# Solar Water Pumping Basics

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Summer is in full swing, and it's been hot and dry. A couple of days ago temperatures breached 90 degrees. Rain has been super sparse. Animals and plants are just plain thirsty. Success under these circumstances will depend on your ability to supply enough water where and when you need it most.

The beauty of using photovoltaic (PV) panels and a solar pumping system is you get water delivery when you tend to need it most, when the sun is shining full blast! A solar water pumping system is ideal in remote locations where grid electricity does not exist or it is cumbersome to carry in gasoline or diesel to feed a pump. All you have to do is set up the solar system and it operates on solar power, free of charge, on its own. But "all you have to do is set up the system" is often not that easy. The drawback of solar pumping systems is they tend to be a lot more costly than fossil fuel or grid-based systems to establish.

New farm enterprise establishment is a critical time, at which the benefits of freedom from fossil fuels are weighed against the high cost of setting up a solar pumping system. Having a good grasp of the basic principles of solar water pumping will enable you to identify the appropriate scale of the system needed, and what parts will best meet your watering needs. This will help you avoid unnecessary purchases or costs, design and install an adequate and properly functioning system, and understand how much water a system may or may not supply at any given time.

First the principles, and later we'll cover the parts and design basics.

## Solar Water Pumping Principles

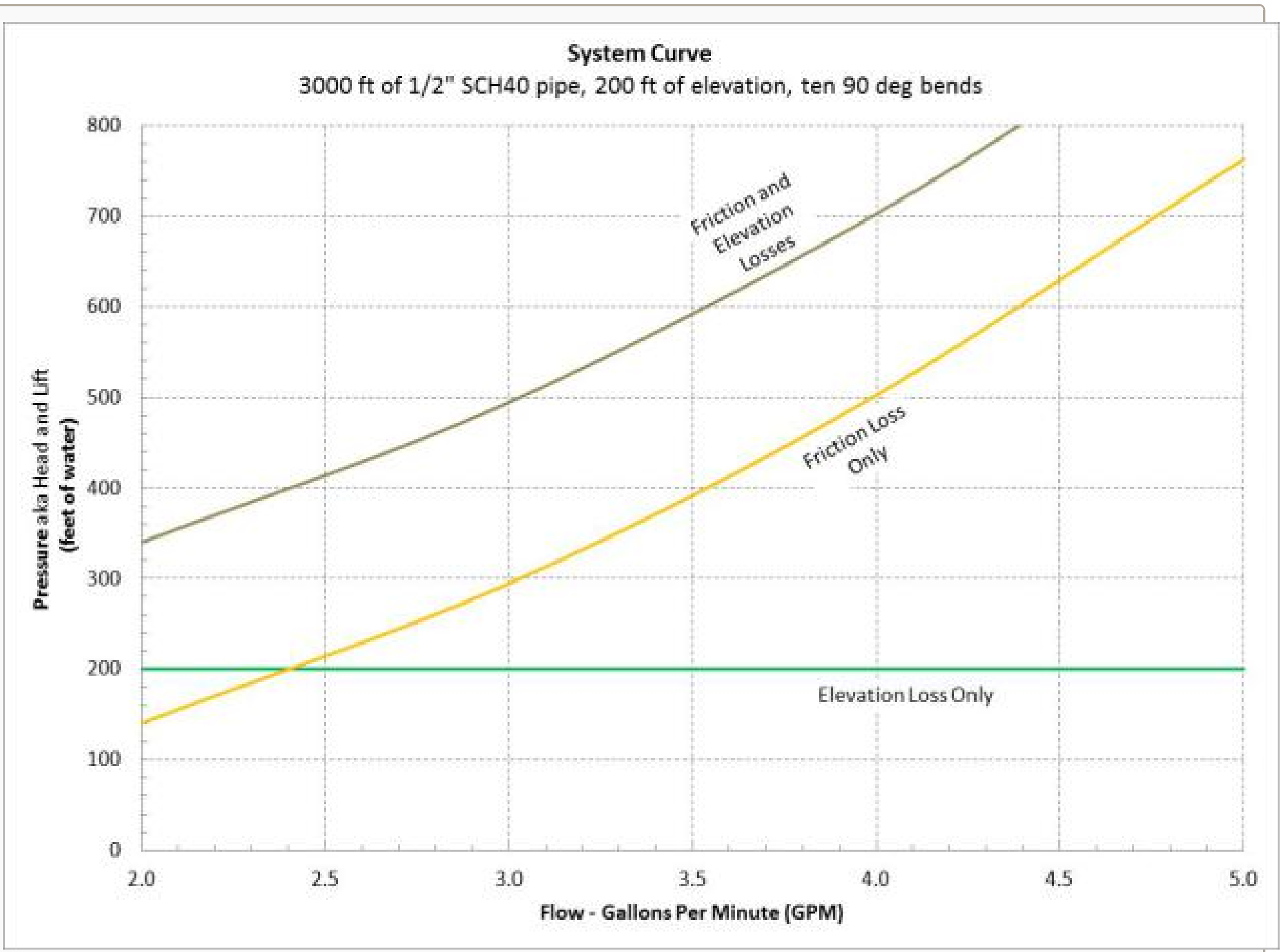
For any solar pumping system, the capacity to pump water is a function of three main variables: pressure, flow, and power to the pump.

1. ***Pressure***: For purposes of designing a solar pumping system, pressure can be thought of as the work that the pump must overcome to move a certain amount of water. This is most often expressed in either **feet of head** or **psi (pounds per square inch).**
This is also referred to as pressure *loss.*

Any elevation difference between the source of water and the final destination will affect how hard the pump needs to work, or how much pressure needs to be created in order for water to flow. A pump must create 0.433 psi for every foot of elevation increase, to be exact. When water flows downhill, the same 0.433 psi per foot of elevation change is gained. If there is a lot of topography, and water flows up and down and all around, the elevation difference between the surface of the water at the source and the level of discharge at the destination is the key figure to use to design a system in terms of how much pressure the pump needs to produce.

Piping diameter, length, bends and restrictions such as valves also affect how much pressure is lost and needs to be created by a pump in order for water to flow. Pressure losses related to piping vary more dramatically with increases in flow as shown in figure 1, below:

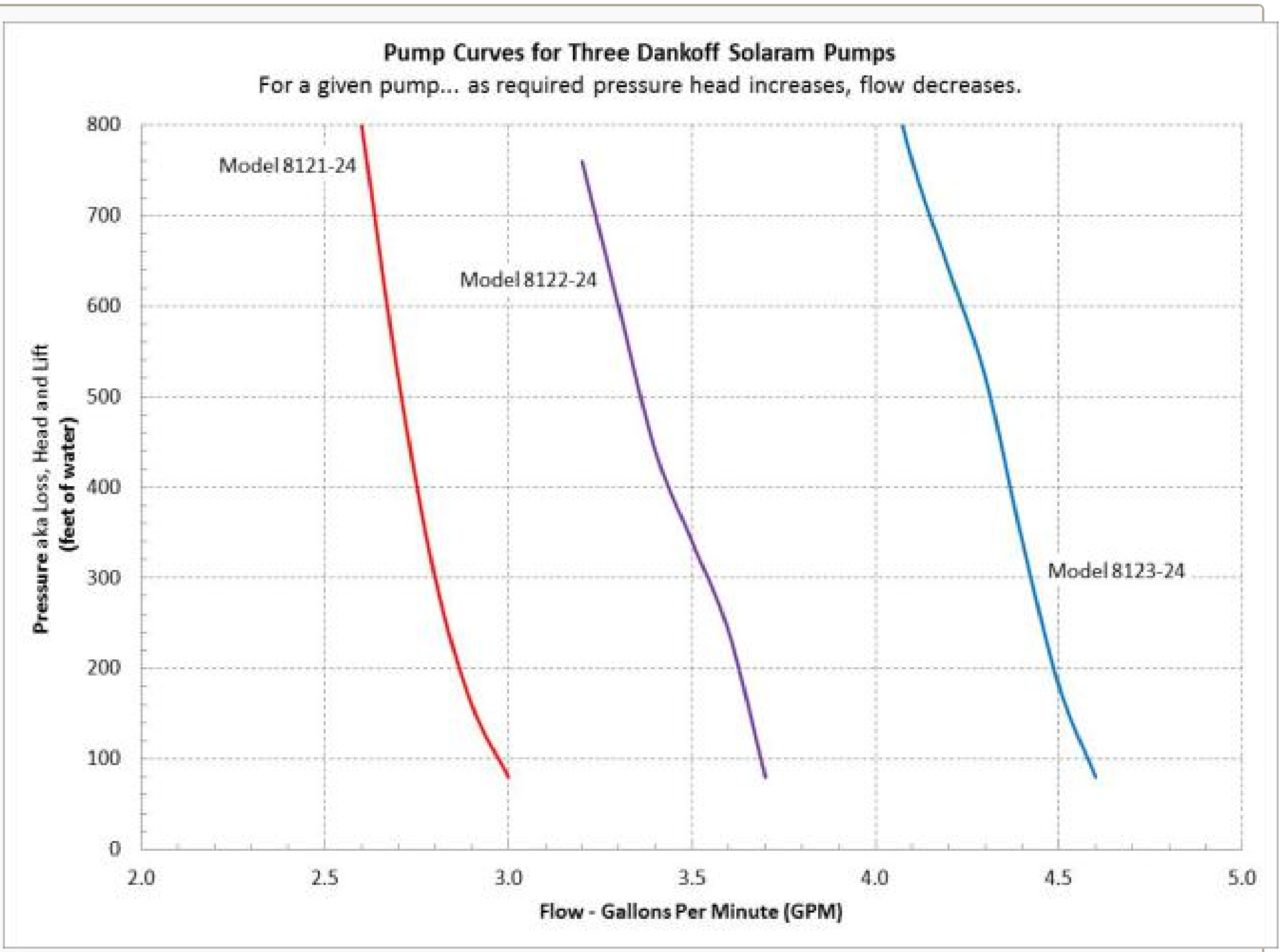
2.



This chart shows the base pressure head required to overcome 200 feet of elevation, but also shows the pressure loss due to 3000 feet of piping and bends. The top line is the total pressure loss as a function of flow for the combination of elevation change and piping losses. Note how this line is curved, not straight. The more flow sent through a piping system the greater pressure loss; or to send more flow through a given piping system the pump will need to generate greater head pressure.

***Flow:*** The amount of water that a system can move during a given time period. It is usually talked about in terms of gallons per minute (GPM) or gallons per hour. If everything else remains the same, flow will decrease when pressure increases and vice versa. For example, using the same pump and the same power set-up, if you increase the amount of work the pump must do by elevating the discharge or using smaller diameter pipe- in other words increasing the pressure the pump must generate, then the pump will deliver less flow in gallons per minute (See Figure 2, below).

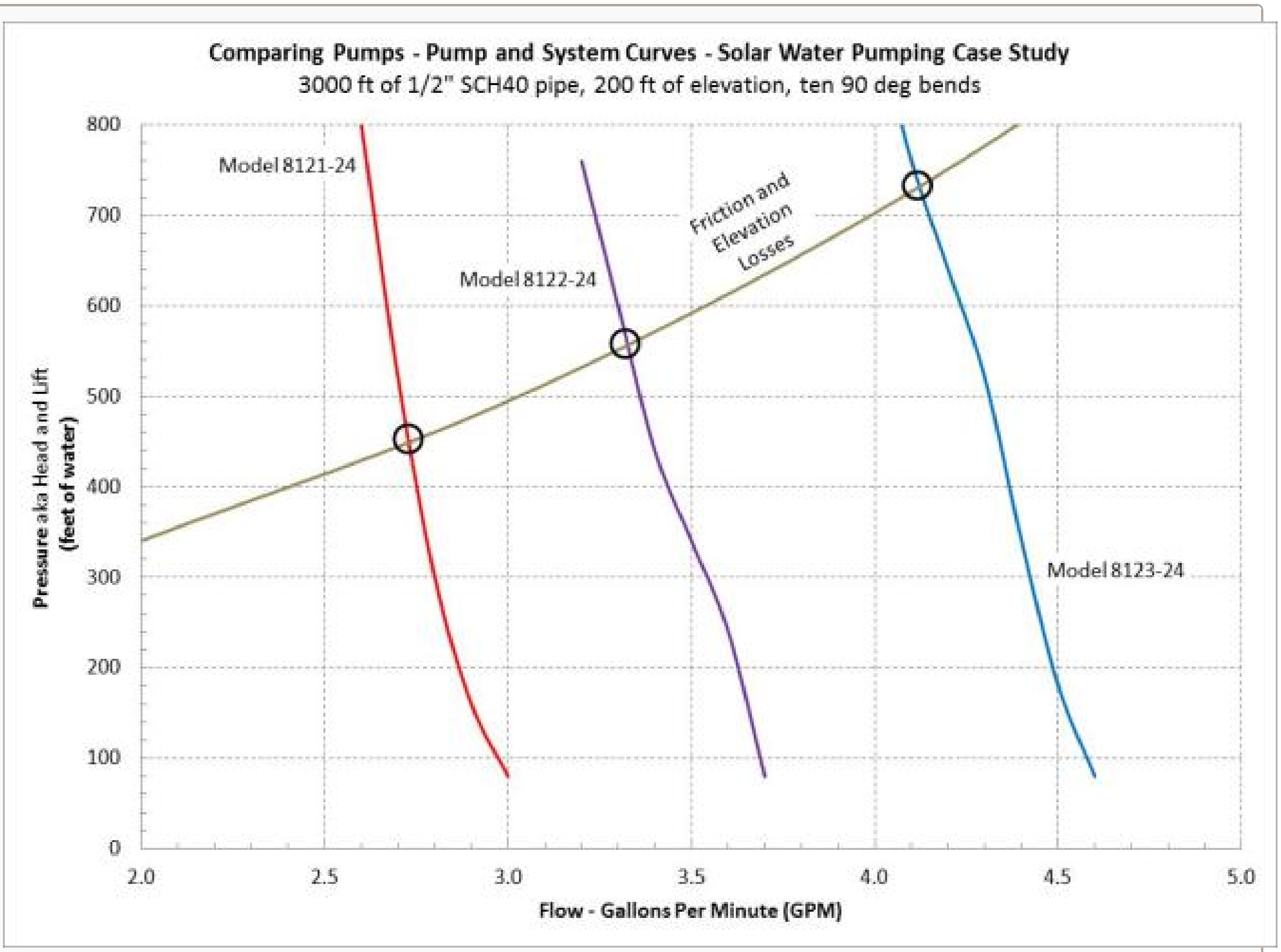
To



For a given pump, flow depends on the pressure drop of the system. The three pumps noted above are designed for three generally different ranges of flow rates. As pressure head (or piping loss) is increased, the pump provides less flow.

determine where a pump will operate, you need to look at both the system curve (pressure loss due to piping, length and restrictions, e.g., Figure 1) and the pump curve (GPM of flow the pump will deliver at different pressures, e.g., Figure 2). The operating point, or the actual amount of work (pressure x flow) the pump will do can be found by plotting these two curves together on the same scale and axis. See Figure 3, below:

3.



Combining the pump and system curves allow you to predict where a given pump will operate for a given system. The system curve can be developed using the pressure drop calculator mentioned below just by entering your expected plumbing system and changing the flow rate. The calculator will estimate the pressure loss at that rate. The pump curves are published by pump manufactures. In the examples above, based on the piping system described, the three pumps will provide 2.75, 3.3, and 4.1 GPM respectively.

***Power to the pump:*** Every solar water pump can produce a range of flows and pressures. Solar pumps draw a certain amount of power according to the amount of pressure that needs to be produced to deliver the water. Power is expressed in Watts, and PV panels are rated in Watts. When sizing a photovoltaic panel array, it makes sense to supply the amount of power that is needed. Adding more PV than is needed might enable the pump to turn on earlier and later in the day or under low-light conditions, but having extra PV power might not increase the flow rate when the sun is shining in full.

## Main Solar Water System Components:

***The Source:*** Water sources can be deep drilled wells, streams, springs, ponds, rivers, etc. The main variables, in addition to initial cost, that factor into system design are the recharge rate of the source and the volume of the source reservoir. Ideally, the source should recharge faster than pump can take water out of it. For example, if the pump will produce three gallons per minute, the source should be able to recharge at a rate that is equal to or greater than three

gallons per minute. If the pump takes water away faster than the source can recharge, the reservoir can run dry, the pump will then be run dry, and that should be avoided to prevent damage to the pump. This is much more of a concern obviously when pumping from a shallow well or spring than it would be when pumping from a raging river or large pond. In other words, it's a concern when the reservoir has little volume. When volume is lacking, there is the potential for the pump to suck the reservoir dry before the sun sets and the reservoir recharges overnight.

***The pump:*** This is the heart and soul of the solar water pumping system. This other online tutorial goes into the different types of pumps.

Pumps fall along a spectrum of high-flow/low-head to low-flow/high-head. In other words, for a given power input, the pump produces a unique combination of flow and pressure. When selecting a pump you are basically selecting that combination of performance characteristics.

If you want the pump to provide a lot of pressure *and* pump a reasonable amount of water then get ready to spend some buckaroos. There are a few pumps on the market, like Dankoff's solar ram pump, that can pump the pressures and flows to rival the conventional gas guzzling, high horsepower gas fueled water pump, but they are expensive and require relatively more solar panels, which can also get expensive. Justifying these costs is a matter of how expensive gasoline will get over the lifespan of the pump, how long of a payback period is acceptable, and to what degree environmental values factor into the decision making.

Solar pumps are rated according to the voltage of electricity that should be supplied. A 12 volt pump is a small one, 24 volt is more the norm, while 48 volts and upwards will require more power and might pump more water. Smaller wire sizes can be used in higher voltage systems without sacrificing power output from panels to pump. Wire is costly, especially large wire. Depending on how far away the panels must be sited in relation to the water source and pump, sometimes it can make financial sense to use a higher voltage pump and buy another PV panel. The savings from being able to use a smaller wire size can sometimes outweigh the cost of buying additional PV and increasing system voltage.

Some pumps require certain accessories to function optimally. These include filters, float valves, switches, etc. The manufacturer or distributor will usually specify what is required; keep this in mind when buying pumps second hand: always refer to product literature or call the manufacturer to determine what else might be needed.

It can be challenging to find a pump curve for a pump even when new. Most manufacturers, however, have these curves available online or will email / fax a copy if requested. This curve is one of the keys to unlocking the world of pumps.

To review: Understand your watering needs in terms of pressure and flow, allowing you to size the pump to meet your needs. (More info on how to do this, under "Basic Steps to Designing a Solar Powered Pumping System," below)

***The power source, photovoltaic (PV) panels:*** A panel is rated in watts of power it can produce. Panels have gotten MUCH more affordable ($ per watt) than ever before. Remember, a pump will only require a certain amount of power to produce a certain amount of pressure and flow. Save money by sizing the PV array by the amount of power that is needed. On the flip side, having a little extra PV wattage can't hurt—most solar pumps actually require about 20% more wattage than specified when wiring the panel directly to the pump (If this is the case, the pump manufacturer usually will state this clearly in the product specification literature.) Also, having a larger panel will allow the pump to turn on earlier and later in the day and also in relatively lower light conditions. Essentially, the large panel surface area acts as a linear current booster (explained below) and may eliminate the need for one.

This panel is being used for water pumping. The wood-framed rack is simple and inexpensive, and can be adjusted to produce more power during seasons when the sun is lower on the horizon

The installation of solar panels is not rocket science, but can be dangerous, and damage can be expensive if installation is not done properly. Consult with a professional PV installer before diving into an installation project you are not familiar or comfortable with. There are many books covering the details of solar installation and design, such as Photovoltaics: Design and Installation Manual, published by Solar Energy International.

***A Linear current booster:*** A small device that is installed between the panels and the pump that allows the pump to switch on during low light conditions. Linear current boosters must be sized for the pump voltage and panel output. Consult with the component manufacturer, such as Solar Converters or a reputable solar systems contractor in your area to confirm what specific model of linear current booster is appropriate for using with your pump and panel setup.

**Wiring accessories:** These include minor components to the system that will connect the panels to the pump. If more than one panel is used, a combiner box is usually used to make wiring safe and simple. Circuit breakers are installed in the box to enable safe and quick shutoff of the panels if the system needs servicing. The circuit breakers can also serve as a switch for turning the pump on and off at your discretion.

***The water distribution system:*** In many countries of the world, trenches are dug to gravity feed water through an intricate network of irrigated plots or holding tanks. Here farmers tend to use black polyethylene piping. Whatever the system is to get water from A to B, there important thing to consider is the smaller the diameter piping and the longer the piping run, the harder a pump has to work and the more pressure the pump must create. The pump has to overcome the friction created when water passes along the insides of the piping. Longer runs that carry water at higher flow rates require larger diameter piping to minimize the amount of pressure lost (requiring the pump to compensate) due to friction.

## Basic Steps to Designing a Solar Powered Pumping system:

1. Determine your needed FLOW,

2. Determine your needed PRESSURE

3. Select a PUMP that will provide the needed flow and pressure

4. Supply enough PV capacity to power the pump to provide the needed flow and pressure.

## Step one: Determine needed FLOW

Flow is the **amount** of water you need, and how much water you need to irrigate or supply to your animals in one minute or one hour. Think of your needed flow in terms of gallons per hour or gallons per minute.

As an example:

You have 40 sheep and 4 non-lactating cattle grazing where they need water. You've found that on a really hot and dry day, the sheep might empty a 40 gallon watering trough that you filled that morning. The cattle empty a 50 gallon trough. That's 40 + 50 gallons consumed, or 90 gallons in 12 hours. Now consider that on average, a solar panel fixed facing one direction on a hot sunny dry day might only produce power for a pump for six hours. On a partly sunny day maybe only 3 hours. So the same 90 gallons would need to be delivered in six hours or even three. Let's use the conservative three: 90 gallons delivered in three hours = 30 gallons per hour or 0.5 gallons per minute. The pump will need to pump water so it flows at 0.5 gallons per minute or more.

## Step Two: Determine how much pressure is needed to get water from source to destination.

Determine this as total pressure in psi (pounds per square inch) or feet of head. Total pressure needed is a combination of:

A) psi to overcome elevation difference (equivalent to 0.433 times the elevation difference in feet between the water level of the source and the discharge at destination), plus

B) psi needed to force water through any filters, special valves, or irrigation fittings, plus

C) psi needed to overcome friction loss in piping.

Consult the filter, valve or fitting manufacturers for estimates of psi needed to force water through these components at the desired flow rate. Friction loss through piping depends on how much water flows through the pipe, what type of piping, the length of pipe, number of bends or restrictions and what diameter of piping is used. There are many tables and calculators available online to assist with this determination, such as this useful one. Generally, to avoid the need to overcome the pressure loss due to friction within piping, a larger diameter distribution piping can be used. Typically the largest diameter pipe is used to get water from the pump to the destination, then smaller branches of piping can be used at the destination if needed, say for example, at the final stage of water exiting the system through drip tape or drip emitters in an irrigation system.

Here is an example of determining pressure needed: You want to pump from a spring whose water level is 50 feet below a field where you have watering troughs for livestock. Remember you determined that you need 0.5 GPM for this task above. Your filter will need the pump to produce at least 2 psi to push water through at this rate. You are using a 400 foot run of ¾" polyethylene tubing. Total pressure needed equals:

For the elevation difference: 50 feet difference X 0.433 psi/foot = 21.65 psi

For the filter and valves: 2 psi (as determined by product literature or consulting with the manufacturers for a specific flow rate)

For the piping: 0.12 psi to get 0.5 gpm water through the 400' of ¾" piping (determined with online friction loss tables or calculators)

Total psi needed is 21.7 + 2 + 0.12 = 23.8 psi, or roughly 24 psi.

1 psi = 0.433 of feet of head, so to convert psi to feet of head we divide 24 / 0.433, which equals about 55 feet of head (Note that after adding pressure loss from piping and filters,etc, this is more than the original 50 feet elevation difference). Some pump specifications are listed in feet of head and some are listed in psi, so it is good to know both.

## Step three: Now you are ready to select a pump!

Pumps are rated to produce a certain flow at a certain pressure when supplied a certain amount of power. Now comes the fun part. You will need to reference pump specifications that rate the pump output in terms of pressure and flow. Tables or graphs, commonly known as pump curves, are available from the pump manufacturers or online in product literature.

When referencing the pump specs, first make sure that the pump will provide the amount of pressure you determined is needed. Then move along the table or pump curve graph to determine whether or not the pump will produce the required flow at the needed pressure. That's it! If flow is not sufficient at the particular pressure you need the pump to produce, then you will need to use a different model or different type of pump.

If you expect to operate the system at various flow rates, you may want to build a system curve as shown above and plot this against the pump curve to determine how the two will interact.

Here is an example evaluating the Dankoff Slowpump. Let's use the pressure and flow that were determined to be needed in previous examples, above: 55 feet of head and 0.5 gallons per minute were needed

The table on page two of the pump specifications for the Dankoff Slowpump lists what flow the pump will deliver at increments of 20 feet of head. You need at least 55 feet of head, so to be safe, use the 60 feet of heat figure on the table. Then look along the table to determine the flow for the different models of pumps at 60 feet of head. You'll see that model 1322 produces 0.51

gallons per minute at 60 feet of head– that meets your needs of 0.5 gallons per minute! You can continue to compare other models that will pump the minimum flow you need at 60 feet of head. Oftentimes a different model of the same make of pump will provide more flow at a given pressure, but may require more power supplied to the pump. You can also compare pricing. The main goal at first is to determine what models won't and will meet your needs.

## Step Four: Determining the power needs for the pump at the desired pressure and flow rate.

Power required by pumps to deliver a certain amount of pressure and flow is listed in product literature and specifications. Take the above example again. According to the Dankoff slowpump specs, the model you chose that will deliver 0.51 gallons per minute at 60 feet of head will need a minimum of 36 Watts of PV. You can then shop for panels that are rated at this Wattage or higher. *Remember, if you are wiring the panel directly to the pump without batteries, be sure to consider whether or not you need 20% more wattage than listed in the specifications. Product literature will usually make mention of whether or not you need to do this. In the Dankoff Slowpump example here, the specifications already take into account that the panels will be directly wired, but other spec sheets are different. When in question, consult with technical support at the pump manufacturer.*

To conclude, here are some online resources that dive into further detail about solar water pumping and irrigation system design:

The University of Tennesse Cooperative Extension article on Solar Powered Livestock Watering Systems

Online tutorials covering many topics related to irrigation system design, including drip irrigation

An online portal to various resources on solar water pumping

*Any reference in the above article to commercial products, trade names or brand names is for information only, and no endorsement or approval is intended.*