

IRRIGATION & TECHNOLOGY *ASSESSMENT*



The University of Georgia
Greenhouse*A*Syst
Publication Series

A Program Designed to Assess
and Manage Issues Involving
Our Natural Resources and
Environment



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**A Program Designed To Assess and Manage
Issues Involving Our Natural Resources and Environment**

Home*A*Syst is a national program cooperatively supported by the USDA Cooperative State Research, Education and Extension Service (CSREES), USDA Natural Resources Conservation Service (NRCS), and U.S. Environmental Protection Agency (EPA).

This publication follows the Farm*A*Syst/Home*A*Syst grower self-assessment model of dividing farming management into a series of issues, dividing each issue into categories, including educational materials, and following up the self-assessment with the development of action plans to address the key areas of concern. Universities that have *A*syst publication series include Oklahoma, Kansas, Texas and Wisconsin. New series have recently been successfully developed at major universities including Orchard*A*Syst, and Food *A*Syst.

The Greenhouse*A*Syst publication Series has been developed to assist greenhouse owners with the task of assessing three management issues: Water management, Environmental Risk and Business Profitability. To date, 6 publications in this 12-part series are being reviewed and 6 more are being developed.

The Greenhouse*A*Syst series of publications is a confidential self-assessment program you can use to evaluate your greenhouse business for risks associated with water management issues. Armed with facts and figures, you will then be able to reevaluate your management strategies and determine ways to conserve water and minimize those risks. By following the guidelines, you will be able to establish a formal company-wide water conservation plan. Implementation of this plan will facilitate more efficient use of resources and impart significant savings in water use, fertilizer and pesticides.

This bulletin will also help you establish a water conservation document you may find useful if and when state or local water authorities develop policies or implement water restrictions. Most water authorities are favorably impressed with businesses that have developed water conservation plans.

Greenhouse*A*Syst risk assessment consists of a series of questions that will walk you through the considerations to be taken into account while evaluating your business. In order to gain the full benefit of the Greenhouse*A*Syst program, we recommend that you utilize all twelve publications in the series in the following order.

Risk Area	Greenhouse*A*Syst Publication	Suggested Order
Water Source and Expansion	Available	1
Delivery and Technology	In production	2
Water Management	In production	3
Water Quality Assessment	In production	4
Water Recycling/Pollution Prevention	In production	5
Water Regulations/Company Policy	In production	6
Fertility Management	In development	7
Operation Safety and Biosecurity	In development	8
Shipping, Transportation, Material Handling	In development	9
Greenhouse Energy Utilization	In development	10
Time and Labor Management	In development	11
Greenhouse Maintenance	In development	12

Irrigation and Technology Assessment

Publication #2 in the Series

Paul A. Thomas, Extension Horticulturist
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What Can This Bulletin Series Do for Me?

One of the most effective ways to reduce cost in a greenhouse operation is to automate the activities that occur on a regular basis. In most greenhouse operations, irrigation is a daily activity and a major source of labor costs. Manual watering not only costs much more, it also is generally wasteful. An automated system using modern irrigation technology is not only more efficient at getting water to the plant it also saves many, many hours in basic labor. However, the benefit most owners fail to realize is the reduction in management time devoted to irrigation. This section will help you assess the true cost of water related activities in your facility and assist you in developing a plan to upgrade your irrigation technology, and your management strategy. The overall savings and water conservation should become a major improvement to your companies overall effectiveness.

The goal of this section is to help you formulate an accurate assessment of your current technology and potential efficiencies gained by upgrading.

How Much Is Water Actually Costing You?

There are many factors to consider besides just the base rate a municipality is charging you. If you own your own well, the water you extract from the ground has a cost. You must consider your fuel or electric rates for pump operation, labor costs of water application, equipment depreciation and replacement, and equipment maintenance

costs. There are a great many hidden considerations here.

Do you know how much the application of water is costing you per hour?

The number of gallons used per month, divided by the dollars of labor used for watering during that time will give you a good assessment. You could then look at the irrigated square feet, apply that cost to specific crops, or as an annual per sq ft expense to plan for.

Do you plan pot-filling operations with a water reservoir level in mind?

Keeping at least a half-inch reservoir reduces water spillage and need for repeat irrigation. Allowing for a water reservoir reduces labor and soil waste.

Have you designed the layout of your pro- duction system with water use efficiency in mind?

Adjusting bench width, pipe diameter, water pressure or other improvements could make it easier to water and even improve water use.

How often do you inspect your water delivery system for needed repairs?

Systems should be thoroughly inspected at least once each year.

Do you have in place a technology that reduces or eliminates off-target water use?

This may include flood floors, drip tubes, ebb-and-flow benches, etc.

If not, have you considered the cost of such technology in relation to labor savings over a 10 - year period?

Most new technologies pay for themselves in 2 to 3 years due to saving from high labor costs.

Delivery and Irrigation Systems

Water delivery systems begin with a pump or a public water meter. For the public water supply source, the water supplier will specify your water meter according to your water needs and usage. If the water supply is on-site, a pump must be selected to get the water to the irrigation system at an optimum pressure for the system operation.

Selecting the Correct Pump

The information needed to select the correct pump for a use is as follows:

- Water Requirement
- Capacity of Water Source
- Suction Head
- Elevation Head
- Irrigation System Pressure Requirement (including friction losses in pipes and fittings)
- Well Diameter (for groundwater)
- Power Available

Determine the water requirement as a flow rate and volume per day. The water supply must be able to supply both. For a large pond, this is usually not a problem. For wells, the well and aquifer have a limit on their production capacity, which is usually determined when the well is drilled and finished. This well production capacity must be greater than the flow rate for the operation's water requirement or another well or water source will be needed to meet the peak demand.

For pumps located above the water level, the suction head is the vertical distance from the pump elevation to the water surface elevation. With wells, if the well has a lower yield rate than the pumping rate of the pump, the pump capacity will be reduced due to increasing suction head. Pump capacity must be matched to well yield. The well yield should be determined when the well drilling has been completed. The suction head is

also critical to the design of a pump for extracting surface water. If the suction head for surface water pumping is too high, meaning the pump is too far above the water surface, the pump cannot pull the water adequately to pressurize the pump or move the water to get the desirable flow rate.

The elevation head is the vertical distance that a pump must lift water. For pumps in wells, the elevation head is the vertical distance to the highest elevation of the irrigation system from the water table surface in the well when the pump is running. For surface water pumps, the elevation head is the vertical distance between the center-line of the impeller to the highest elevation of the irrigation system.

Water coming out of the pump must be pressurized to overcome friction losses in the distribution lines and meet the irrigation system pressure requirement. If the pump goes directly into a pressure tank, then the pump must pressurize the water to some amount greater than the high pressure switch of the tank. Every sprinkler or emitter has an optimum operating pressure, and the pump imparts pressure to the water to reach the required operating pressure. The horsepower of the pump is directly related to the irrigation system pressure of the water. Thus, a drip irrigation system that requires less operating pressure will require a pump with less horsepower than a sprinkler system requiring more pressure to operate. Also, certain kinds of pumps are more appropriate for increasing pressure while other pumps are more appropriate for increasing flow rate. This is why centrifugal pumps are more desirable for certain situations and turbine pumps are more desirable for other situations. Table 1 (page 7) gives some general indication of the advantages and disadvantages of different kinds of pumps.

For electrically powered pumps, the site of the pump must have adequate power available, including adequate wiring, fuses and circuit breakers to allow continuous and safe pumping over time. Thermal overload protection is usually a component of the electronics of the pump. Table 2 (page 7) provides the wire size and fuse rating for various Size 60 cycle AC motors, both single and three phase circuits.

Table 1. Characteristics of different pumps (adapted from Aldrich and Bartok, 1994).

Pump Type	Typical Suction Head (ft)	Typical Total Head (ft)	Remarks
Centrifugal	15	230	Advantages: Reliable, good service life; will pump water containing sand Disadvantages: Loses prime easily; capacity decreases as suction head increases
Jet	85	162	Advantages: Few moving parts; high capacity at low head Disadvantages: Damaged by sand or silt in water; capacity decreases with service time
Submersible		> 1,000	Advantages: Easy to frost-proof; high capacities and efficiencies Disadvantages: Damaged by sand or silt; repair requires pulling from well
Deep well turbine		> 1,000	Advantages: Easy to frost-proof; high capacities and efficiencies Disadvantages: Needs straight well casing; repair requires pulling from well

* Total head is the suction head, the elevation head and the irrigation system pressure requirement added together.

Table 2. Wire size and fuse ratings for single-phase 60 cycle AC motors (adapted from Aldrich and Bartok, NRAES-33, 1994).

115V Circuit						230V Circuit					
Motor Size (HP)	Fuse Size (amps)	Wire Size				Motor Size (HP)	Fuse Size (amps)	Wire Length of Run			
		50 ft	100 ft	150 ft	200 ft			50 ft	100 ft	150 ft	200 ft
1/4	15	14	12	10	8	1/4	15	14	14	14	14
1/3	20	14	12	8	8	1/3	15	14	14	14	14
1/2	25	12	10	8	6	1/2	15	14	14	14	12
3/4	30	12	10	6	6	3/4	15	14	14	12	12
						1	20	14	14	12	10
						1 1/2	25	14	12	10	10
						2	30	14	12	10	8
						3	45	10	10	8	8
						5	70	8	8	6	6

The above values are based on 2% voltage drop in the wire and 125% of the name-plate current (in amps) wire carrying capacity.

The power requirement for selecting the correct pump is based on its flow rate and total pressure head required for the system. The flow rate is provided by the manufacturer's specifications and determined by the well head size. Along with the flow rate, the total pressure head must be calculated. The total pressure head is the sum of four components of head.

1. suction head.
2. elevation head.
3. irrigation system pressure requirement.
4. friction loss head from distribution pipes.

When the term *head* is used, the units of measure are feet. Feet of head can be converted to pounds per square inch of pressure (psi) by dividing the feet of head by 2.3 (the conversion is 2.3 ft/psi). For example 23 feet of head is equivalent to 10 psi.

To determine the horsepower requirement of a pump, the total pressure head (psi) is multiplied by the flow rate (gpm) and divided by a conversion factor of 3960 (to convert feet of head and gpm to horsepower). This horsepower value is called the *water horsepower*. It is a measure of the actual energy required to provide adequate pressure and flow rate. The water horsepower is divided by the pump efficiency to size the pump. Pump efficiency is provided by the manufacturer of the pump and depends on the make, model and type of pump desired.

To determine the size motor and electric power requirement, the horsepower calculated for the pump sizing is divided by the motor efficiency to get the horsepower of the motor, which is called the *brake horsepower*. Most small electric motors have an efficiency of about 90 percent. Other kinds of power supply will have different efficiency values.

Example Pump Selection:

Given: Water is to be pumped at 30 gpm from a pond to a greenhouse 200 feet away (length of delivery line). The pump will be powered by an electric motor. The operating pressure requirement for the irrigation system is 45 psi. The minimum elevation of the pond water surface is about 45 feet below the greenhouse bench elevations. The pump is located 15 feet elevation above the minimum elevation of the pond water surface.

The suction line is 42 feet of 2-inch PVC pipe, and the pipe from the pump to the greenhouse is 1½-inch PVC pipe. The intake line has a jet screen in the pond. Friction losses of this system consist of the loss through the intake screen, the suction line losses and delivery line losses as given here:

Jet Screen losses – 10 ft

Suction Line Losses – 0.7 ft

Delivery Line Losses – 12 ft

The losses given above are calculated from friction loss tables for the pipe or given from manufacturing specifications for the jet screen.

The components of the total pressure head requirement are calculated in feet of head:

Suction head = 15 feet (from elevation difference of pump and minimum water surface level)

Elevation head = 45- 15 = 30 ft (elevation difference from pump to greenhouse bench elevation)

Irrigation System Pressure Requirement converted to Head = 45 psi X 2.3 ft/psi = 103.5 ft

Total Friction Losses = 10 + 0.7 + 12 = 22.7 ft

Total Head Required =

15 + 30 + 103.5 + 22.7 = 171.2 ft

Water Horsepower =

$$\text{GPM} \times \frac{\text{Total Head Required}}{3,960} = \frac{30 \text{ gpm} \times 171.2 \text{ ft}}{3,960} = 1.3 \text{ hp}$$

The pump chosen should have an efficiency of at least 0.55. If we assume the pump efficiency is 0.55, the pump horsepower required is

$$1.3 \text{ hp} / 0.55 = 2.4 \text{ hp}$$

With the pump horsepower and flow rate requirement, the correct pump can be selected from manufacturer pump curves or tables that provide the head, flow rate and efficiency ratings for different pump sizes.

The last step is to determine the motor horsepower required to power the above specified pump. For this step, the pump horsepower is divided by the motor efficiency to get the required horsepower for the motor. Assuming an electric motor efficiency of 90 percent:

$$2.4 / 0.90 = 2.6 \text{ hp}$$

This would indicate that a 2.5 horsepower motor would be undersize, so a 3 horsepower pump would be chosen.

Pressure Tanks

Smaller watering systems not on a municipal water supply may need a pressure tank to supply the needed pressure to the irrigation system. A pressure tank is placed between a pump and the point of use of a water system to allow the water to become pressurized in the tank. The pump forces water into the tank, compressing the air in the tank. As the air compresses, the air and water pressure in the tank increases. Tanks have a pressure switch that controls the range of pressure that occurs within the tank. For a greenhouse system, the typical pressure ranges are 30-50 psi or 40-60 psi. The pump will start when the lower pressure is reached in the tank and run until the pressure in the tank reaches the upper pressure value, when the pump will turn off. The proper setting for the tank depends on the irrigation system operating pressure requirements.

The size of a pressure tank depends on the pump size. In most tanks, only 20-40 percent of the volume actually holds water; the rest of the volume is filled with the pressurized air. The pressure tank size should be 10 times the pumping rate in gpm.

Water Supply Protection and Backflow Prevention

When you remove water from any kind of water supply without proper water supply protection equipment, you run the risk of contaminating the water supply with pathogens or chemicals that you use. Cleanup of contaminated water is often expensive and can be avoided by proper protection equipment. Redundancy, or back up protection devices for water supply protection, is recommended so the failure of one component does not mean instant contamination.

Water supply protection equipment is designed to prevent back-siphoning of water into the source once it has been removed from the source. Back siphoning can occur when pressures change quickly within a distribution system, causing the water to move differently from the intended direction. For example, if a pump for a pressurized system stops running, the pressure from the downstream water will push that water back through the pump and into the water supply if there is no

backflow prevention equipment to prevent this. Backflow equipment must be rated for the operating pressures of the system. There should be water protection equipment immediately downstream of any pump and upstream of valves, irrigation or injection system components. For municipally supplied water, there should be backflow prevention devices immediately downstream from the water meter.

While public water systems usually will specify what water supply protection equipment must be used when connecting to the supply, utilities do not set requirements for backflow prevention for on-site water supplies. Any time there is a connection linking your water source to another system operating at a higher pressure, such as a fertilizer injector, there is a danger of backflow into the water source. The rules of the Georgia Department of Agriculture, *Prevention of Ground and Surface Water Contamination*, Chapter 40-23-2, require all irrigation systems designed or used for application of fertilizer or chemicals other than pesticides must be equipped with backflow prevention equipment consisting of a functional check valve, low pressure drain and vacuum/air relief valve. Pesticides labeled to be applied through irrigation systems will have water supply protection guidance on their labels. Pesticides not labeled for use through irrigation systems should not be applied through watering systems at all.

Anti-siphon devices should also be placed just upstream of any faucet with hose connection. These devices prevent back-siphoning from submerged hoses that could contaminate the water supply. The anti-siphon devices are required by law for any water system where the water is considered potable; so, if you are not using potable water and you are pumping from surface waters or ground water, you do not need to have the anti-siphon devices at hose connections, but you must put up signs declaring that the water from the faucet is not potable to prevent anyone from drinking the water.

Maintaining an air gap of at least 8 inches between the hose outlet and the water level where water is being directed is an alternative way to prevent backsiphoning from hoses into the supply pipeline system.

Why Back-Flow Prevention Is Essential

Why do you need back-flow prevention? If you intentionally or unintentionally cause contamination of your local water supply by failing to have a back-flow preventer, the fines and resulting lawsuits could quickly put you out of business.

Florida, a state that takes this issue very seriously, has 36 case histories you can review, on the University of Florida website at <http://www.treeo.ufl.edu/backflow/casehist.html>

Using the Watering System to Apply Chemicals and Fertilizers

Many operations use the watering system to apply fertilizers, chemicals and sometimes certain pesticides. Drip irrigation systems will also inject chemicals to unclog emitters and clean out the system at times. In addition, chemicals to neutralize or acidify water applied to crops may be injected into the water.

When any chemical is mixed into the water lines, the water supply must be protected by some kind of backflow prevention device. Also, a pesticide must be labeled for application through irrigation systems to be legally applied through an irrigation system. The pesticide label will provide instructions on the water supply protection requirements to inject that pesticide into an irrigation system. For any injection of chemicals into the water supply, the chemical supply line must have an anti-back flow injection valve that will not allow water to flow into the chemical tank or container if for some reason the injector device fails.

There are two basic kinds of equipment for injecting chemicals and fertilizers into a watering system. They are **venturi metering devices** and **positive displacement pumps**. Either one of these injectors can be adjusted to change the mix ratio of chemical to water. The venturi device will vary its rate when pressure in the water supply changes, but the positive displacement pumps do not vary in their rate with flow rate or pressure changes in the water supply.

The two styles of positive displacement pumps typically used are **piston injectors** or **diaphragm injectors**. The diaphragm injectors are only for low rate chemical injections, while a wider range of injection rates is possible with piston injectors.

The larger piston sizes inject larger rates of chemicals.

Injector units are usually rated in gallons per hour (GPH). Typically, for either type of injector, the range of injection rates varies from a tenth of the nominal injection rate to the nominal rate as the maximum. For example, a 10 GPH injector will have an injector rate range of approximately 1 GPH to 10 GPH. To change the injection rate with piston injectors, the injection device must be turned off. Diaphragm injection pumps can be adjusted while running. For chemical applications where the rate of injection does not vary from day to day, a piston displacement pump is suitable; but if rates of injection are variable from day to day, the diaphragm injector will be easier to manage.

Important characteristics and components to consider in choosing a good injection device are.

- Accuracy of calibration of ± 0.5 percent
- Calibration tube included
- Adjustable while running
- Durable, non-corrosive components – stainless steel balls and Niton seals
- Chemical tank agitation
- Access for repairs to equipment
- Appropriate size for chemical tanks.

Good management practices to ensure the life and accuracy of injection equipment include cleaning the system when injection is complete. Flush the injection system with clean water after all of the chemical has been injected to prevent accumulation of precipitates and long-term contamination of the equipment. After the chemical injection is complete, continue to run water through the irrigation system to clean the chemical out of the system as much as possible when this will not defeat the purpose of the injection. The injection system should be frequently monitored while operating to observe that the chemical is moving out at a steady rate into the irrigation system. For the chemical concentration to be accurate in the irrigation water, the irrigation system operations should be tested to measure flow rate or a flow meter should be in place to make sure flow rates are consistent during the injection. Any non-uniformity in the water application results in a similar non-uniformity of chem-

ical application to the plant materials. Any off-target water application has an associated off-target (or waste) of chemical application. Test the injection system for accurate calibration anytime the rate of chemical application is changed.

Overhead Sprinkler Irrigation System Design, Operation and Maintenance

The first key to efficient irrigation is a good system design. This involves choosing an adequate pump size, making sure the water pressure is adequate for the entire irrigation distribution system, economic pipe sizing for the distribution system, and the appropriate application device (sprinkler, emitter or microspray). Pump sizing and water pressure requirements have been discussed previously. This section will consider pipe sizing and application device choices.

Irrigation that uses sprinklers requires a high operating pressure compared to other irrigation means. Sprinklers provide a rain-like blanket of precipitation at a relatively high application rate to plants. Sprinkler systems are best used with plant packs, small containers, plug establishment or germination where drip tubes or emitters would be impractical.

There are two kinds of sprinkler devices typically used in greenhouses: spray heads or rotating impacts. The spray heads have no moving parts and can make a full or partial circle pattern. Rotating impacts move a stream of water in a full or partial circle pattern. Table 3 gives guidelines to appropriate uses of the sprinkler types.

Distribution lines for sprinklers may be overhead, on the ground or buried. Either situation is



similar in terms of the sprinklers required. Overhead lines require rigid pipe, and can be set up to move from one bench or side of the greenhouse to the next. Overhead lines are usually in greenhouses or shade structures to keep them out of the way of carts and people. In ground or above ground lines are typically found on outside production beds and should also be placed carefully to keep them out of traffic patterns.

Alternatives to fixed sprinkler systems are mobile sprinkler systems such as watering booms or watering carts. The movement of these systems while they apply water allows a more uniform application rate than fixed sprinklers can provide. Portable watering booms in greenhouses are supported on a track system. One unit can be used among several greenhouses if the booms can fold and pivot. The idea for the watering cart came from growing tobacco seedlings in cell flats. The cart can be folded and moved from house to house like the watering boom. The cart is pulled slowly through the greenhouse by a cable

Table 3. Sprinkler types.

Type	Precipitation Rate	Comments
Fixed spray heads	1.6 to 2.6 in/hr	Advantages: lower operating pressures, short time for application, suitable for watering benches, partial circles available. Disadvantages: high application rates, smaller application diameter, many nozzles needed for large areas.
Rotating impact	0.5 to 1 in/hr	Advantages: slower application rate, best for larger areas such as outdoor production beds, partial circles available. Disadvantages: higher operating pressures, application rates are not too high, uses fewer sprinklers to cover an area.

attached at one end of the house. These irrigation systems can be re-nozzled and connected to a high pressure sprayer to apply fungicide, growth retardants or insecticides to plants in the greenhouse. These kinds of systems are being used by some growers in Florida and Canada. They do not reduce the time it takes to water an area, but they do reduce labor needs for watering.

Drip Irrigation System Design, Operation and Maintenance

Drip irrigation systems (sometimes called trickle irrigation or micro-irrigation systems) are the most expensive system in terms of capital costs, but the water and labor savings that can be achieved with drip irrigation systems make give overriding long-term value. There are a variety of drip and micro-irrigation applicators. The simplest drip irrigation method is the use of spaghetti tubing as emitters, but there are some problems with spaghetti tube applicators that more modern drip emitters have overcome.

Micro-sprays are increasingly found in greenhouses as a more targeted approach to spray application than traditional overhead sprinklers. The micro-sprays and sprinklers typically apply much less water over a smaller area than overhead sprinklers and sprays, so the micro-sprays and sprinklers can be more targeted in applying overhead water to bench areas without wetting the between-bench areas.

Drip irrigation is designed to apply water at very low rates directly to the root zone of plants. It uses less water and does not wet stems or leaves of plants when water is being applied, so the opportunity for disease spread from soil to plant is reduced, and leaves and stems are not exposed to wet conditions conducive to pathogen attack. Drip irrigation usually requires less energy for operation because the drip applicators require lower operating pressure than overhead irrigation. Water savings have been reported consistently at 30 percent in converting from overhead to drip irrigation systems. This also means a reduction in fertilizer needed because of the reduction in off-target application.

Another management advantage of drip irrigation is that larger areas can be irrigated at the same

time because each drip emitter has much lower flow rates than overhead applicators. Runoff is less likely with drip emitters as efficiency of fertilizer application is increased.

Kinds of Drip Emitters

The many kinds of drip irrigation emitters can be divided into categories that describe their design. Typical kinds of drip emitters are **long path emitters**, **orifice emitters** and **combination emitters**.

The long path emitters use a very narrow tube in a long, winding path within the emitter. The design dissipates energy so the water drips out of the end of the emitter at a constant flow rate. The long path is like a spaghetti tube squeezed into a tight maze of turns that is internal to the emitter body.

Orifice emitters do not have the long flow path. They dissipate pressure by the sizing of orifices within the emitter as the water moves from one orifice into a chamber and then through other emitters.

Combination emitters have elements of the long path and orifice emitters combined to dissipate the pressure and apply a precise amount of water.

Emitters may or may not be pressure compensating. Pressure compensating emitters have a greater tolerance to variability in pressure along the delivery line without a change in the flow volume of the emitters. Pressure compensating emitters usually cost more than non-pressure compensating emitters. Non-pressure compensating emitters are not good for longer delivery lines or changes in elevation along the delivery line.

Another desirable characteristic for drip emitters is that they be self-flushing, which means that when the pressure goes low in the emitter, it automatically flushes the water and any particulates that are in the emitter as it stops flowing. Flow rate for individual emitters varies from 0.5 to 2 GPH typically.

Distribution System for Micro Irrigation

Drip emitters are placed in flexible black polyethylene tubing that is the lateral distribution line. Because the black polyethylene tubing is flexible, it must be anchored to stay in place. For placing

an individual emitter into each pot on a bench, there is spaghetti tubing and a stake from the lateral to the emitter. The stake holds the emitter in place while the spaghetti tubing supplies the water from the lateral to the emitter. The several lateral lines are connected into a manifold pipe that is typically rigid polyvinyl chloride.

Uniformity of emitter application depends on uniformity of pressure in the lateral lines of the system. For proper drip irrigation system design, the pressure differential (difference of lowest to highest pressure in the lateral line) along the longest lateral line should be no more than 7.5 percent when emitters are non-pressure compensating. If emitters are pressure compensating, the pressure differential along a lateral line can be much greater and depends on the range of pressure that the pressure compensating emitter can be operated in. The pressure differential in a manifold line should be about 45 percent of the total system pressure losses. This pressure loss limit is used to choose the right size pipe for the manifold line. Larger diameter manifold line will cost more initially, but a manifold line that is too small will reduce the uniformity of application of emitters in the system. There will automatically be dry zones in the pots that must be scouted for and hand watered regularly to make up for the non-uniformity of the system. Therefore, the smaller manifold line turns out to be much more costly in the long run.

Micro-spray and micro-sprinkler systems are designed similarly to the design given previously for drip emitters, except micro-systems are not

usually designed with an individual micro-spray or sprinkler per pot.

All micro-irrigation systems require much cleaner water in terms of particulate matter and chemicals that can precipitate in the applicators. The design of the system should allow periodical flushing of the manifold to clean trapped particles.

Clogging is the number one problem and disadvantage of micro-irrigation systems. Good filtration and water quality is essential for keeping a micro-irrigation system running efficiently. Because fertilizer is often applied with micro-irrigation systems, you need to do regular cleaning to rid the applicators of precipitated salts and particulates that accumulate, as well as bacteria or algae in some cases. Acids are typically periodically injected into the system to clean the lines.

For control of bacteria, chlorine may be injected on occasion, but chlorination is not recommended for water that has more than 0.4 mg/L dissolved iron, because chemical reaction will occur that will create iron oxide precipitates in the lines. Some alternatives for controlling bacteria include xylene permanganate, ozone, quaternary ammonium salts, copper salts, acrolein, hydrogen peroxide, bromine and iodine. The frequency of chemical injection depends on the water quality and the fertilizer formulations being applied through the system.

Automating Your Irrigation System Is a Great Investment

Exploration: Would an automated water delivery system pay off in the short run?

Using computer-controlled water conserving systems, such as drip irrigation and ebb and flow benching, many growers report a 35 percent or greater savings on labor and even more (60%) for those growers who hand-water pot crops only. In spring, growers indicate that daily labor savings can be as much as 6 hours per day per employee assigned to water 20,000 sq ft growing space.

Many growers report a 25 percent savings on fertilizer costs. Many growers report an average of 30 percent less water used per year. The average drip, trough or grower-installed ebb and flow system designed for a small Quonset greenhouse



can pay for itself in less than 1.5 years. More extensive systems may also pay for themselves in less than 2 years. The savings come primarily from the reduction of labor hours used for watering.

Tensiometer devices that control the application of water based on plant needs can reduce water use and fertilizer applications by as much as 60 percent on a yearly basis when coupled to ebb and flow, trough or drip irrigation systems. This system greatly reduces runoff and costly watering mistakes.

Thinking about automating your watering system? It turns out that this will likely be the best investment you will ever make. Given new water use regulations and pressure from municipalities to regulate nursery and greenhouse use of water, installing a water-efficient, automated system makes good sense.

Below is an example of a small greenhouse firm with eight double poly, 30' x 100' greenhouses. If we assume 80 percent space use, and we install a drip irrigation system for 2,400 square feet of 6-inch pot crops and 200 linear feet of 10-inch hanging baskets per house, the following are the costs and returns for each house. Remember to multiply the savings per year by 8. Efficiency is even better for gutter-connected houses. (In our example, all number are rounded up.)

Installation — Net investment per 30 ft x 100 ft Quonset greenhouse:

tensiometer	2 x \$350	=	700
cycle timers w/controller boxes	2 x \$140	=	280
header tubes & emitters	6260 x \$0.50	=	3,130
re-design pressure lines		=	500
labor to install all	2 x 10 hrs x \$8.40	=	167
Total Investment		=	4,778 x 8 = \$38,224

Savings of Efficient Versus Traditional

Traditional equipment

150' hose, filter, check valve	=	100
labor (1 hr, 1 man, 8.40/hr, 183 days)	=	1,537
water (.5 gal; 6,260 pots, 183 days, \$.01/gal)	=	5,730
Total traditional/yr/Quonset	=	\$7,367 x 8 = \$58,936

Efficient equipment

labor (2 hr/wk, 1 person, 52 wks., 8.40/hr)	=	218
water (.3 gal/pot; 6,260 pots, 183 days, .01 gal)	=	3,437
Total efficient	=	\$3,655 x 8 = \$29,240

Net savings per house/year for next 10 years:
\$3,712 x 8 = \$29,696

Economic Analysis: Most growers would agree that a significant purchase is acceptable as an investment **if** it pays for itself in less than 2 years. In this case, the automated drip irrigation system pays for itself in 1.3 years!

Personal preference on priority or acceptance and standard decision points for: Payback ROI, NPV, IRR, and BCR for this decision.

NPV (Net Present Value) > \$5,000
BCR (Benefit Cost Ratio) > 1.0
IRR (Internal Rate of Return) > 15%
ROI (Return on Investment) > 20%
Payback < 2.0 (Less than 2 Years)

Assumptions:

Net investment = \$4,778 per house.
Product expected life = 10 years w/no salvage

Note: This analysis excludes depreciation and tax considerations.

Analysis techniques:

Payback = $\frac{\text{net investment}}{\text{annual cash flow savings}} = \frac{\$4,778}{3,712} = 1.26 \text{ yrs or } 15 \text{ mos}$

Return on Investment or

Simple Accounting Ratings:

$\frac{\text{cash flow savings}}{\text{net investment}} = \frac{\$3,712}{\$4,778} = 77.7\%$

Net Present Value of Investment Using 6 Percent as Normal Opportunity Return and 10-Year Life

Present value of cash flow = 3,712 x 7.36 = 27,320
Present value of net investment = -\$4,778
\$22,542

Net Present Value (NPV)

Summary Comments: Automating your irrigation system proves to be a very good investment. Payback (breaks even) under 1.2 years with 8 percent return on investment; @ 6 percent for 10 years net present value, is greater than \$22,000 or a 65-percent internal rate of return with a benefit cost ratio of 5.8. That is a fantastic investment.

Non-monetary tangible benefits: More uniform plant growth, scarce labor now freed up to

do more pressing work such as planting or loading trucks, allowing you to perhaps hire fewer staff members or survive if a key employee leaves. Do not forget the real conservation effect of using between 30 percent and 70 percent less water and the public relations benefit gained by being efficient.

Can you think of a reason not to take advantage of the savings gained by automating your watering system?

Greenhouse*A*Syst Assessment of Water Delivery and Irrigation Technology

Instructions for Completing the Risk Assessment

For each subject given in the leftmost column, read through each column and then select the description that best describes your operation. Do not rate practices that do not apply to your operation. Record the risk rating value in column 6 (the rightmost column), and then calculate the overall risk rating for this section at the end of each section. We will use these ratings to assess the overall water related risk of your operation at the end of the document.

	Low Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
OVERHEAD SPRINKLER EQUIPMENT					
Irrigation Uniformity — Design	Sprinkler spacing less than or equal to 50% of throw diameter along lateral line. Operating pressure carefully matched in design and maintained in use of pumping system.	Sprinkler spacing about 50% of throw diameter along lateral and less than or equal to 65% of throw diameter from one lateral to the next. Operating pressure is occasionally checked.	Sprinkler spacing greater than 50% of throw diameter along the lateral and greater than 65% of throw diameter from one lateral to the next. Operating pressure is unknown and not considered in the design and operation of the system.	Sprinkler spacing greater than 60% of throw diameter along the lateral and greater than 70% of throw diameter from one lateral to the next. Excessive number of sprinkler heads operating at once causing inadequate sprinkler operating pressures.	
Irrigation Uniformity — Pressure	Pressure variation less than 15% of design pressure from the highest to lowest operating pressures.	Pressure variation less than 20% of design pressure from highest to lowest operating pressure OR pressure compensating nozzles are used.	Pressure variation between 20-30% of design pressure from highest to lowest sprinkler operating pressures.	Greater than 30% pressure variation from design pressure from highest to lowest sprinkler operating pressure.	
Irrigation Uniformity — Nozzles	Nozzles are sized according to the original design. Nozzles are routinely checked for wear and replaced with the same size nozzle as needed.	Nozzles are sized according to the original design, but nozzle wear is not considered.	-----	When nozzles changed out, nozzle size may not be correct according to design specifications.	

	Low Risk 4	Low-Moderate Risk 3	Moderate-High Risk 2	High Risk 1	Rank Your Site
DRIP IRRIGATION EQUIPMENT					
Irrigation Uniformity — Design	Emitters for a given size pot are all the same size. Equal number of emitters per lateral line. Flow from each emitter is periodically checked.	Emitters for a given size pot are the same size. Number of emitters per lateral line varies but pressure compensating emitters are in use.	Emitter flow rate is not necessarily matched with pot size. Non-pressure compensating emitters are used.	Number of emitters per pot is not consistent and flow rates are not matched to appropriate pot sizes.	
Irrigation Uniformity — Pressure	Pressure variation less than 7.5% of design pressure from highest to lowest operating pressures, or pressure compensating emitters are used.	Pressure variation less than 10% of design pressure from highest to lowest operating pressures.	Pressure variation greater than 10% of design pressure from highest to lowest operating pressures.	Pressure variation greater than 15% of design pressure or pressure variation is unknown and untested.	
Irrigation Uniformity — Plugging	Emitters checked for plugging and cleaned or replaced regularly. Water treatment plan and filtration system in place, well-maintained and systematically followed.	Emitters checked for plugging and cleaned or replaced occasionally. Filtration system in place and periodically back flushed.	Emitters not checked for plugging. Filtration system in place and periodically back flushed.	Many plugged emitters. No filtration in place.	

Ranking Totals	÷	Total Areas Ranked	=	Technology Risk Rating
_____	÷	_____	=	_____

Summarizing, Evaluating Your Greenhouse*A*Syst Assessment Results and Identifying Action Steps

The purpose of this section is to assist you in summarizing your overall risk to your business from water related issues.

Once you have filled out the seven sections of risk assessment, you may summarize the results in the table provided below. This will allow you to easily see what areas your company needs reduce risk in, and where effort needs to be made for improvement. An overall risk value for the company is the last step in the process.

STEP 1.

Identify Areas Determined to Be at Risk

Fill in this summary of your Greenhouse*A*Syst Assessment for Your Operation.

Risk Area	Greenhouse*A*Syst Publication	Overall Risk Rating
Water Source	Bulletin 1274	
Delivery and Technology	Bulletin 1275	
Water Management	Bulletin 1276	
Water Quality	Bulletin 1277	
Water Recycling/ Pollution Prevention	Bulletin 1278	
Legislative Awareness/ Company Policy	Bulletin 1279	
Total Overall Risk Level for Water (Average of 6)		

* Bulletin are Georgia Cooperative Extension bulletins; visit <http://www.caes.uga.edu/publications/>

Low risk practices (4s) are ideal and should be your goal. Low to moderate risk practices (3s) provide reasonable results and protection. Moderate to high risk practices (2s) provide inadequate protection in many circumstances. High risk practices (1s) are inadequate and pose a high risk for causing environmental, health, economic or regulatory problems.

High risk practices, rankings of "1," require immediate attention. Some may only require little effort to correct, while others could be major time commitments or costly to modify. These may

require planning or prioritizing before you take action. All activities identified as "high risk" with a ranking of "1" should be listed in your action plan developed from this assessment. Rankings of "2" should be examined in greater details to determine the exact level of risk and attention given accordingly.

STEP 2.

Determine Your Overall Risk Ranking

This value provides a general idea of how your water use practices might be affecting your efficiency of water use and your understanding of proper watering practices and maintaining good water quality in your operations and impacts to surface and groundwater.

Water Use Risk Ranking	Level of Risk
3.6 to 4.0	Low Risk
2.6 to 3.5	Low to Moderate Risk
1.6 to 2.5	Moderate Risk
1.0 to 1.5	High Risk

This ranking gives you an idea of how your water use practices might be affecting your business success and conservation of water. This ranking should serve only as a very general guide, and not as a precise diagnosis since it represents the average of many individual rankings.

STEP 3.

Transfer Information on Risk to a Formal Plan for Improving Your Water Management and Use Practices

From the results of this assessment and after studying the provided guidelines and facts section, outline a plan of changes you want to incorporate into your operations with a timetable on

when you will achieve these changes. A plan can always be amended and changed due to new information, but if you do not make a plan with the new knowledge about your own practices that you have gained, then odds of follow through with real changes is unlikely. The plan outline can be as brief or as detailed as you want to make it. Be sure and note where you need to gather more information or consult with someone in your plan so that you will take action only after careful consideration of complex issues.

STEP 4.

Develop A Formal Action Plan

Simply put, assign specific staff to accomplish specific tasks in a known period of time. If more information is needed to make appropriate decisions, delegate specific fact-finding tasks to personnel best suited to accomplishing the task. Set goals and time lines based upon realistic expenditures of time and resources. Have each individual task written up for the entire team to assess and put into the larger context of the company. A formal action plan form is provided in the Appendix.

STEP 5.

Develop A Company Water Use and Monitoring Policy

The final step in this process is to sit down with your management team and decide upon how to

address your plans. The best method is to establish company water conservation/use policy. By doing so, every new and existing employee will be able to learn and follow your expectations for water management. By developing a policy document, you are also showing legislators and regulators that your company is serious about water management. Such documents will greatly improve how your business is viewed in the community.

STEP 6.

Implement the Policy

Your policy document stands as a symbol of your commitment to resource preservation. Consistent implementation will yield greater profits and better relations with your community.

References

- Bartok, J.W., and R.A. Aldridge. 1994. *Greenhouse Engineering*. NRAES -33, Cooperative Extension Service, Cornell University, Ithaca, New York. 1-209.
- Dole, J.M., J.C. Coile, and S.L. von Broembsen. 1994. Growth of poinsettias, nutrient leaching, and water use efficiency respond to irrigation methods. *HortScience* 29:858-864.



Contacts and Information Sources

Organization/Individual	Responsibilities	Address	Phone Number
Georgia Department of Agriculture, Pesticide Division	Questions regarding anti-siphon requirements for irrigation systems.	Agriculture Building 19 Martin Luther King Jr. Dr. Atlanta, GA 30334	404-656-4958 www.agr.state.ga.us
Geologic Survey Branch Environmental Protection Division	Regulations concerning water well drinking standards.	Georgia DNR 19 Martin Luther King Jr. Dr. Suite 400 Atlanta, GA 30334	404-656-4807 www.state.ga.us/dnr/envIRON — Geologic Survey Branch
Department of Biological and Agricultural Engineering, University of Georgia	Questions related to well-head protection or ground water on a farm.	Extension Unit Landrum Box 8112, GSU Statesboro, GA 30460	912-681-5653 www.bae.uga.edu
Drinking Water Program Environmental Protection Division	Questions regarding public drinking water.	Georgia DNR 205 Butler St SE Floyd Towers East, Ste. 1152 Atlanta, GA 30334	404-651-5157 www.state.ga.us/dnr/envIRON — Water Resources Branch
Safe-Drinking Water Hotline U.S. Environmental Protection Agency	General drinking water questions. 8:30 a.m. - 5:00 p.m. EST	401 M Street SW (Mail Code 4604) Washington, DC 20460	1-800-426-4791 www.epa.gov/safewater
U.S. Environmental Protection Agency	General drinking water questions.	U.S. EPA Region IV 61 Forsyth St SW Atlanta, GA 30303	404-562-9424 www.epa.gov/region4
Water Protection Branch Environmental Protection Division	General water quality questions.	Georgia DNR 4229 International Parkway Suite 101 Atlanta, GA 30354	404-675-6240 404-675-1664 www.state.ga.us/dnr/envIRON — Water Protection Branch
Pollution Prevention Assistance Division	Pollution prevention references	Georgia DNR 7 Martin Luther King Jr. Dr. Suite 450 Atlanta, GA 30334	404-651-5120 1-800-685-2443 www.p2ad.org
Robert A. Aldrich and John W. Bartok Jr.	Greenhouse engineering. NRAES-33	National Resources Agricultural and Engineering Service. 1994	
Karen L. Panter Steven E. Newman Reagon M. Waskom	Pollution Prevention for Colorado commercial greenhouses. SCM-206.	Colorado State University Cooperative Extension	
Sharon L. Von Broembsen Mike Schnelle	Best Management Practices (BMPs) for nurseries to protect water quality. E-951, <i>Water Quality Handbook for Nurseries</i> .	Department of Entomology and Plant Pathology Oklahoma State University Cooperative Extension Service	http://zoospore.okstate.edu/nursery/recycling/shy.html

Reagon M. Waskom	Best Management Practices for irrigation practices. XCM 173. August, 1994.	Colorado State University Cooperative Extension
Don Wilkerson	Irrigating Greenhouse Crops. From <i>Texas Green- house Management Hand- book</i> .	Texas Agricultural Extension Service
Don Wilkerson	Treating and recycling irrigation runoff. From <i>Texas Greenhouse Management Handbook</i> .	Texas Agricultural Extension Service

Environmental Protection Agency (EPA)

National Service Center for Environmental Publications
U.S. EPA/NSCEP

PO Box 42419; Cincinnati, OH 45242-0419

Phone: 1-800-490-9198 or 1-513-490-8190

M-F 7:30 a.m.-5:30 p.m. EST (www.epa.gov/ncepihom)

Drinking from Household Wells, EPA 570/9-90-013

LEAD In Your Drinking Water, EPA 810-F-93-001

Protecting Our Ground Water, EPA 813-F-95-002

Citizens Guide to Pesticides, EPA

University of Georgia, Cooperative Extension Service

Ag Business Office; Room 203, Conner Hall, UGA

Athens, GA 30602

Phone: 706-542-8999 (http://www.caes.uga.edu/publications/alpha_list.html)

Northeast Regional Agricultural Engineering Service, Cooperative Extension

Cornell University

152 Riley-Robb, Ithaca, NY 14853-5701

Phone: 607-255-7654 (www.osp.cornell.edu/vpr/outreach/programs/ageng.html)

Home Water Treatment, NRAES-48. Includes water-treatment basics, physical and chemical treatments, USEPA Primary Drinking Water Standards and health advisories, and pesticide products that contain USEPA drinking-water contaminants. (120 pp.)

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Action Plan Form

Use this action plan form to organize your ideas and to map out the activities necessary to complete your goals. Be sure to make the time frame realistic. Changes in basic resources take time. Please consult the list of references provided if you need additional information to develop this plan.

Area of Concern	Risk Rating	Planned Action	Time Frame	Estimated Cost

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