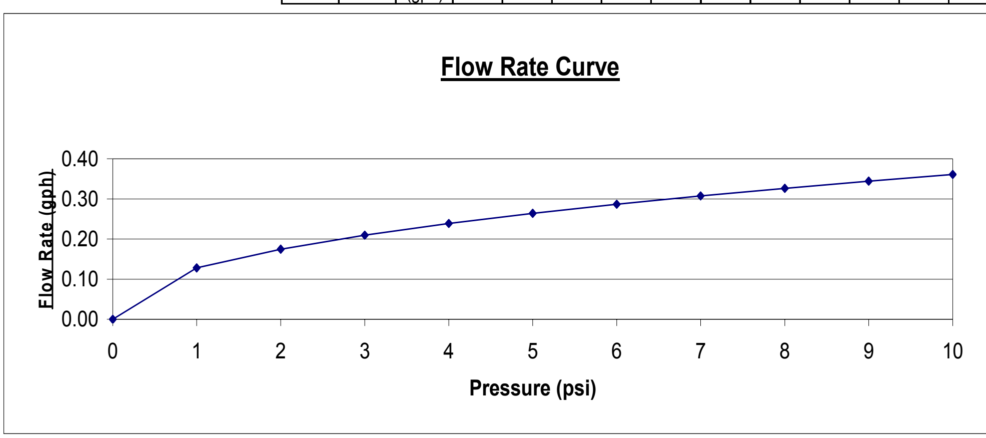

Figure 5

A second test was applied which looked at dripper turbulence. The turbulence factor denoted by K is a measure of the amount of turbulence produced in a dripper. The K factor is a function of the cross sectional area of the flow path, the number of teeth in the dripper and the pressure flow relationship. The application of the pressure flow data from the above experiments to the flow coefficient (K) indicates that the dripper maintains its turbulence down to 3.9 feet of head (1.7psi) (Figure 6).

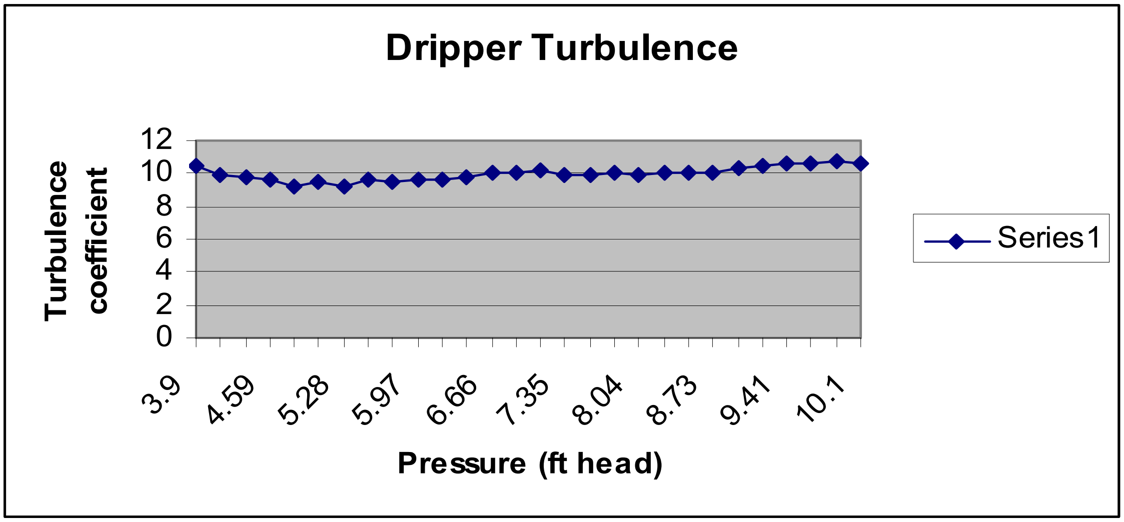

Figure 6

LPS is designed to work with level fields or those graded for flood irrigation. One of the system objectives is to work with 400 meter (1300 ft, or ¼ mile) rows. This was investigated by applying a standard dripper lateral design program using the appropriate dripper parameters determined above and varied slopes (Figure 7). The tubing internal diameter was 7/8 inches and the dripper spacing of 24 inches employed. The lateral input pressure was maintained constant at 3 psi and pressure along the lateral computed. Even over a distance of 1300 feet at an inlet pressure of only 3 psi the maximum variation in pressure was 1 psi or less. In all cases the emission uniformity was greater than 90%. The effect of slope on the pressure in the lateral is to increase pressure on the end of the line. The greater the slope the more pressure is increased as you move to the end of the lateral. There is obviously a “sweet spot” where the slope overcomes the pressure drop in the lateral line and the beginning and ending pressures are the same.

This computation shows that LPS systems can deliver excellent uniformity at row lengths up to 1300 ft. This computation only considered one flow rate emitter, 7/8 inch pipe and a single spacing. By varying these parameters it is possible to address a wide range of design challenges. Although the design uniformity for these computations was over 90% for all slopes uniformity is not the only reason for converting flood irrigated land to drip irrigation. The ability to provide water at any time needed in the crop cycle and the ability to send equipment into a field you are irrigating are just two cultural advantages of drip irrigation compared to flood or furrow irrigation.

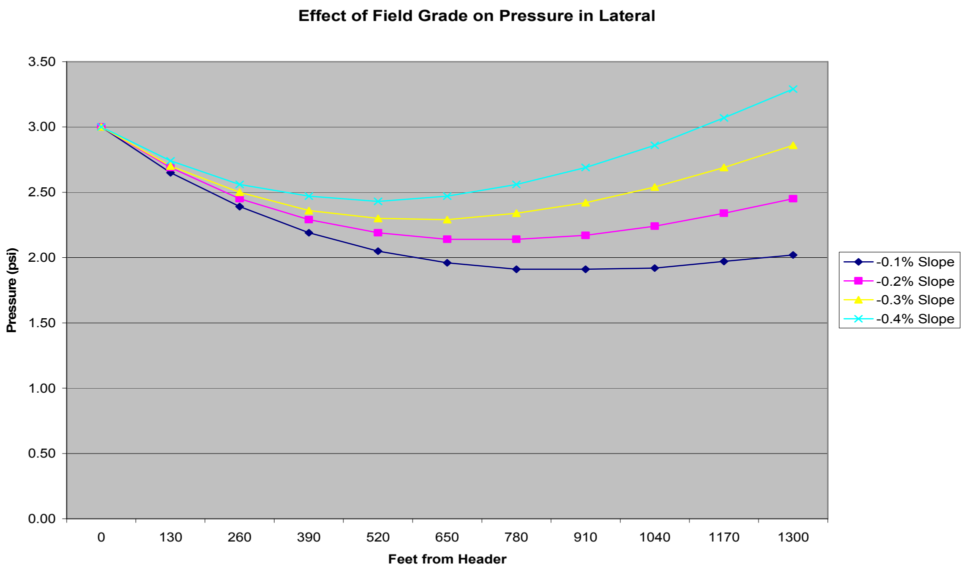

Figure 7

Agronomic Considerations of LPS

Operating drippers at low pressures results in lower dripper flows generally about one half the nominal flow rate (see Figure 5). At low flow rates water behaves in the soil differently than at higher application rates. At higher application rates the soil becomes saturated. In saturated soils the dominant force for water movement is gravity and thus water moves down the soil column and there is less lateral movement. At lower application rates the soil does not become saturated and the matric forces in the soil dominate. The matric potential is the result of small pores in the soil structure attracting water much like a straw. These forces pull the water in all directions and tend to result in a larger wetted area. An additional advantage of low flows is that the large pores remain filled with air resulting in a better root environment. Figure 8 demonstrates graphically the water movement in soils under higher flow and lower flow (LPS) drip regimes.

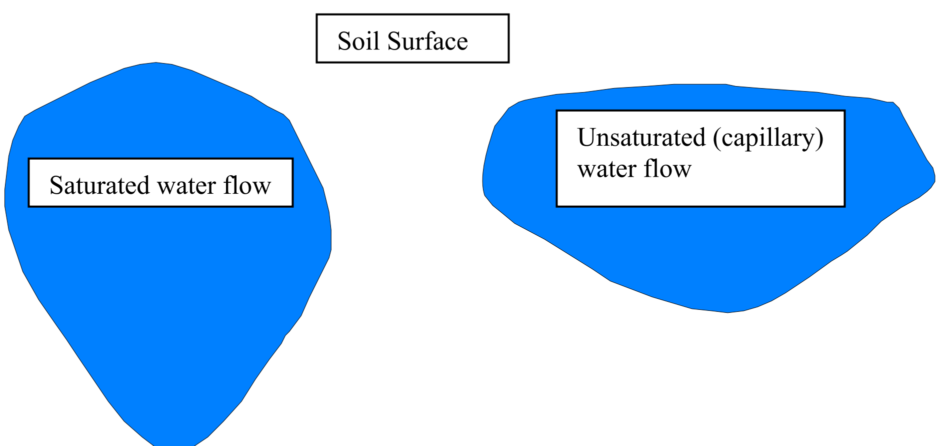

Figure 8

Experimental results on potatoes and corn show that the theoretical advantages of LPS can be translated into real savings in water when compared to flood irrigation. Figure 9 summarizes the results on water use efficiency for a crop of potatoes grown in Chihuahua, Mexico. The LPS plot yield required 40% less water than typical flood plot to produce equal yields. Figure 10 gives shows even more impressive savings with corn.

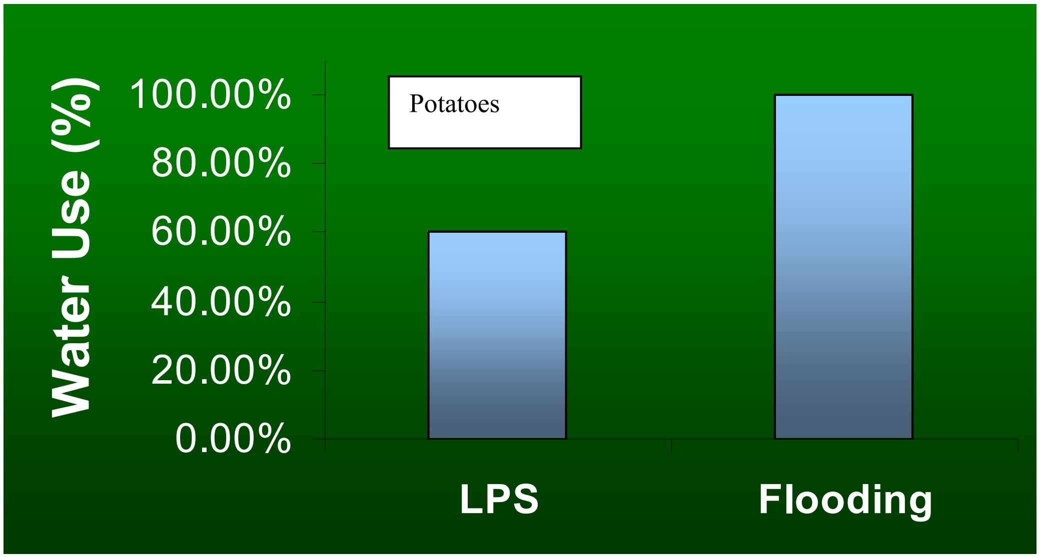

Figure 9

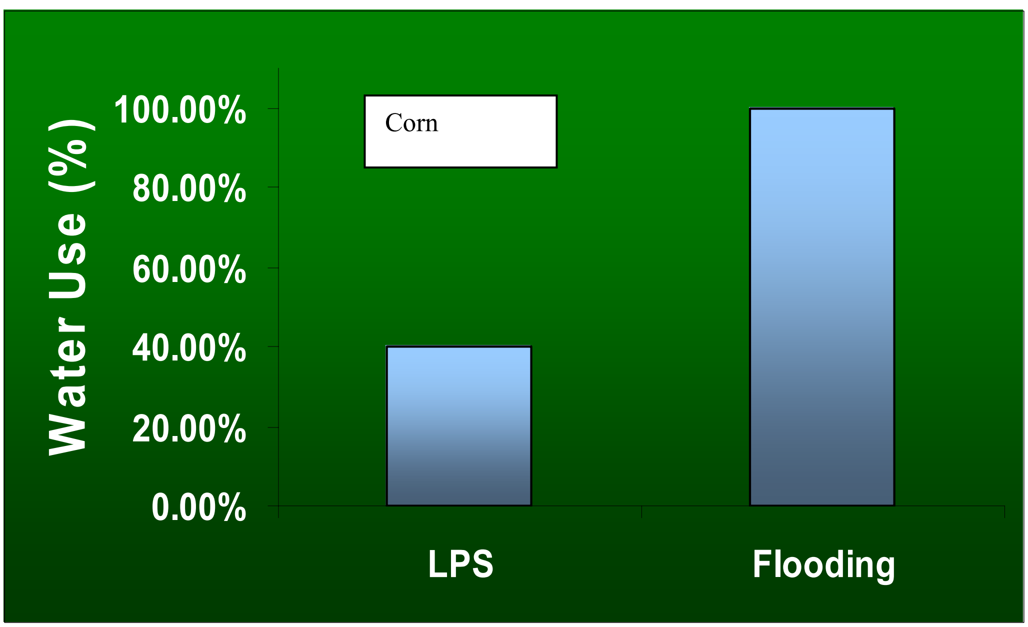

Figure 10

The most obvious advantage of LPS may be energy savings. Of course a flood irrigated crop using gravity or low head pumps on the surface is one of the most energy efficient irrigation systems. However when you consider the potential increased water use efficiencies as illustrated in Figures 9 and 10 about twice the energy is required to produce a flood irrigated crop than an LPS crop. As many farmers are turning to sprinkler systems to conserve water it is important to consider the relative energy savings LPS has over these systems

There are several major variables which directly affect energy uses and cost of irrigating crops:

1. Lift of water when pumping groundwater.
2. Pressure required to distribute water uniformly.
3. Amount of water required to sustain crop growth.
4. Pumping efficiency.
5. Energy price.

To illustrate potential energy savings three hypothetical irrigation scenarios were considered

1. A Fanjet/microsprinkler/drip system irrigating a 40-ac block, operating at 65% pumping efficiency, with a lift of 100 ft. at a pressure of 35 psi, a kWh cost ranging from $0.1 to $0.3/kWh, with a cotton crop requiring 3.5 ac-ft water application to meet water requirement.
2. A LPS or Furrow system irrigating a 40-ac block, operating at 65% pumping efficiency, with a lift of 100 ft. at a pressure of 4 psi, a kWh cost ranging from $0.1 to $0.3/kWh, with a cotton crop requiring 3.5 ac-ft water application to meet water requirement.
3. A LPS irrigating a 40-ac block, operating at 65% pumping efficiency, with a lift of 100 ft.at a pressure of 4 psi, a kWh cost ranging from $0.1 to $0.3/kWh, with the same cotton crop as above but requiring 2.5 ac-ft water application to meet water requirements.

The costs for system 1 above in $/kWh/ac-ft. range from $99.83 for a kWh rate of $0.1/kWh to $299.48 for a kWh rate of $0.30/kWh.
The costs for system 2 above in $/kWh/ac-ft. range from $60.40 for a kWh rate of $0.1/kWh to $181.19 for a kWh rate of $0.30/kWh.
The costs for system 3 above in $/kWh/ac-ft. range from $43.14 for a kWh rate of $0.1/kWh to $129.42 for a kWh rate of $0.30/kWh.
The $/ac. cost difference attributed to pressure reduction (down from 35 psi to 4 psi operating pressure) ranges from $39. 43 to $118.29 in $/kWh/ac-ft.
The $/ac. cost difference attributed to water application reduction (down from 3.5 ac-ft. to 2.5 ac-ft. water applied) ranges from $17.26 to $51.77 in $/kWh/ac-ft.
These are achievable and significant operating cost reductions that help justify the case for switching to the LPS concept.

Conclusion

LPS is a well researched system for drip irrigation at low pressures, typically those available for flood irrigated crops. There are significant agronomic advantages to using a low pressure, low flow drip system specifically related to greater lateral water movement in the soil and a better air water ratio. These advantages translate into measured improved water use efficiency when compared to flood irrigated crops and energy savings compared to flood and sprinkler irrigated crops.