Michigan Department of Agriculture

Generally Accepted Agricultural and Management Practices for Irrigation Water Use

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In the event of an agricultural pollution emergency such as a chemical/fertilizer spill, manure lagoon breach, etc., the Michigan Department of Agriculture and/or Michigan Department of Environmental Quality should be contacted at the following emergency telephone numbers:

Michigan Department of Agriculture:	**(800) 405-0101**
Michigan Department of Environmental Quality:	**(800) 292-4706**

If there is not an emergency, but you have questions on the Michigan Right to Farm Act, or items concerning a farm operation, please contact the:

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Right to Farm Program
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PREFACE

The Michigan legislature passed into law the Michigan Right to Farm Act (Act 93 of 1981, as amended) which requires the establishment of Generally Accepted Agricultural and Management Practices (GAAMPs). These practices are written to provide uniform, statewide standards and acceptable management practices based on sound science. These practices can serve producers in the various sectors of the industry to compare or improve their own managerial routines. New scientific discoveries and changing economic conditions may require necessary revision of the Practices.

The Generally Accepted Agricultural and Management Practices that have been developed are the following:

1) 1988 - Manure Management and Utilization
2) 1991 - Pesticide Utilization and Pest Control
3) 1993 - Nutrient Utilization
4) 1995 - Care of Farm Animals
5) 1996 - Cranberry Production
6) 2000 - Site Selection and Odor Control for New and Expanding Livestock Production Facilities
7) 2003 - Irrigation Water Use

These practices were developed with industry, university, and multi-governmental agency input. As agricultural operations continue to change, new practices may be developed to address the concerns of the neighboring community. Agricultural producers who voluntarily follow these practices are provided protection from public or private nuisance litigation under the Right to Farm Act.

The Web site for the GAAMPs is http://www.michigan.gov/gaamps.

I. INTRODUCTION

The Generally Accepted Agricultural and Management Practices (GAAMPs) for Irrigation are based on the core principle of stewardship. Stewardship in irrigation management includes stewardship of water quantity, water quality, soil, plant quality, and crop yield.

- Stewardship of the water quantity means using water as efficiently as possible while providing for the crop/landscape water needs. Utilizing more water than necessary for production of a quality crop is wasteful of the water resource and can have negative environmental and production impacts resulting from leaching of nitrogen and possibly pesticides. With certain exceptions, over-irrigation is when water applications exceed the quantity needed to replace the soil/substrate moisture deficit. The amount of irrigation water to apply generally is equal to the total evapotranspiration since the last irrigation minus any precipitation that occurred during the period.

- Stewardship of the water quality means being careful to apply water at a rate that will infiltrate uniformly into the soil/substrate and be properly stored for crop use while not causing surface runoff or water movement below the root zone.

- Stewardship of the soil means following management practices that will sustain and improve soil surface infiltration characteristics and soil moisture holding capacity through increasing organic matter levels and biological activity while reducing compaction.

- Stewardship of the crop means managing water to promote plant establishment, sustain plant development, and foster the long-term sustainability of the managed landscape system.

- Stewardship of the agricultural sector of the Michigan economy means producing high-quality crops that maintain and enhance Michigan's reputation as a superior supplier in the marketplace.

These GAAMPs do not establish legal criteria to resolve water use conflicts, nor do they confer priority rights to water use. Individual water users who are concerned about their rights or abilities to establish new uses or to continue or increase their water withdrawals are encouraged to consult with advisors at Michigan State University Extension (MSUE), the USDA Natural Resources Conservation Service (NRCS), the Michigan Department of Agriculture (MDA), the Michigan Department of Environmental Quality (MDEQ), or an attorney versed in this area of law.

II. GENERALLY ACCEPTED AGRICULTURAL AND MANAGEMENT PRACTICES FOR IRRIGATION WATER USE

System Management

Proper management of an agricultural irrigation system is an integral part of GAAMPs. Seven practices contribute to proper system management.

1. **Determine all water applications accurately**.

   The objective of this practice is to accurately apply a known amount of water with each irrigation. To do this, irrigators need to accurately determine the water delivery. Application amount may be determined by knowing the actual flow delivered when the system is operating at a set pressure and monitoring time of application. Another method is to have a flow meter installed that will measure the flow. In addition to indicating the irrigation application rate and total flow, these meters will also serve as a warning of possible problems with wells or pumps. On pressurized systems, the flow meter used in conjunction with a pressure gauge can show whether the system is performing as it was designed. To be accurate, flow meters must be installed according to manufacturer's specifications.

2. **Evaluate the irrigation system uniformity**.

   The objectives of this procedure are to ensure the irrigation system hardware is in good operating condition and the irrigation system design is matched to the site conditions. It will also indicate where system management can be improved so distribution uniformity and overall potential application efficiency is increased. System uniformity evaluation involves 1) the overall condition of the system, and 2) how the design and management of this system work together to achieve high or low distribution uniformities and application efficiencies. Checklists are available from NRCS, irrigation dealers, and MSUE, and can be used to evaluate the overall conditions of the irrigation system and to assure that all vital components are in place.

3. **Maintain the irrigation system in good working condition**.

   The objective of this practice is to maximize the potential application efficiency by maintaining the sprinkler system so that it operates as designed. An important aspect of uniformity is to make sure every component is in good operating condition and the nozzles/emitters are not worn. Regular inspection for obvious equipment malfunctions should take place. The system should be periodically inspected for leaky pipeline or riser gaskets. Leaks can result in a significant loss of water. Deep percolation from leaking pipes could leach nutrients or chemicals to groundwater. Pressure should be checked in the system regularly. Pressure variations can be an early indication of problems with a pump that could indicate a malfunctioning or an incorrectly set valve. Correct system pressure is essential for efficient operation. Keep a record of when inspections are made.

4. Operate sprinkler systems to minimize drift and off-target application.

The objective of this practice is to reduce the detrimental effects of wind on application uniformity and off-target application of water. High winds can greatly reduce application uniformity and waste water. Avoiding operation under high wind situations will improve application uniformity and reduce the potential for water applications to non-target areas. Care should be taken to avoid drift or direct spraying of water over roads, adjacent property, or structures. Systems should be both designed and managed to avoid off-target application that does not fall on the irrigated field.

5. Ensure that irrigation system output does not greatly exceed the infiltration rate of the soil or substrate.

The objective of this practice is to maintain system uniformity and infiltration into the soil or substrate, and reduce transported sediments and other pollution to surface water. This is accomplished by ensuring the application rate of the sprinkler system is lower than the infiltration rate of the soil or substrate at all times during irrigation. This practice can be implemented by checking the application rate versus the infiltration of the soil or substrate and modifying the application rate when it is appropriate to do so. Runoff can be managed to some extent by applying lower amounts per irrigation and/or, in the case of container production, by increasing the gap between the container rim and the substrate surface. If runoff is noted, reduce the application amount and increase the frequency of irrigation. Check to see if there is a soil structure problem or if surface crusting is caused from too large of water droplets being applied. Center pivot sprinkler systems vary in application rates over the span of the pivot. The application rates under the pivot center are much lower than the rates near the end. This is because the field areas covered by the outside portions are much greater than those covered by the inside. Since the pivot will pass over a spot much more rapidly toward the outside end of the pivot, yet apply the same amount of water, the amount applied per hour is much greater.

Irrigation systems used for container production include traditional overhead sprinkler systems, flood, trickle or drip, low volume or microsystems, and sub-surface. Each system employs technology, equipment, and materials to satisfy the delivery requirements. It is important that the application characteristics of the irrigation system match the targeted plants, production and/or management operations, intake characteristics of the soil/substrate, and subsequent collection/discharge systems.

6. **Provide noise control for engine driven pumping units.**

Where an internal combustion engine is used to power a part of the irrigation system, such as a pump or electric generator, provisions should be made for sound control. This may be in the form of mufflers specifically designed to quiet the sound from the engine or sound baffles to minimize sound carrying toward neighboring properties. Sound travels easily over water bodies. Placement of engines should be considered carefully with respect to population density and sound transmission.

Record Keeping

Written documentation of an agricultural irrigator's water applications and management practices is an integral part of generally accepted agricultural and management practices.

7. **Records should conform to the requirements of the Michigan Water Use Reporting laws and regulations.**
8. **Keep records on all system inspections and repairs that influence uniformity and leaks.**
9. **Maintain records of regularly calibrated chemigation equipment, if used.**
10. **Keep records of the results each time the sprinkler system uniformity is evaluated.**

Irrigation Scheduling

Irrigation scheduling for each field or unit to be irrigated is an integral part of GAAMPs. Irrigation scheduling is the process of determining when it is necessary to irrigate and how much water should be applied during each irrigation event.

Various irrigation scheduling aids exist to help the irrigator keep track of the soil/substrate moisture balance, determine when to irrigate, and the quantity of water to apply. However, these aids do not replace the need for good judgment on the part of the irrigator, who must balance a multitude of factors in managing irrigation, such as:

- Soil variations within an irrigation unit
- Species variations within an irrigation unit
- The time from start to finish of an irrigation cycle

- The probability of rainfall in the near term future
- Stage of plant growth and its susceptibility to a moisture deficit
- Wind and heat energy impacts
- Potential environmental impacts

Scheduling can be done by manually keeping a running balance of the soil moisture status in each field or irrigation unit using a balance sheet approach, by using various instruments to measure soil moisture status and trigger irrigation, or by using a computerized approach to do the record keeping. All irrigators schedule by some method, and they should keep sufficient records so that they accurately apply the correct amount of water.

Irrigation scheduling helps the irrigator determine the appropriate timing and amount of water to be applied to the growing crop. The primary factors in scheduling are:

- Available soil water per unit depth of soil.
- Depth of rooting for the crop being scheduled.
- Soilless substrates, water retention, and container volume in nursery operations.
- Allowable soil/substrate moisture depletion at each stage of crop growth.
- Crop evapotranspiration at each stage of crop growth as determined by measured evaporation multiplied by the crop co-efficient. The crop co-efficient relates the actual evapotranspiration for a crop to the potential evapotranspiration. It depends on the crop development stage, is low during the initial stage, and reaches a peak at mid-season.
- Rainfall in the field.

11. Avoid applying irrigation water in excess of the quantity of water needed to replace the soil/substrate moisture deficit.

Plant water stress occurs when soil moisture has been depleted below some critical level, expressed as a percentage of available soil water. For a particular soil, *available soil water* is the amount of moisture held between its field capacity or drained upper limit (the amount of water retained in the total soil pore space after saturated soil has drained) and the permanent wilting point (the point at which plants can no longer obtain water from the soil and thus wilt and die). In Michigan, this difference for most soils is typically on the order of 0.07 to 0.15 inches of water for every inch in soil depth (e.g. a 10-inch layer of soil with a 0.13 inches of available water per inch of soil would contain 1.3 inches of plant available water at the drained upper limit). The coarser-textured soils more commonly irrigated in the state fall closer to the lower end of this range. The amount of available soil water for crops in a particular soil largely depends on its texture (the proportion of sand, silt, and clay particles), organic matter content, and the effective rooting depth of the crop in that soil. It may also vary with depth, as does soil texture. In general, the amount of available soil water increases with increasing clay content of the soil. For the highly variable soil textures and types in Michigan, this translates to a typical range of three to eight inches of plant available water in the top six feet of the soil profile. However, because losses of yield and quality occur long before the permanent wilting point is reached, the amount of available soil water that can be depleted without inducing damage is less than the total available. This amount is defined as the *allowable depletion,* and it is crop specific.

12. Know the available water for each unit scheduled.

13. Know the depth of rooting for each crop irrigated.

The amount of water needed for irrigation and the frequency of application also depends on the crop to be irrigated. Some crops, such as alfalfa, have a very extensive primary and secondary rooting system that penetrates to greater depths. The effective rooting depth of alfalfa will vary from three to six feet, or more depending on soil physical properties and depth of the water table. Corn also has a very good branching root system and can effectively use water to a depth of four feet or more. Soybeans, however, have a tap root system with secondary branch roots and seldom use water effectively from more than two feet deep. Field grown nursery stock usually has roots concentrated in the upper two feet of soil. Lettuce and many other vegetable crops have a very shallow root system and will rarely use water below one or two feet. Shallow rooted crops need to be irrigated frequently with small amounts of water, while deep rooted crops may be irrigated with larger applications of water at less frequent intervals.

Available water holding capacity data for a specific soil type can be obtained from USDA/Natural Resources Conservation Service's Field Office Technical Guide (FOTG), Section II, at http://www.mi.nrcs.usda.gov/. These data can be used to calculate the available soil water within the rooting depth of a crop grown on that soil. An average or representative value can then be determined for each field and can be used to calculate the allowable depletion for the field.

14. Use container capacity in scheduling irrigation for container grown crops.

In container production systems, soilless substrates contain a limited amount of water and roots and are confined to the container volume (Southern Nurserymen's Association, 1997). Container capacity refers to the container's capacity to hold moisture. It is used to define the maximum volume of water a substrate can hold following irrigation and drainage, expressed as the percent water retained relative to the substrate volume. Container capacity depends on the type of substrate and the container dimensions. A substrate is a mixture of different components to provide desired physical and chemical properties for proper plant growth. Increasing the percentage of fine particle substrate components, such as peat and sand, increase the moisture holding capacity of a substrate. However, addition of too many fine particle components can result in inadequate drainage. Container capacity is also influenced by the height/diameter ratio of the container. Recommended container capacities range from 45 to 65 percent, with the resultant available moisture ranging from 25 to 35 percent.

Weather conditions, the availability of water, the particular plants grown, and production cycles, are used in determining the scheduling of irrigation. Irrigation often occurs daily during the season and starts earlier and extends later in the season compared to traditional field operations.

15. Know the allowable soil moisture depletion at each stage of crop growth.

Most soils must be maintained above 40 percent to 65 percent of available water in the rooting zone to avoid plant stress, and that critical value varies by crop. During certain stages of crop growth of some sensitive crops, it is necessary to maintain very uniform soil moisture above 70 to 75 percent of available water, to avoid impacting yield and quality. Examples are tomatoes during fruit set and potatoes during tuber formation.

16. Measure, estimate, or use published evapotranspiration data and crop co-efficient (when available) to determine crop water use.

For some crops, you may wish to consult an irrigation specialist for assistance.

Because of the difficulty and expense of direct measurement of available soil water, most irrigation scheduling is based on an indirect measure. In this case, irrigation is scheduled according to a water budget in which crop water use estimated using meteorological measurements is balanced against water applied as irrigation and measured precipitation. Crop water use or evapotranspiration is the sum of two forms of water loss – evaporation from the soil surface and transpiration from the plants. Evapotranspiration is affected by several climatic factors and plant characteristics. It increases as solar radiation, air temperature, and wind velocity increase, and as the size of the plant canopy (leaf area) increases. It decreases as relative humidity increases and as stomata on the leaves close in response to water (or other forms of) stress. In relatively humid climates such as Michigan's, the most important meteorological factors in determining the evapotranspiration rate are solar radiation and temperature.

Even with good evapotranspiration estimation and accounting, the available water should be monitored in the field or container to determine when the allowable depletion has been reached. This can be accomplished by judging the feel and appearance of the soil at depths throughout the root zone, or by using direct measurement and monitoring instruments, such as tensiometers, Time Domain Reflectometry (TDR), or electrical conductivity sensors.

Guides to Michigan crop water use are available from your local NRCS or MSUE office that provide accurate estimates of water use patterns of specific crops.

17. Measure rainfall in each field irrigated.

Natural rainfall and irrigation applications work together to replace water used by plants. Accurate determination of how much irrigation water is needed depends directly on knowing how much rain falls in the field where irrigation is being scheduled. Rainfall events, especially summer storms, are variable and may drop widely varying amounts of water in locations that are not far apart geographically. Every field being managed for irrigation must have a rain gauge in the field in order to accurately manage irrigation water applications.

Scheduling methods:

Irrigation scheduling programs must be tailored to take into account soils and climatic conditions at a given location and also the requirements of different types of crops at different stages of growth. These programs can then calculate daily depletions of available water, usually from estimates of evapotranspiration. They also estimate how much water needs to be added when allowable depletion has been reached.

Irrigation scheduling programs commonly use the following data:

- Allowable depletion (AD) of soil moisture determined for the field or container.
- Initial AD balance – the portion of AD that is present at crop emergence, or when irrigation scheduling begins.
- Amount of rain and irrigation water added to the field.
- Daily potential evapotranspiration (ET) estimate based on calculations done by the manager or obtained from local sources.

- Percent canopy cover (or other coefficient) to adjust the ET estimate when the crop is at less than full cover (These coefficients are crop specific and adjusted for stage of growth).

The program then provides the following information for management:

- ET estimate adjusted for the crop at less than full cover
- Current AD balance – the portion of AD present in the field
- Projected AD balance for the next 24 and 48 hours

The manager then can decide how much and when water should be applied. Scheduling recommendations are adjusted to allow for the crops changing water needs at various growth stages.

Additional Reasons to Irrigate

18. At certain times during the growing season, the need for irrigation may be compelling even though water applications are not driven by the need to replenish a soil moisture deficit.

Examples of such other reasons to apply irrigation water include:

a. Frost protection: Application of water through sprinkler irrigation systems, during radiation frosts and conditions where the temperature drops below freezing for a few hours, may prevent crop damage. As water freezes, it releases heat that keeps the crop from freezing even though ice builds on the foliage. Irrigation must be sustained until all the ice is off the plant to prevent the thawing water from extracting heat from the plant.

b. Aid in seed germination or transplant establishment: Light applications of irrigation water may be needed at planting to assist in seed germination, assist transplants through the shock of being placed in the soil, and stimulate root movement into moist surrounding soil.

c. Aid in herbicide activation: Herbicides require moisture within the first few days of application to enhance the release of the effective ingredients. A light irrigation application can be used to provide the needed moisture.

d. Reduction of disease: Some disease organisms proliferate under dry conditions. A timely water application can function as a natural disease-control agent.

e. Establishment of post-harvest cover crops: Soil moisture may be limiting, when cover crops are seeded or irrigation water application may assist soil contact for seeds, if they are broadcast.

f. Control of wind erosion in small and emerging crops: Wind erosion can destroy small, tender seedlings of crops like vegetables and sugar beets, just as they are emerging, by blowing soil particles against them and essentially cutting them off. Irrigation to maintain a moist soil surface can be used to reduce wind erosion.

g. Post-harvest maintenance of ornamentals: Post-harvest maintenance refers to care and handling between harvest and subsequent use, whether use is replanting in continued production systems or shipping to an end user. Plants are held during this period as bare-root, balled and burlaped, or in some form of a container and require appropriate irrigation for the stock type.

h. Provision of proper soil conditions for harvesting crops: Harvest of some crops requires soil moisture above a critical level. Irrigation may be needed to provide proper conditions. Optimal soil moisture aids in the efficient use of equipment, allows for the ease of soil separation from roots/tubers in specific crop types, and minimizes damage to the desired plant part. Soil moisture is especially critical in the lifting of bare-root seedlings and in harvesting root/tuber crops and plants with soil balls.

i. Chemigation: Application of fertilizers and pesticides through irrigation equipment with properly chosen, usually small, amounts of irrigation water can be beneficial and reduce field operations and/or aerial applications. Correct amounts of water can assist soil incorporation or apply the chemical primarily to the foliage, as needed.

j. Crop cooling in special cases: Certain sensitive crops may benefit from light applications of water through an overhead irrigation system to wet plant surfaces and keep the plant cooler through evaporation.

k. Establishment and maintenance of a water table for sub-surface irrigation: Sub-surface irrigation is not generally addressed in these GAAMPs, but application of water through specially designed tile drainage systems may be used to control the water table in certain soil conditions and provide capillary movement unto the root zone of crops to provide their water need from below.

<u>Application Practices</u>

Irrigation can be applied at or below the quantity of water needed to replace the soil/substrate moisture deficit.

19. Choose irrigation application amounts that will avoid surface runoff under sprinkler irrigation.

The amount to apply with each irrigation cycle will depend on the soil type (or container substrate) and its infiltration rate. Runoff can be minimized when irrigating soil by reducing application rates to not exceed the soil infiltration rate. By adjusting the frequency and amount of irrigation water applied, the irrigator should maintain adequate soil moisture within the rooting zone. More frequent applications of smaller amounts may be desirable for some crop, soil, and cultural practice combinations. The application rate at which water can be applied is determined by the infiltration characteristics of the soil. The actual intake rate varies with soil structure, organic matter content, tillage practice, and the amount of crop residue remaining on the surface. Soils with good soil structure, high organic matter, and plenty of plant residues on the surface have higher rates of water intake than compact soils low in organic matter or without residues on the surface. Management practices that include cover crops and other practices to increase surface residue and soil organic matter, along with practices to reduce compaction, will help improve infiltration and soil moisture holding capacity. No-till and conservation tillage result in higher intake rates than clean tillage.

Leaching of nitrate-nitrogen or any other contaminant into groundwater should be prevented as much as possible. Manage irrigation systems to minimize nutrient leaching. The following list of practices may be used to minimize nutrient leaching:

20. Assure that sprinkler application rates are below the soil infiltration rate in order to prevent runoff and accumulation of water in lower areas, which may result in excess infiltration and leaching.

21. When irrigation is used, split application of nitrogen fertilizer or use controlled release fertilizer.

Multiple applications will help to ensure that nitrogen is available when plants need it most and to minimize the amount that can be leached.

22. Incorporate appropriate backflow-prevention safety devices if a chemigation system is used.

Practical Considerations

Many Michigan soils are variable. Thus, it is necessary to decide which soil type or which zone in the field should govern irrigation management. This decision may compromise the moisture stress situation for another soil type in the field. The irrigator must always consider the time it takes for the irrigation system to complete the irrigation cycle in any given field. An irrigation cycle may need to be started when part of a field still has some allowable depletion left in the profile. This decision is made in order for the system to irrigate the entire field before any segment of the crop has gone beyond the allowable depletion and moisture stress has resulted. Field soil variability should be taken into consideration when designing drip irrigation systems. Drip irrigation systems should be zoned, when possible, with zones designed so that the soil within a zone is as consistent as possible.

Monitor pumping plant efficiency. The objective of this practice is to maintain the design pressure and flow in the irrigation system while maximizing energy use efficiency. The distribution uniformity and the potential application efficiency of many irrigation systems are dependent on maintaining the design flow and pressure from the pumping plant. If the flow or pressure during operation are not as designed something may be wrong with the pumping plant. The system may not be set up correctly, is being operated incorrectly, or there may be worn nozzles.

Other management factors that influence irrigation include crop scouting schedules, crop protectant application schedules, and any restricted entry intervals that must be observed. For example, growers may use a custom applicator and may not have total control of the timing of applications, which can complicate irrigation management. In all of these situations, growers need to consider good stewardship practices, as well as the crop needs, with the goal of producing profitable yields and acceptable quality, and promoting environmental stewardship.

III. BACKGROUND

The material in this section of the document is educational and informational in nature and should not be interpreted as containing specific generally accepted agricultural and management practices. The GAAMPs and their explanation are in Section II.

Irrigation in Michigan

The importance of irrigation in agricultural production is recognized worldwide and is especially important in the United States. Of the total crop production area in the United States, only 18 percent is irrigated; but the irrigated area produces 23 percent of the total value of production. For high value crops, the proportion produced under irrigation is even higher.

In Michigan, only 6.7 percent of our land is irrigated, but the irrigated area produces primarily high value crops, making the value of the irrigated crops as a percentage of all crops produced higher than 6.7 percent. High-value crops such as vegetables, potatoes, seed crops, turf, and ornamentals are almost 100 percent produced and/or managed under irrigation.

The major reason for irrigation is to minimize or eliminate the negative impacts of moisture stress and thereby produce a high quality crop at a profit. The goal of irrigators should be to maximize crop quality and profit while minimizing the effect on the environment and water resources of the state. Michigan is a water-rich state, but rain-fed crops often suffer from a moisture deficit during a part of the growing season. Rainfall records show that Michigan is the driest state east of the Mississippi River during the critical growing months of July and August. However, annual rainfall exceeds annual crop and landscape water use. Therefore, there is typically water available to recharge aquifers and supply surface water needs in rivers, lakes, and wetlands during other parts of the year. In much of the state, groundwater is abundant and can be used for irrigation. However, these GAAMPs do not establish legal criteria to resolve water use conflicts nor do they confer priority rights to water use.

Water used in irrigation replaces water extracted by plants from the soil profile or substrates in container nursery systems. The main reason that plants use water is to moderate their temperature and remain in a productive state through evaporative cooling. Only a very small fraction of the water taken up by plants actually is used in their metabolic processes such as photosynthesis. Plant growth and associated crop production are dependent on the ability of the plant to remain within an acceptable temperature range. If the plant gets too hot, it wilts and dies, or at the very least, experiences a loss of productive potential. As long as plants can access soil/substrate moisture, they can transport water to plant surfaces that are exposed to the energy from the sun and make water available for evaporation from the plant surface (typically the leaves), thus cooling the plant. If insufficient water is available, the plant then must try to reduce the energy it is absorbing by curling or dropping the leaf so that less area is exposed to the sun. When the plant is stressed in this way, it not only is likely to get warmer than normal, but suffer a reduction in its ability to produce new dry matter, whether in the form of foliage, floral, fruit, or grain. Irrigation allows the producer to maintain soil moisture at a level where plants can extract the water they need for cooling. Thus, the main effect of irrigation is to provide the moisture plants need to stay cool and productive.

Agricultural irrigation water use in Michigan began to develop rapidly in the early 1970's with the availability of highly mechanized sprinkler irrigation equipment and the recognition that in certain low-water-holding soil areas of the state there was abundant water available. Irrigation could greatly increase production, crop quality, and the number of crops that could be grown. The ability to irrigate meets contract requirements to grow certain high value crops, maintains crop production requirements for a wide variety of commodities, and allows managers to reduce risks. High-value crops currently grown could not be produced in Michigan without irrigation. Examples are potatoes, seed corn, vegetables, turf and landscape, and nursery crops. Loss of the ability to produce these crops would not only jeopardize the farms on which they are grown, but would have serious adverse economic ripple effects in both the agricultural and non-agricultural sectors of the economy. Access to irrigation water for these crops is the keystone in the production of the quality and reliability of yield that Michigan growers have accomplished.

The amount of water applied through irrigation in Michigan augments natural precipitation, which ranges from 28 inches annually in northeastern sections of the state to over 38 inches in far southwestern and northwestern counties. While in some areas of the country, irrigators may need to provide for the total crop water needs through irrigation, in Michigan, only some of the plant water is provided through irrigation. Irrigation water requirements vary greatly depending on the rainfall, the crop grown and its stage of development, weather conditions, and the water holding capacity of the soil. There are usually episodes or periods of the growing season when precipitation is not sufficient to meet crop needs. The ability to irrigate enables growers to effectively minimize or eliminate soil/substrate moisture deficit periods by increasing the moisture available for plant growth.

Limitations to utilizing irrigation include the significant capital and energy costs, labor and management requirements, and the availability of adequate water supplies that are impacted by a variety of environmental, economic, and legal factors. Most important of these is the availability of a sufficient supply of surface water and/or groundwater. Irrigation is concentrated during the summer months when stream flows and lake levels are at their lowest. This makes careful evaluation of the adequacy of the water source available at a site before irrigation is started and the subsequent good management of the water resource very important.

The last available data, as reported in the federal Census of Agriculture for 2002, identified 4,413 Michigan farmers irrigated 456,278 acres that year. This represents an increase in number of irrigators from 4,123 and an increase in number of acres irrigated up from 407,071 acres, as reported in 1997. These federal census numbers are reported in a five-year cycle and give a sense of present trends for the state.

In 2004, of all farms irrigating 14 or more acres, St. Joseph County had the largest agriculture irrigation water use (MDEQ, 2004). The next largest water withdrawal counties were Montcalm, Branch, Kalamazoo, and Cass counties. Together these five counties accounted for over 32 percent of the total agricultural irrigated acres and 32 percent of the total agriculture irrigation statewide. The primary source of water for agriculture irrigation in these counties was groundwater (75 percent), with the remainder withdrawn from surface water sources. Eight counties reported no farms irrigating 14 acres or more.

The largest irrigated agriculture crop in Michigan during 2004 was corn grown for grain and seed. This crop accounted for nearly 40 percent of the total irrigated acreage in the state and approximately 37 percent of the total water withdrawn. The next largest irrigated crop categories were soybeans, potatoes, vegetables, and greenhouse nursery crops (including sod). Together, these categories accounted for 84 percent of the total agricultural irrigated acreage in Michigan and 85 percent of the irrigation water withdrawn.

Agricultural Water Use Reporting

In accordance with PA 148 of 2003, as amended, and amendments passed in PA 33 of 2006, as amended, all systems with the capacity to withdraw more than 100,000 gallons per day (70 gallons per minute) average in any consecutive 30 day period are required to register and annually report their water use. This requirement applies to both surface water and wells. These laws apply to all agricultural water uses (irrigation, cooling, animal watering, etc.). Forms and information are available from the MDA's Web site at www.michigan/gov/mda or by contacting Abigail Eaton at (517) 241-3933.

Overview of Existing GAAMPs and their Relation to Irrigation

The Michigan Right to Farm Act, PA 93 of 1981, as amended, states that "generally accepted agricultural and management practices" means practices defined by the Michigan Commission of Agriculture. The Act indicates that the Commission, in developing these practices, shall give due consideration to information available from:

Michigan Department of Agriculture
Michigan State University Extension
Michigan Agricultural Experiment Station
USDA Natural Resources Conservation Service and Farm Service Agency
Michigan Department of Natural Resources
Other professional and industry organizations

Previously, GAAMPs have been developed on:

Manure Management and Utilization
Pesticide Utilization and Pest Control
Nutrient Utilization
Care of Farm Animals
Cranberry Production
Site Selection and Odor Control for New and Existing Livestock Production Facilities

Some of these GAAMPs specifically mention irrigation. The Manure Management and Utilization GAAMPs (MCA, 2008a) recognizes (Section III) that irrigation is one method whereby manures may be applied to the surface and indicates that the irrigation must be done in such a manner that it does not cause ponding or runoff. The GAAMPs for Nutrient Utilization (MCA, 2008b) discusses irrigation in Section V, Part 16 and 17. It recognizes that proper irrigation management can help assure plant growth and yields that are sufficient to remove applied nutrients and that irrigators should use modern scheduling techniques to avoid applying excess water that could result in movement of nitrates below the root zone. The GAAMPs for Nutrient Utilization recommend that irrigation water be applied in a manner such that after irrigation, some soil water holding capacity remains unfilled to hold rainfall should it occur shortly after irrigation. Specifically, it recommends that “irrigation should occur when 40 percent to 70 percent of the available soil water is depleted, depending upon the soil, crop, and capacity of the irrigation system…” and that “irrigation water should not fill the soil rooting profile to more than 80 percent” of its moisture holding capacity. The nutrient management GAAMPs also indicates that “irrigators should use multiple applications of N-fertilizer to improve N-efficiency and minimize potential losses of nitrate-N to groundwater.” It states that “nitrogen fertilizer applied through the irrigation system, referred to as fertigation (or chemigation) offers special advantages to irrigators, and 1) may be applied when the crops demand is the greatest, and in trickle-irrigated orchards, where roots are the most concentrated; 2) the technique requires little energy for application; and 3) it is well suited to sandy soils where irrigation is needed and leaching may be a problem.” The GAAMPs cautions producers who fertigate should test the uniformity of their irrigation system to assure that no extremely high or low zones of water application occur. Irrigation systems used for pesticide and nutrient application must have appropriate back flow prevention safety devices.

Section VI of the Nutrient Utilization GAAMPs states that “frequent fertilization and irrigation of container grown plants are needed since common root media lack nutrient and water holding capacity.” In such conditions, it is important that effective management practices be adopted to minimize water and fertilizer leaching and/or runoff.

The Pesticide Utilization and Pest Control GAAMPs (MCA, 2008c) recognize that chemigation (application of pesticides through irrigation equipment) is one generally accepted method for application (Section II). Section II, G-6, states that when utilizing chemigation, the applicator should make a determined effort to “utilize safety measures including back flow safety devices” to prevent possible contamination of the water source.

Water Law and Agricultural Water Use

The Michigan Right to Farm Act, PA 93 of 1981, as amended, provides Michigan farmers with limited protection from nuisance suits. The statute authorized the Michigan Commission of Agriculture to develop and adopt GAAMPs for farm operations. Adherence to the GAAMPs does not provide a complete barrier against lawsuits, but it does give protection from nuisance litigation in many circumstances. The Act [MCL 286.472, Sec. 2 (b) (iii)] defines “farm operation” as including:

> “The operation of machinery and equipment necessary for a farm including, but not limited to, *irrigation* and drainage systems and *pumps* …” (emphasis added)

It also states in MCL 286.473, Sec. 3 (1):

> "A farm or farm operation shall not be found to be a public or private nuisance if the farm or farm operation alleged to be a nuisance conforms to generally accepted agricultural and management practices …"

In addition in MCL 286.473, Sec. 3 (3):

> "A farm or farm operation that is in conformance with subsection (1) shall not be found to be a public or private nuisance as the result of any of the following:
>
> (a) A change in ownership or size
> (b) Temporary cessation or interruption of farming
> (c) Enrollment in government programs
> (d) Adoption of new technology
> (e) A change in type of farm product being produced"

These GAAMPs do not establish legal criteria to resolve water use conflicts nor do they confer priority rights to water use. Individual water users who are concerned about their rights or abilities to establish new uses or to continue or increase their water withdrawals are encouraged to consult with advisors at MSUE, NRCS, MDA, MDEQ, or an attorney versed in this area of law. Water withdrawal for irrigation purposes has the potential to impact other adjacent property owners, other riparian surface water users, and/or the natural resources of the area. Several regulatory programs exist to consider those potential impacts.

<u>Permits and Regulatory Considerations</u>

MDEQ has the key regulatory and program provisions involving wetlands, lakes, and streams. The MDEQ administers what is commonly known as the Inland Lakes and Streams Part and the Wetlands Protection Part of the Natural Resources and Environmental Protection Act (NREPA), PA 451 of 1994, as amended. This authority was granted to the MDEQ by the state legislature. The MDEQ also administers Section 404 of the Federal Clean Water Act in the non-coastal areas of Michigan through a Memorandum of Agreement with the United States Environmental Protection Agency. Permit applications for construction activities in regulated wetlands, lakes, and streams are submitted to the MDEQ's Land and Water Management Division.

Inland Lakes and Streams, Part 301 of NREPA, requires permits where construction activities will occur in a lake or stream to facilitate the withdrawal of water. A state inland lakes and streams permit will generally be required for dredging in the water body, construction of a structure in or over the stream, stream relocations, creation of a lake (water body five acres or larger), or creation of a pond within 500 feet of a lake or stream. Wetlands Protection, Part 303 of NREPA, may require permits where irrigation activities will result in the drainage of or construction in a regulated wetland. Regulated wetlands include any of the following:

(a) Wetlands located within 500 feet of other surface waters, or within 1,000 feet of the Great Lakes, regardless of wetland size.
(b) Isolated wetlands larger than five acres.
(c) Other wetland areas deemed essential to the preservation of the natural resources of the state and where the property owner has been so notified.

A state wetlands permit will generally be required for work in regulated wetlands where the project will require grading, filling, construction of dikes, construction of ditches, and/or the placement of other structures within the wetland area.

The MDEQ has a Wetland Identification Program (WIP) whereby a person can request the wetlands be identified and their regulatory status is determined. The findings of the MDEQ under this program are guaranteed for a three year period. Application forms for a WIP assessment can be obtained at the MDEQ website at www.michigan.gov/deqwetlands.

State wetland inventory maps which combine information from the Michigan Resources Information System (MIRIS), the US Fish and Wildlife Service National Wetland Inventory maps (NWI), and the USDA Natural Resources Conservation Service soil surveys are available at the County Register of Deeds, the County Clerks office, the County Extension Service, and at the MDEQ Web site: www.michigan.gov/deqwetlands.

Planning and Preparation

Irrigation is used to provide moisture for plants when natural rainfall, coupled with the soil's capacity to store available moisture, is insufficient. Plants obtain needed moisture from water stored in the soil. The need for irrigation depends upon how much water the soil can store and how frequently rainfall occurs. In Michigan, the annual rainfall exceeds annual water use by plants, but the temporal distribution of precipitation is not sufficient to keep up with plant needs unless the soil can store several inches of available moisture. Where soils have high moisture holding capacity and crops with the capability of developing roots several feet in depth are grown, irrigation may not be necessary. Irrigation is beneficial and necessary for crops grown on sandy soils that have limited ability to store moisture. Planning for irrigation should include consideration of:

- The soil/substrate and its moisture holding capacity
- Crops to be grown and their rooting depths
- Susceptibility of the crop to moisture stress
- Available water supply for irrigation and other nearby users
- The overall economics of investing in irrigation

Water Supply:

Planning for irrigation includes not only determining whether irrigation would be beneficial based upon soil, plant, and economic characteristics, but also the assessment of whether an adequate water supply capable of providing the quantity of water needed in the driest years exists. In most areas of the state where irrigation is practiced, the water supply is more than adequate. Groundwater supplies are sufficiently abundant for irrigation and other uses in most of Michigan, even in exceptionally dry years. However, there are some areas where groundwater may not be sufficient for all uses, even in years of average precipitation.

As a general rule, irrigation systems in Michigan should be capable of keeping up with a plant water use rate of about 0.25 inches per day over the entire irrigated area. The flow rate required will depend upon the percentage of the total time the irrigation system can be expected to operate considering the necessary downtime for maintenance and making new irrigation sets. For example, center pivot irrigation systems can be expected to operate nearly 24 hours per day, but other systems such as 'traveling big guns' require downtime for making new sets. System capacity planning must take into account that less than 100 percent of the water applied is actually stored in the root zone. Procedures for planning irrigation water needs are outlined in detail in MWPS-30 (1999). Water supplies for sprinkler irrigation systems that wet the entire surface area must be capable of providing at least five gallons per minute for each irrigated acre. Requirements for drip (trickle) irrigation used for trees or other crops, and irrigation practices where the plant foliage and the wetting process does not cover the entire area, may be less.

Water for irrigation may come directly from groundwater or surface water sources, or in some cases of turf and landscape or nursery production, from municipal supplies. Procedures for evaluating surface water sources to determine adequacy for irrigation are provided in MWPS-30 (1999).

Some surface water, such as streams, lakes, and wetlands, may be sensitive to large withdrawals of groundwater for irrigation. Nearly all groundwater naturally flows out to surface water. Groundwater removed from an aquifer for irrigation may reduce this flow to surface water. Plants and animals in surface water depend upon groundwater, which help to maintain stable temperature, chemistry, and flow. Surface waters that may be most affected by nearby irrigation from groundwater are smaller lakes, wetlands, and headwater streams. The irrigation season is typically a time period when these smaller surface-water bodies are most reliant upon groundwater.

Aquifer Monitoring:

Irrigation with groundwater also has the potential to lower water levels in nearby wells. It is difficult and expensive to determine a potential affect prior to installing a new irrigation well. Well drillers, nearby irrigators, extension agents, universities, MDA, MDEQ, or USGS, may have information about potential effects of irrigation on nearby wells. In areas where there is a known potential to lower water levels in nearby wells, an irrigator may wish to install one or more monitoring wells. Such wells should be drilled to the same aquifer as potentially affected wells. They should be located between the irrigation well and potentially affected wells and as far away as possible from the irrigation well.

All well work should be performed by a licensed, Michigan, water well drilling contractor. Irrigation well design should include drilling and test pumping of a test well prior to installing the irrigation well. By carefully monitoring the water level in a test well during an appropriately long period of pumping, the driller will be able to predict the performance of the irrigation well.

Water levels in an irrigation well should be monitored, both to determine the effect of pumping on the aquifer and to determine if the well is approaching a need for maintenance. The irrigation well should be set up with monitoring equipment so that it is easy to monitor the water level in the well. An air line and specially calibrated gauge may be installed on the well for this purpose. Measurements of water level should be made prior to the irrigation season, approximately midway through the irrigation season, and after the irrigation season. For monitoring the long-term conditions in the aquifer, these measurement dates should be on about the same date every year. Water level measurements prior to and after the irrigation season should be made when the pump has been off for several days. Water level measurements during the irrigation season should be made while the pump has been operating for some time (for instance, just prior to shut-off), and when the pump has been off for some time (for instance, just prior to irrigating). Long-term records should be kept on these measurements to provide data on any change of aquifer level or lack thereof. Dynamic pumping levels can reveal a change in well efficiency that may indicate a need for service. If both pumping and non-pumping levels are measured annually, these records are useful for system maintenance. They can be used to detect any change in well efficiency or pump performance. If the drawdown, the difference between non-pumping and pumping level, increases, it is an indication that the well screen or the formation around the well is becoming plugged and may need maintenance. If the drawdown decreases, it may be an indication that the pump is not pumping as much and may be becoming worn, or there is a severe restriction to flow somewhere.

If an irrigator is using monitoring wells to determine impact on the aquifer, they should be measured more frequently. During the irrigation season, water levels should be measured as frequently as possible, but not less than once a week. During the remainder of the year, water levels should be measured not less than once a month. Preferably, all measurements should be taken at about the same time of day. In all monitoring, either of the irrigation well or monitoring wells, care must be taken to avoid aquifer contamination. “To protect the aquifer from contamination, Part 127, PA 368 of 1978, as amended, requires all wells be properly plugged upon abandonment of the well. Technical assistance on the proper closure of wells may be obtained from the soil conservation district office.”

Irrigation Equipment:

There is a variety of irrigation equipment available. Most irrigation systems in Michigan are overhead sprinkler systems. Where crop foliage does not develop to provide complete ground cover, drip or micro-sprinkler irrigation systems may provide greater water use efficiency. The application characteristics of the irrigation system should be matched to the intake characteristics of the soil. Information on soil intake rates is available from NRCS soil survey data and should be consulted in choosing the sprinkler package or specific sprinkler system to be utilized. Water that does not infiltrate during application is not beneficial. Water that runs off one spot may move to another, causing over infiltration resulting in nutrient and pesticide leaching and inefficient water use. It may also result in water leaving the field and entering a waterway resulting in potential water quality impacts.

IV. REFERENCES

2002 Census of Agriculture, Federal

Davidson, H. Mecklenburg, R., Peterson, C. *Nursery Management, Administration, and Culture*. 4th Ed. Prentice Hall, Englewood Cliffs, New Jersey, 2000.

Green, J.L. *Practices To Minimize Contamination of Groundwater and Runoff Water in Production of Container–Grown Plants: A Literature Review*. Horticulture Department, Oregon State University, 1998.

MCA. 2008a. Right to Farm. *Generally Accepted Agricultural and Management Practices for Manure Management and Utilization*. Michigan Commission of Agriculture.

MCA. 2008b. Right to Farm. *Generally Accepted Agricultural and Management Practices for Nutrient Utilization*. Michigan Commission of Agriculture.

MCA. 2008c. Right to Farm. *Generally Accepted Agricultural and Management Practices for Pesticide Utilization and Pest Control*. Michigan Commission of Agriculture.

MDEQ. *Irrigation Water Use in Michigan*. A report prepared by the Michigan Department of Environmental Quality Office of Water, 2004.

MWPS – 30. *Sprinkler Irrigation Systems;* first edition. A handbook from the Midwest Plan Service, Ames Iowa, the Agricultural Engineering Department, Michigan State University, 1999.

Southern Nurserymen's Association. *Best Management Practices – Guide for Producing Container Grown Plants*. Southern Nurserymen's Association, 1997.

Stark, J. C., McCann, I. R., Westermann, Izadi, D. T., B. and Tindall, T. A., 1993. *Potato Response to Split Nitrogen Timing with Varying Amounts of Excessive Irrigation*. American Potato Journal, 70:765-777, 1993.

State of Michigan. *Water Resources for the Future*. Report of the Great Lakes and Water Resources Planning Commission. Commission report to Governor William Milliken. September, 1987.

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