THE UNIVERSITY OF GEORGIA
COOPERATIVE EXTENSION
Colleges of Agricultural and Environmental Sciences & Family and Consumer Sciences

Water Management Assessment

The University of Georgia
The Greenhouse*A*Syst Publication Series
A Program Designed To Assess and Manage Issues
Involving Our Natural Resources and Environment

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The University of Georgia

The Greenhouse*A*Syst Publication Series

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

Water Management Assessment

Publication #3 in the Series

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What Can This Bulletin Series Do for Me?

Water conservation depends mostly upon management policy and philosophy. In this publication, you will be asked to take a candid look at how you approach water management. The answers you formulate may indicate areas that you, as an owner or manager, can improve upon with respect to your operation's efficient use of water through policy, changes in technology or changes in business approach. The result can be significant savings to the business in the long run. You can obtain additional savings in the area of total chemicals used, total fertilizer used and reduced crop losses. Review the following questions and determine to what extent your management guidelines cover these subject areas.

The goal of this section is to help you formulate an accurate assessment of your current water use practices and management decisions.

Have you experienced any crop losses or setbacks due to over- or under-watering?

This is a strong sign that water management needs reassessment.

Do you know if your water pressure is correct for your particular system component?

Incorrect pressure can affect water use efficiency, equipment life and labor costs.

Do you have particle filters and properly calibrated injectors or proportioners?

Filters significantly reduce repair costs and improve efficiency and accuracy.

When did you last formally test the irrigation and fertilizer systems?

You should test your system twice a year, between major crops, or before each season when the greenhouse is empty.

On what basis do you decide to irrigate?

There are several methods, only one of which is efficient.

A. Quantified water need defined by sensors inserted in the medium, i.e., tensiometers and lysimeters.
B. Same time each day on a timer, regardless of weather.
C. Visual assessment, which is determined by the grower.

Do you have a daily time set to irrigate after you decide to water?

Watering between 4 a.m. and 10 a.m. to decrease disease occurrence and evaporative loss is recommended.

Do you train employees to water according to need and plant type?

Small plants in large containers need much less water than established plants. Vinca need much less water than New Guinea Impatiens.

Do you group plants based on daily water requirements?

This improves water efficiency. Start by classifying your inventory and production space.

Do you know how much water is applied "off target"?

Off-target application is considered to be the surface space between pots, aisles, roadways, etc.

Do you organize containers in as tight an offset pattern as possible for that crop?

You can improve crop space use efficiency 15 percent by using the offset pot arrangements. This affects water use efficiency even more.

Do you periodically observe your employees' watering skills?

Watering skills degrade quickly among new employees. Monthly evaluations are essential.

Are you sure of employees' watering efficiencies?

The "tuna can" test can help you find out. Simply place several empty tuna cans among the pots or flats throughout the bench (or floor) area, and ask your employees to irrigate using the same watering wand motions they normally do. See Appendix B on page __ for this test procedure.

Considerations for Water Use Efficiency

Assessing Peak Demand

You have often heard that growers should irrigate their plants thoroughly by 11 a.m. to allow sufficient time for leaves and stems to dry. Experienced growers also know that, due to sun and heat, water demand by the plant increases rapidly after 11 a.m. For these reasons, efficient operations try to have all water operations completed in the morning. Operations with inadequate labor or water supply, however, must string out watering over the entire day. If your company does not have the capability to irrigate the entire facility, or a pre-planned half-section of the facility, each day before noon, you need to reassess your water delivery system and your employee management. The goal of this assessment is to determine your peak use demand and compare this in regard to your management strategy.

The closer you get the having the ability to water your entire facility through automation and expansion of your water supply, the more likely you will experience a reduction in cultural problems and, by default, you will save water by not applying it during periods of high evaporation. Specifically, the water you apply in the morning will be more efficiently used for the growth of plants during morning and afternoon hours.

Decision Parameters

When do your crops require water? Many factors will determine the right day to water. Many growers, especially those with understaffed greenhouses or where water supply is limited, simply water as often as their employee can get around to the crop. As the season progresses, this type schedule becomes fraught with shortage issues and dry plants. Another approach — equally as problematic — is an operation with automated systems that are simply put on a daily schedule and left to run regardless of the crop needs. Disease, root rots and poor growth often result.

The ideal situation is one where plants are scouted almost hourly and watering decisions made based on a combination of visual clues, such as slight wilting, and more quantitative measurements, such as pot weight. To most growers that hand water, this may seem impractical, yet if each greenhouse range had a person in charge of water management, their tasks could incorporate watering on demand. For automated systems, water application can be tied electronically to pot weighing devices, to moisture sensors, and to several other quantitative measurements that would more accurately identify which morning plants actually need irrigation. The middle ground is to establish a company policy about watering that takes into account several management factors/decisions before watering ever begins. The following sections describe just some of the factors that can play a role in effective water management.

Group Plants by Water Use Requirements

Most greenhouse operators know that impatiens need more water than vinca, and that perennials such as achillea respond poorly to being watered as frequently as hosta. Due to space limitations or, more likely, lack of planning crop spacing and location, however, these crops are often being grown side by side. Many greenhouses wind up with the same cultivar or species in seven or eight different places in the greenhouse. With just a few short hours of planning by the grower in charge, plant cultivars, species and even genera can be grouped by water needs and irrigation preference. The advantages are many: (1) Inventory management is much easier, (2) water use is much more efficient and better management decisions can be made specifically for that crop, (3) crop diseases and other cultural problems are reduced, (4) scouting for problems is much easier, and (5) less water is used in the overall operation.

Incorporating State of Growth

The next level of sophistication growers can achieve in water management is to adjust watering practices based on the plants' stages of growth. Large crops such as poinsettias are easy to manage this way and, in fact, most growers are making proper adjustments. Many pot crops mid-winter are also relatively easy to manage. When bedding plant season arrives, however, and perennials are being grown outdoors, all that is forgotten despite many bedding plants and perennials having rigid requirements at different stages of their development.

There are no golden-bullet guidelines. Each grower must determine the plants' requirements from reading books, consulting with plant suppliers and based on their own experience through the years. The significant step to take is to bring up the issue when crop schedules are being discussed with growers or employees. This allows everyone to visualize the schedule in relation to what he or she is watering and what each one needs to look for in plant responses.

Keep Water Use Records

Keeping a logbook of water use records by bay, zone or house. With crop notations and weather information, this can be a valuable tool over the years. Not only will it tell you how significant weather trends affect water use, it will tell you a great deal about what to expect and how close to the norms your current growing practices are. When crop problems do arise, a water use record can be added to the list of resources that may help you determine the cause of the problem. Most importantly, these kinds of records can be produced to answer regulators' questions. They may even help counter any accusations by uninformed citizens who complain that your operation is using all the county's precious water. As far-fetched as this may sound to you, this kind of misunderstanding happens often where water supplies are limited and community water restrictions are in place. There is no down-side to keeping good records.

Schedule Scouting

Scouting can be an effective tool in preventing disease and insect outbreaks. An additional advantage to scouting is that you can use the time to monitor your water use and limit production problems caused by improper watering.

An example of activities by a scout working on a weekly basis might include checking for leaks in the irrigation system, constant wet spots, excessive shore flies/fungus gnats, clogged emitters, improper use of water by employees, poor watering skills, algae buildup, excess condensation, dry spots in large crop areas, weather factors not being accounted for, presence of root rots, slow growth, excessive crop wilting, and improper nutrition. Scouting well done obviously will prevent most of the common greenhouse problems from getting out of control or causing a loss. What is less obvious is that scouting for water use efficiency will save money and resources in the long run.

Eliminate Off-Target Application

Off-target application is essentially the water you apply that misses the pot or, in the case of automated systems and new employees, the excess water that runs through the pot during periods it should not. Leaching soil is a valid activity in the greenhouse. Leaching every day, however, and/or over-watering a crop each day through poorly timed automation or lack of employee training not only wastes water, it can lead to pollution problems by runoff and soil percolation, disease problems, and many cultural maladies tied to

humidity and water condensation, especially in cooler seasons.

Eliminating off-target application is one of the easiest things for a manager to accomplish. In most cases, changing watering duration, reducing water pressure at the hose end, increasing the reservoir of space at the top of the pot, and adjusting sprayer heads and spray head direction can reduce water loss. Proper plant spacing, using trays under pots to capture water, and applying higher technology such as ebb and flow or flood floor systems can all but eliminate off-target water loss and resulting pollution. Despite budget shortfalls and time constraints, many of these adjustments take only a few minutes of management time to implement, especially if they are done at the beginning of the crop before planting and setting out.

Review your operation now for future adjustments and then plan to implement them within a reasonable schedule. Make notes and discuss the changes with your staff. Be sure to set up methods to monitor water use to determine if the improvements are actually helping conserve water.

Establish Employee Training Program

Most business owners have a short training period for employees. Water use training is usually limited to showing the employee how to water and then observing him for a day or so until things get busy. A better approach is to have a slightly more formal training period. The old saying that the person with the watering wand will make or break the business has never been truer. Mandate watering skills in the job description. Establish the techniques, policies and philosophy in writing. Make sure the employee has the skill, persistence and patience to do a proper job of watering crops. If your system is automated, be sure the person in charge of settings and timing has the persistence and attention to detail you need to implement your policies. Most importantly, follow up with a scheduled observation period every three months for the first year and twice a year for the next three years to be sure no bad habits develop.

Another step is to provide signage to remind employees daily about proper water use. These signs can be simple, laminated sheets with a few catchy sayings. Better yet, use stylized human figures using proper and improper techniques. Placing the signs near the hose bibs and irrigation timers can remind employees to think twice about what they are doing. These signs also reinforce your company's policy about water use and send a powerful message to regulators and county officials who visit the greenhouse.

Finally, establish proper water skills and diligence to good water management as criteria for annual evaluation. If you do not mention it when you hand out raises or distribute annual evaluations, the employee will quickly establish other, perhaps new, priorities based on whatever else you indicated in the written or verbal evaluation. Make sure that water use and proper management are always in the top five evaluation aspects you cite.

Water Use Records as a Scouting Tool

Another advantage to keeping water use records by zone or bay is that, given a few years, excessive use of water in any season can be spotted quickly. New crops, aberrant weather or, more likely, a new employee who uses a heavy wand in the greenhouse may explain this. Many growers produce the same crops each season and, within reason, most changes are in the area of cultivar, soil manufacturer or weather. In any event, knowing how your management decisions affect overall water use will make for a more efficient greenhouse and yield a crop schedule with fewer problems and better quality plants.

Greenhouse*A*Syst Assessment of Water Management

Instructions for Completing the Risk Assessment

For each subject given in the left-most 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 right-most 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 3	Moderate-High 2	High Risk 1	Rank Your Site
Peak water use demand	During peak water use period, you are able to adequately water all zones in 3 hours or less.	During peak water use period, you are able to adequately water all zones in 4 hours or less.	During peak water use period, you are able to adequately water all zones twice a day.	You are able to adequately water all zones twice a day if the weather is not too hot.	
Plants grouped together by water needs	Plants needing the same amount of water and same number of irrigations a day are grouped together in zones according to watering amount and frequency needs.	Plants that are irrigated the same number of times per day but may have different water use amounts are grouped together for ease of irrigation application.	Plants are grouped together by container size only, which is a good estimate of water use similarity.	Water use and frequency for requirements of different plants is not a consideration in how plants are grouped in the greenhouse.	
Water use adjusted for different crops and growth stage of the crop	Duration and frequency of irrigation are adjusted for different crops and different growth stages of a crop.	Duration and frequency of irrigation are adjusted for different crops but stay the same for the entire culturing of a particular crop.	----------	Duration and frequency of application are not changed to adjust to the needs of different crops and their changing growth stages.	
Water use adjustments for seasonal variations in water needs	Irrigation frequency and duration are changed according to ambient climatic factors.	Irrigation frequency or duration are changed with the time of year only.	----------	Irrigation frequency and duration are not changed with changing climatic factors.	
Greenhouse layout maximizes watering efficiency	Drip irrigation, ebb and flow or porous mats are used for supplying water so water is not sprayed into the air at all. Layout and irrigation system make capture of all leachate water possible.	Width of benches is matched to spacing or diameter of sprinkler patterns; walkways between benches are not wet by sprinkler pattern. Leachate may or may not be captured.	Sprinkler pattern and bench widths are not matched up so that much of the walkway and other work areas are regularly wet from sprinklers.	Sprinklers wet almost all the interior of the greenhouse, applying a great percentage of water in places where it cannot be captured for recirculation or used by plants.	

	Low Risk 4	Low-Moderate 3	Moderate-High 2	High Risk 1	Rank Your Site
Over/under watering signs	You rarely see any signs that plant materials are over- or under-watered.	Occasionally plants are over- or under-watered, but this never lasts for the whole development of the plants.	Signs of over-watering are prevalent when plants are young, and more mature plants do not show signs of over- or under-watering.	Signs of under-watering are indicated by the more mature stages of plant growth, but younger plants are neither over- or under-watered.	
Irrigation scheduling for automated systems	Soil moisture or plant moisture stress conditions measured with sensors to determine when irrigation is needed.	Estimated evapotranspiration is calculated from weather parameters and plants are irrigated according to their crop coefficient and the estimated ET.	Daily heat units are calculated and irrigation is initiated after a set number of heat units since the last irrigation.	Irrigation systems run on a constant frequency and duration throughout the growth of the crop.	
Irrigation scheduling for non-automated systems	Irrigation is applied when the soil reaches an appropriate level of dryness.	Estimated evapotranspiration is calculated from weather parameters and plants are irrigated according to their crop coefficient and the estimated ET.	Daily heat units are calculated and irrigation is initiated after a set number of heat units since the last irrigation.	Watering is usually carried out at the same frequency and duration throughout the growth of the crop.	
Irrigation decision parameters	Irrigation frequency and duration depend on the kind of irrigation system, the plant cultivar, the pot size, and a measure of soil moisture or plant stress index.	Irrigation frequency and duration depend on the kind of irrigation system, the plant cultivar, the pot size, temperature, radiation and air circulation.	Irrigation frequency and duration depend on the kind of irrigation system only, or the plant cultivar ony or pot size.	Irrigation frequency and duration are not different for various plants or irrigation systems and pot sizes.	
Off-target water application	Drip, ebb and flow, or porous mats are used so off-target water lost between containers is minimal.	With sprinklers or sprays, containers are placed as close together as possible to maintain suitable growing conditions to minimize off-target water.	With sprinklers or sprays, containers are not placed as close together as possible.	With sprinklers or sprays, spaces between containers are greater than the area of the containers, causing more than 50% of the water applied to be off-target water.	
Hand Watering Application Management and Training					
Employee training – how much	Employees who water are trained to know how much water is required for different plants and different weather conditions, or to decide when to irrigate from soil moisture.	Employees who water are trained to recognize the differing water needs for various plant cultivars but do not test the soil moisture for deciding whether or not to irrigate.	Employees who water are not expected to know the different water requirements and must take direction on how much an when to water using someone else's judgment.	There is little to no training for employees on the water needs of particular plants or how to adjust the amount of water for weather conditions.	

	Low Risk 4	Low-Moderate 3	Moderate-High 2	High Risk 1	Rank Your Site
Employee training – methods	Employees learn to water with efficient techniques and are observed about once a month to evaluate their technique and efficiency.	Employees learn to water with efficient techniques and are occasionally observed by managers to evaluate their technique and efficiency.	Employees learn to water with efficient techniques, but there is not follow-up monitoring of technique and efficiency.	Employees are not individually trained on efficient watering techniques.	
Follow-up and reinforcement of watering skills	Catch can testing is carried out with different employees to measure their watering efficiency and uniformity.	Water metering and record keeping of who is doing watering chores provide an indication of when someone is not watering efficiently.	Watering is rarely evaluated and usually only when a serious problem arises within a crop. No written follow-up is given.	There is no measure of water use and efficiency for different employees to provide them feedback on their watering skills.	
Cost of labor for hand watering	A cost/benefit analysis of hand watering versus installing irrigation system equipment has been carried out, and hand watering is more cost efficient.	Cost/benefit analysis of hand watering versus installing irrigation system equipment has been carried out, and irrigation equipment would have a reasonable payback, but capital is not available for the transition.	Man-hours for watering at different times of the year are unknown, so labor costs cannot be determined for watering chores.	Neither the cost of labor nor the cost of the water is known, so a cost/benefit analysis is not feasible without more data.	

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

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

The purpose of this section is to help you summarize 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 to reduce risk in and where you need to make 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)		

* Bulletins are all 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 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 7.
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.

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, *Water Quality Handbook for Nurseries*.	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 *Texas Greenhouse Management Handbook.*	Texas Agricultural Extension Service
Don Wilkerson	Treating and recycling irrigation runoff. From *Texas Greenhouse Management Handbook.*	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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Appendix A
Management Forms

Water Use Tracking Form — Part 1

Week of Production	House or Range 1 (gallons)	House or Range 2 (gallons)	House or Range 3 (gallons)	House or Range 4 (gallons)
1				
2				
3				
4				
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6				
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25				

Water Use Tracking Form — Part 2

Week of Production	House or Range 1 (gallons)	House or Range 2 (gallons)	House or Range 3 (gallons)	House or Range 4 (gallons)
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Appendix B
Estimating Water Application

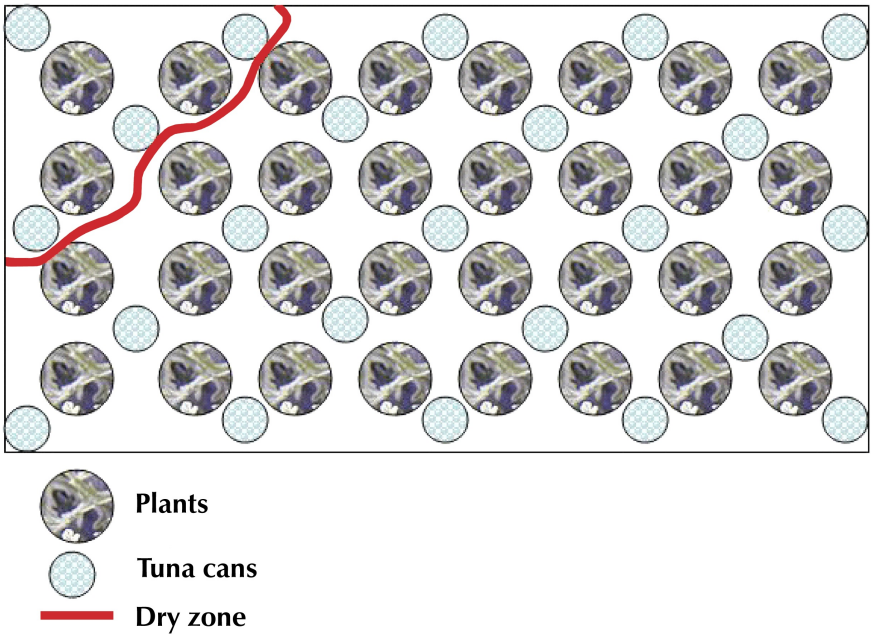
"Tuna Can" Assessment of Employees' Watering Skills

To measure your staff's water application efficiency or to test your automated equipment, try the following test.

Begin by numbering approximately 30 empty 12-oz. tuna cans per bench, using an indelible marker on the external bottom of the can (see diagram below). Distribute the tuna cans on the bench throughout the crop. Make sure the cans are located between the plants. Have your employee water the bench, or turn on your automated sprinkler systems. If you have drip irrigation, place the emitters in the cans. Water as is your normal irrigation policy.

Obtain a 100 ml graduated cylinder. In sequence, have an employee empty each can into that cylinder and measure the water that was in the can. Record the information. If your employee or watering system is efficient and accurate, there should be less than a 10-percent difference between the most filled and least filled cans. Pay attention if there is any pattern to under- or over-watering areas. Some employees tend to water more near the center of the bench than near the edges or vice versa.

Example of a "Tuna Can" Sampling Array



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

Learning for Life

Bulletin 1276 **Reviewed March 2009**