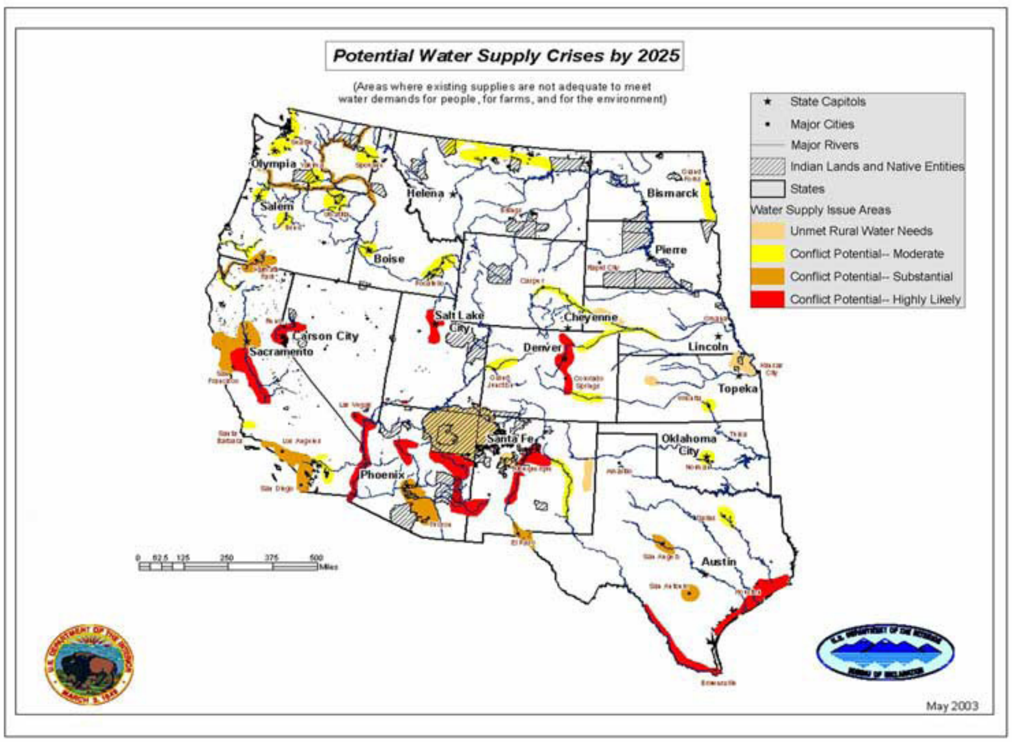
Chapter Five

Smart Controllers

The Government Accounting Office released a study in July 2003 stating that 36 of 50 states are actively seeking ways to avert water shortages expected during the next 10 years. The United States Bureau of Reclamation issued a report entitled *Water 2025: Preventing Crises and Conflict in the West* which has identified areas in the western part of the United States where the conflict potential over water resources is either substantial or highly likely. Those areas are represented in the shaded areas of the map below. The areas with the greatest challenges are also the areas that are experiencing large growths in population.



As cities continue to grow at accelerated rates, people will still desire attractive landscapes around their residences. Gardening is the number one rated hobby in the United States, and eight out of ten households participate in outdoor lawn or garden activities. These landscapes will need water, and the majority of the water used for irrigating lawns and plants comes from potable water supplies.

For those areas where population growth will continue, water purveyors are aware of the need to reduce the "waste" of water resources caused by poor irrigation practices. They have recognized the need to improve irrigation efficiency. The *Water 2025* report specifically lists four key tools to meet the challenges of the future. Three of those key tools are: (1) conservation, (2) improved efficiency and (3) utilizing improved technology.

These circumstances have created a new opportunity for the irrigation industry to offer solutions toward conserving water, improving watering efficiency and utilizing new technology in home and garden applications. By doing so, homeowners can maintain attractive landscapes while preserving the natural environments unique to their locations.

For a number of years, manufacturers of irrigation products have marketed many new and innovative ideas for conserving water resources in both agricultural irrigation and landscape irrigation. Some of the products developed for turf and landscape irrigation include matched precipitation rate nozzles; flow control devices for nozzles; pressure regulating devices for heads, valves and the whole sprinkler system; rain shut-off devices; and controllers with more features such as budget adjustments, multiple start times and multiple programs to meet different irrigation schedules for different plant types.

While these innovations are hardware related, very few improvements have been made to irrigation management, especially ways to respond to water needs of the landscape based upon the environments in which the landscapes were growing. Although irrigation management can be accomplished with many of the existing controllers, it requires constant vigilance to minimize water waste. Adjusting watering schedules is an example of a deficiency in some hardware solutions.

The need for improved irrigation management – which will improve irrigation efficiency and conserve water resources – created the need and demand for smart water application technology, or smart controllers.

Smart controllers differ from traditional controllers in that they calculate the irrigation schedules after receiving the appropriate inputs. They can respond to weather changes that affect plant growth, or they can respond to changes caused by irrigation. In the end, the big difference is that the irrigation manager no longer programs minutes into a controller. Rather, the manager provides the controllers with all parameters that affect the creation of an irrigation schedule, such as sprinkler head performance, actual precipitation rate of the sprinklers, how evenly water is applied by the sprinkler system, soil types, slopes, plant material in each zone being irrigated, etc. The use of smart technology requires better-trained professionals to install and program the new controllers and to educate their customers so they can be successful in utilizing the technology.

Methods of Operation

These smart controllers utilize a variety of methods to implement proper irrigation schedules. They can either monitor weather conditions or soil conditions to make decisions to about how much and how often irrigation will occur based on the parameters programmed into the controllers.

Weather Data

Some smart controllers utilize weather data. Each manufacturer uses unique methods to estimate the amount of water needed by the different plants in the landscape. Utilizing historic evapotranspiration information has been done for many years, and some of the new controllers have that information built into the firmware of the controller. The schedule is modified based on historic trends, less water in the spring and fall and more in the heat of the summer.

Some weather-based controllers will interface in some way with nearby weather stations that are frequently owned by some other entity such as a state government or water district. These controllers can receive the weather data or ET information via some type of communication such as a paging signal or the Internet. These controllers can calculate the water requirement or get the ET values and modify them for the site conditions where the controller is located. Other controllers have on-site weather instruments to collect and input data into the controller to calculate and determine plant water requirements that will, in turn, affect the irrigation schedule.

Soil Moisture Data

Other smart controllers monitor the soil moisture as plants extract water or water is evaporated out of the root zone. The type of plant, how it is maintained, its growth cycles, and the type of mulch being used all affect how much water is extracted from the soil. The soil moisture controllers constantly interrogate one or more soil moisture sensors, which are proprietary to the control system. The feedback that is provided by the soil moisture sensor will impact the irrigation schedule.

Soil moisture controllers require the user to have knowledge of soil properties, especially water holding properties, as well as the irrigation system that will supply the water. Soil moisture controllers have the ability to link stations throughout a project to a specific station that has a sensor attached to it. This becomes the reference station, and all stations that would be linked to it would have the plant material, soil type and conditions and microclimates that affect a plant's demand for water in common. If that hydrozone type requires water, then all stations that are linked to the reference station will be part of the irrigation event.

Smart controllers can fall into one or several of the following general categories:

Historical ET

These controllers utilize historical evapotranspiration information to modify the scheduled run times for each station automatically within the controller. The historical information is an integral part of the controller's firmware and can be obtained for specific regions of the country. Historical ET information is useful because it tends to be relatively stable from year to year; however, it does not respond abnormal conditions that can occur on a daily or weekly basis. Some manufacturers utilize sensors to compare real-time weather conditions to the historical average and modify the historical ET to more accurately reflect current conditions, whether warmer or cooler than the historical average. It is highly recommended that a rain shut-off device be incorporated with the controller.

Internet-Based

These controllers require access to the Internet, usually via a telephone connection. Internet-based controllers typically receive current ET or weather information from the manufacturer's server that accesses nearby weather stations. The host server creates irrigation schedules that are downloaded to the field controller via the Internet. The controller can also give feedback to the server about field changes and irrigation taking place. Programming the controller takes place via the Internet on a website. The operator can access the controller from any computer. The irrigation schedule is determined by the manufacturer's software through online input from the irrigation manager. This optimal frequency of irrigation is dependent on the inputs. Usually, there is a modest fee associated with this type of system.

Paging Signal

These controllers can receive daily or even hourly ET or weather information to determine when and how much irrigation should take place via a paging signal that is controlled or operated by the manufacturer. A fee is usually paid to have that signal transmitted to the controller. Verifying that the signal strength is adequate and will be received reliably at the controller location is important. If necessary, an external antenna may need to be added. These controllers depend on the availability of weather stations close to the area to get pertinent data to transmit. The controllers receive the information, store it and do the calculations necessary to determine how long the valve needs to run to deliver the appropriate amount of water. The set-up of the controller is specific to the site for which it will be controlling the irrigation. Typically, these controllers should have rain shut-off devices or rain gauges to measure site rainfall and account for it when creating the irrigation schedule.

On-Site Systems

These controllers have their own style of weather station and take measurements necessary to calculate plant water need. They measure weather conditions at the site and are not dependent upon a remote weather station or receiving a signal. The mini weather stations are proprietary to the controller, meaning they will only work with that particular type of controller. Using rain shut-off devices is highly recommended with these controllers.

Soil Moisture-Based Systems

These controllers determine ET by measuring changes in soil moisture. The inputs to the controller have more to do with soil properties and rely upon the irrigation manager to calculate the number of minutes to apply a given amount of water based upon sprinkler head performance. The idea of a balanced schedule is to know how many minutes each station will need to run. The amount of deficit in soil moisture can be determined by the soil type and depth of root zone, but ultimately it depends on the amount of water that should be in the soil between saturation and wilting point.

Frequently, volumetric soil moisture is expressed as a percentage of the pore space that should be filled with water for optimal plant growth. Rain shut-off devices are not needed because if the rain is entering into the soil profile, the sensors will detect it and give feedback to controller. If there is enough soil moisture, the next irrigation will be delayed.

One of the critical steps in installation is the proper placement of the soil moisture probe. It needs to be in a representative location of the area avoiding spots that are too wet or dry out very quickly. When these conditions exist, improving sprinkler performance will be recommended.

Online Sources of Information

The Bureau of Reclamation produces a report comparing the available products that re currently being sold. The full report can be obtained at **http://www.usbr.gov/waterconservation/docs/SmartController.pdf**

Notes

Chapter Six

Environmental Sensors

Climate sensors are devices that interact with one or more aspects of local weather patterns. Simple weather sensors are easy to install on almost any system with very little cost. They can help save money by inhibiting irrigation when certain weather conditions are present.

Sensors can be individual devices, designed to record or interact with just one weather factor, or sensors can be "clustered" into a single device that monitors and interacts with multiple weather features. The following is a rudimentary list of differing types of sensors and how they work.

Rain Sensors

Rain sensors have been around for decades and are more in demand every year. The purpose of the sensor is to record any natural precipitation that has occurred and relay this information back to an irrigation control device of some type. The rain sensor interrupts the normal irrigation cycle from happening, by creating an "Open" in the wiring of the irrigation system. The controller program still cycles through its normal operation, as if everything is working but no valves open due to the "open" circuit. Rain sensors do not interact with a controller nor can they adjust irrigation programs. They are simply a switch which allows the system to function or not. They basically are designed to limit over watering during a natural rainfall. Water agencies implementing water use efficiency programs have begun to require these devices to be installed in all new residential projects.

Figure 6-1
Rain Sensor

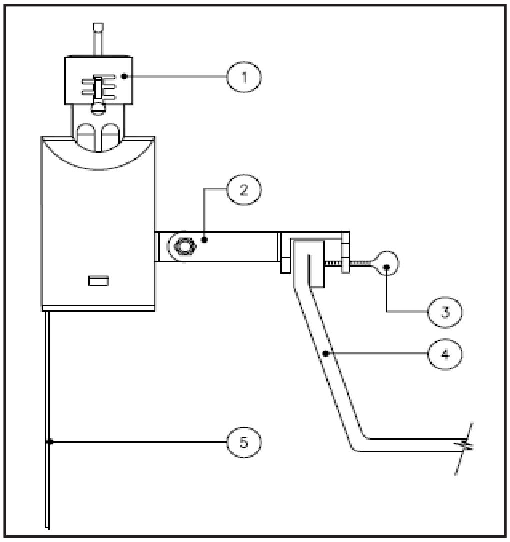


Figure 6-2

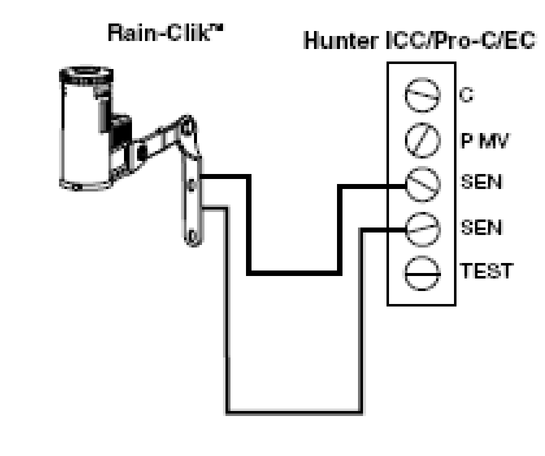


Figure 2

Figure 6-3

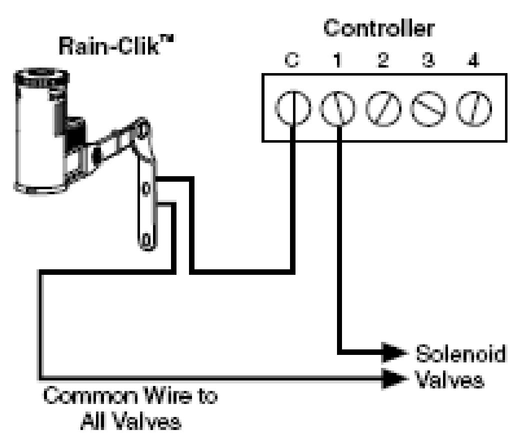


Figure 3

There are a few different types. Rain cups, which collect rain in a "cup" type container and an electrode measures amount of water in the cup. Disc type rain sensors are more common and are very simple in design. As rain falls it is collected in a small chamber where absorbing cells or discs swell from the moisture. As the discs swell they come in contact with a switch that opens a switch at a certain point. This point is calculated to be at a certain distance equal to the amount of rainfall. Normally they can be adjusted from 1/8th'-1" (see figure 6-1) by turning the top and sliding it upward. Either type is basically opening a contact switch.

When wiring rain sensors, it is best to use the terminal post provided by the manufacturer whenever possible (figure 6-2). However, if no specific sensor contacts are available on the terminal strip inside the controller, removing the field common wire from the terminal and using a wire nut to connect one wire from the sensor and the second will be connected to the valve common terminal screw (figure 6-3) .

Figure 6-4
Proper installation of rain sensors

When installing rain sensors, placement of the rain collector is important. The location should be free of any obstruction by roofline, eaves, or trees now and after a few years of growth. Locating the sensor is the most simple and yet critical factor that will determine the effectiveness of a rain sensor. Sensors do not work well when placed adjacent to or under deciduous trees (one wet leaf laying over the top of the sensor can throw it off). Rain sensors do not work well when placed under the eaves of a house or when the sprinklers hit them!

Freeze sensors are used to prevent the irrigation system from working in the event of a freezing condition in the landscape. These sensors work in the same manner as a rain sensor, in that they interrupt the normal operation of the controller by creating an "open" circuit. Freeze sensors are useful in northern climates to prevent systems from running in a freeze condition. They are also useful for preventing ice formations caused by the irrigation system, which can be very destructive to plant materials in a landscape as well as causing ice sheets to build on flat surfaces. These ice sheets create significant liability concerns, especially at night and in the dark.

Wind sensors

Wind sensors are similar to rain and freeze sensors in terms of how they work; they prevent the system from working when winds at the sensor reach a certain point. The Irrigation Association recommends that irrigation systems not be utilized when winds exceed 5 mph. Beyond this limit, the amount of sprinkler pattern distortion is so great that most water applied will not be utilized by plant materials but will instead be leached away or runoff. Wind conditions quickly change and are difficult to predict, so a sensor is an invaluable aid in areas prone to high wind. Wind sensors are often used in conjunction with water features like fountains to limit water losses due to high winds.

Some of these sensors are bundled together into "weather sensors" or "weather stations". A bundled weather station sports a combination of sensors, designed to interrupt an irrigation cycle if any one of the weather features exceeds a preset limit. These sensors typically only interrupt the irrigation wiring and prevent the system from running – they do not adjust the system runtimes according to the weather.

Overview of Need for Soil Moisture Sensors

It has been said that two thirds of the world is water, and of all the water world wide, about 3% is available for usable consumption. With this in mind, 90% of this water is used for agriculture, leaving very little for residential and most commercial use. From past surveys, it has been determined that landscapes with automatic sprinkler are over-watered about 30-40% during the growing season. In contrast, those who still pull a hose around tend to over-water about 10%. For many years the "hose draggers" were perceived to be water "wasters". They would let water run on paved surfaces or for too long of a time and we would see water running in the gutters. However, with a new awareness of using water wisely, plus the increased cost of water and because so many people now have automatic sprinkler systems, the abuses of the past by "hose draggers" are not seen as frequently. They tend to water only when the lawn needs it, which is usually determined by visual observation.

Using soil moisture control products for adjusting irrigation systems is not new. Agriculture has been using soil moisture sensors in irrigation dating back to the early '50's. Automatic sprinkler systems have the potential to save water if they are well designed, installed and maintained. People choose automatic sprinkler systems to avoid being bothered with the chore of lawn watering, but people tend to "set them and forget them". This method of watering accomplishes the task of keeping the lawn green, but over the growing season uses significantly more water than the grass requires. They will, on occasion, increase run times during hot summer months, and leave this added run time all the remainder of the year. Another observation is that many people with automatic sprinkler systems have broken pipes, broken or missing sprinkler heads or sprinkler heads that are not correctly aligned. All of these problems contribute to water waste and are not often fixed because they are unnoticed when the lawn is being watered at night while they sleep.

Considerable amounts of time and effort have been invested to encourage people to be better water managers. But in reality it is a difficult and challenging task. Most urban dwellers have very little knowledge of plant materials and managing soils and water. Currently all irrigation controllers (timers) are programmed using minutes per watering zone, but lawn watering information made available to the public is given in inches of water. The great challenge for municipalities is teaching people how to make inches of water equal minutes of run time. And just to make it more complicated, the amount of water a lawn will need is always changing and every sprinkler system applies water at a different rate.

So there needs to be a better way for controlling sprinkler systems to conserve water and pulling a hose around the yard is not the solution that people will accept. They want a sprinkler system that is "set it and forget it", will manage water correctly and keep the lawn green. A couple of possible solutions include changing how controllers function and are programmed or using soil moisture sensors to help manage the sprinkler system. New types of "interactive" controllers are being developed and brought to market but are not yet widely available. These controllers truly rely on multiple soil moisture sensors to adjust and "fine tune" the management of the irrigation system – automatically. Traditionally, soil moisture sensors would just shut down a system when soil moisture levels reached a preset limit. New soil moisture controllers are being developed which interact with soil moisture sensors to provide superior control of irrigation water. And almost all soil moisture sensors can be hooked up to existing controllers to control and limit over watering. Finding the right sensor, learning what it will and won't do and gaining confidence in its ability to control the sprinkler system is a challenge. This section will look at different soil moisture sensors and control products to aid in this exploration.

Soil Moisture Sensor Technology

The basic concept of a soil moisture sensor system is to place a sensor in a representative part of the lawn and allowing the sensor to "sense" if there is sufficient moisture in the soil for the grass. If there is sufficient moisture, then the sensor will prevent the sprinkler system from activating and applying water. However, if it senses that the soil is dry, it allows irrigation to take place. The following information is to help explain in simple terms, the different types of soil moisture sensors that are available and how they work. Also included is a short summary report of a comparative demonstration of soil moisture sensors controlling irrigation for turfgrass.

Figure 6-5
Tensiometer

Tensiometers measure the soil moisture tension or suction. This device is a plastic tube with a porous ceramic tip attached at one end and a vacuum gauge on the other end. The porous ceramic tip is installed into the soil at the depth where the majority of the active root system is located. The vacuum gauge measures the soil moisture tension or suction. It measures how much effort the roots must put forth to extract water from the soil and is measured in centibars. The higher the reading, the less moisture that is available and the harder roots must work to extract water. A lower reading indicates more available water. A tensiometer can be used to take manual readings or a special model can be installed to provide the capability for the tensiometer to be wired into the sprinkler system to provide control. The tensiometer needs routine maintenance to make sure enough liquid is in the tensiometer and that it hasn't broken tension because the soil has separated away from the ceramic tip. In climates where the ground freezes, tensiometers must be removed and stored for the winter months and reinstalled the following year.

Figure 6-6
Electrical resistance block

Electrical resistance blocks measure soil moisture tension with two electrodes embedded in a porous material such as gypsum or a sand-ceramic mixture. The block allows moisture to move in and out of it as the soil dries or becomes moist. The electrodes measure the resistance to electric current when electrical energy is applied. The more moisture in the block, the lower the resistance reading, which indicates that more moisture or water is available to the plant. The blocks use gypsum or similar material to be a buffer against salts (such as fertilizer) that would also affect resistance readings. The sensors using a granular matrix seem to work well and last for a longer time when compared to gypsum blocks.

Figure 6-7
Electrical conductivity probe

Electrical conductivity probes measure soil moisture in the soil by how well an electrical current is passed between two probes. In many ways the concept is similar to resistance blocks but the probes (electrodes) have direct contact with the soil and are not buffered as in resistance blocks. The more moisture in the soil, the better the conductivity or the lower the electrical resistance. This method is very sensitive to the spacing of the probes, soil temperature, as well as being influenced by soil type and salts that come primarily in the form of fertilizers.

Heat dissipation sensors measure soil moisture by measuring how much heat is dissipated in a ceramic medium. The heat dissipated is directly proportional to the amount of water contained within the ceramic's void spaces. The more water that is contained in the ceramic, the more heat is dissipated and the lower the sensor readings. This corresponds to a higher soil matric potential or in other words, more available water for the plant. The sensor works when water moves in or out of the ceramic due to capillary forces in the soil. The manufacturers claim this type of sensor is independent of soil type or salinity influences.

Dielectric sensors have been developed that will calculate the soil moisture content by measuring the dielectric constant of the soil. A dielectric is a material that does not readily conduct electricity. Dielectric sensors use two different methods to measure soil moisture without measuring electrical conductivity. **Capacitance** sensors use frequency-domain-reflectometry and **TDR** sensors use time-domain-reflectometry. Dielectric sensors are generally expensive and are used more in scientific research than to actually control a lawn sprinkler system. They are very accurate and are often portable devices that can be taken into the field to "spot check" soil moisture levels.

Capacitance sensors contain two electrodes separated by a dielectric. The electrodes are inserted into the soil or in an access tube in the soil and the soil becomes part of the dielectric. A very high oscillating frequency is applied to the electrodes, which results in a resonant frequency, the value of which depends upon the dielectric constant of the soil. The moisture content of the soil will change the dielectric constant of the soil; therefore more moisture in the soil will change the frequency. This change is converted into a soil moisture measurement.

Figure 6-8
TDR sensor and portable hand held unit.

TDR measures the time required for an electromagnetic pulse to travel a finite distance along a wave guide (steel rods or length of wire) and is dependent upon the dielectric properties of the material surrounding (the soil) the wave guide. As moisture increases in the soil, the time taken for the pulses to travel slows down. The signal is then converted into a soil moisture measurement. This technology is very complex and quite expensive, but seems to provide high accuracy.

The sensor shown on the left is an example of a TDR sensor and is a portable hand held unit, popular in the golf industry for measuring soil moisture levels on different sand based golf greens.

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Figure 6-9
A permanently fixed TDR sensor

A very different TDR sensor is the sensor shown below, which is a permanently fixed sensor, buried in the ground and wired back into a controller. This sensor is more commonly used in conjunction with irrigation controllers to assess soil moisture and to affect irrigation controllers

Figure 6-10
Neutron Probe

The ***Neutron Probe*** has been around for many years and works by sending out neutrons from a probe (the radioactive source) that is lowered down a tube in preset increments. Neutrons emitted by the probe enter the soil and are thermalized by the hydrogen present in water. These thermalized neutrons enter a helium-3 detector and are registered as a count. As the instrument takes readings of how the neutrons are moving, a calibration is made that converts the neutron count into soil moisture content. The neutron probe needs to be calibrated for each type of soil but it has proven to be very reliable and accurate and is usually the benchmark by which other instruments are compared. However, it is not useful for controlling an irrigation system. It uses radioactive materials that many people don't want to be around and the required paper work to keep licensed etc. is almost overwhelming and very costly. Again this type of sensor, while extremely accurate, is not meant to directly control an irrigation system, but rather provide the manager with information upon which water management decisions can be made.

Locating the Sensors

Install in representative area for the zone.

This means you select an "average" location – not too wet (like a low spot) and not too dry (like a top of a berm or a south facing incline). Somewhere out in the open (not shaded or affected by trees) that is relatively flat and covered with healthy turfgrass. The sensor should be in the middle of the sprinkler pattern. Usually the sprinkler zone with the soil moisture sensor will need to be wired into the controller as the last sprinkler zone.

Figure 6-11

There is no good location for soil moisture sensor within this zone.

Figure 6-12

Avoid installing sensors in high spots (too dry) and low spots (too wet).

Avoid high-traffic areas

Figure 6-13
An example of a high traffic area.

High traffic areas will have abnormal compaction levels which may not be representative or normal soil conditions. Compacted soils have lower water infiltration rates and poor soil percolation rates. These will throw off the feedback from the sensors.

Avoid large rocks and tree roots

Rocks and tree roots will affect water movement rates in the soil. Rocks can create dry spots by funneling or altering water flow through the soil profile. Similarly, tree roots will dry out soils far more quickly then open turf covered soils. Aggressive tree roots can also lead to damage to either the sensor or its wire connections.

Install a sensor in healthy turf

If you were to install the sensor in a damaged or unhealthy turf area, you would not get accurate results. Thinned out turf or dead turf will have higher evaporative water losses than healthy turf, giving an inflated reading for dryness

Installing Soil Moisture Sensors

Carefully remove a 2-foot square turf plug

For the sensor to work the best, the soil around the sensor needs to be representative of the soil for the whole site. After an installation hole is dug, some sensors can be easily installed **into undisturbed soil**. This is the best because achieving the same bulk density of disturbed soil may take weeks or months of time. Otherwise the sensor will be placed in a situation where the disturbed soil will be replaced into the hole and tamped or compacted or watered in a way that will make it different than the surrounding soil. This difference will affect how well the sensor is sensing the soil moisture that is supposed to be representative.

You typically will need a relatively undisturbed solid chunk of grass removed to install the sensor into an established turf area. Less than 2′ square may not be big enough, depending on the type of sensor you are installing. Bigger than a 2′ square just becomes too heavy and will require multiple chunks of sod to be removed; this will disturb the soil in the sensor area.

Figure 6-14
Installing the sensor

Install sensor within the turfgrass root zone

This would be approximately 4″ - 6″ deep for cool season turfgrass (bluegrass, ryegrass & fescues) and 8″-10″ for warm season turfgrass (Bermuda grass, zoysiagrass & buffalo grass). There should be roots both above and below the sensor. On new installations, you will be installing the sensors where the root mass eventually will grow into. It is important that the sensors be located, as much as possible, in undisturbed ground.

Figure 6-15
Replacing the turf plug.

Replace turf plug and re-compact soil around rods to original compaction levels

Again, the sensors accuracy will be tied to the amount of disturbed soil around it. By keeping the removed sod as one piece, there is minimal disruption. Gently tamping the sod back into place on top of the sensor helps in settling the soil around the sensor. Additional loose soil can be added around edges to fill any air spaces and to assist with re-firming the removed plug.

Wiring the Sensors

The nature of how soil moisture sensors are to be wired will be determined by the purpose and function of the sensor. If the sensor is to be wired strictly to interrupt the irrigation controller from performing an irrigation event throughout the whole system, then a single sensor is usually wired back to the controller. But newer controllers may allow for more than one sensor and for more control within the system, e.g. one sensor per zone valve to give individual zone control.

Single Sensor systems

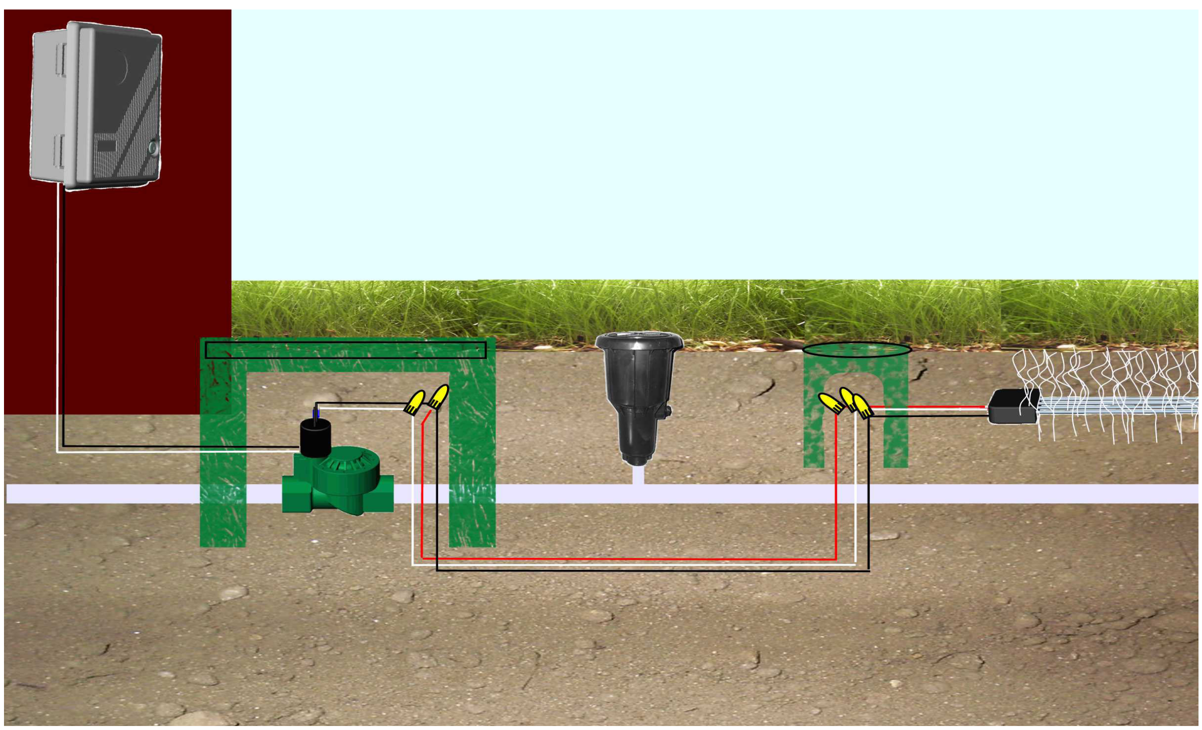
Many older conventional controllers can be retrofitted with a single soil moisture sensor to prevent over-watering. For a single sensor which is used to control the whole system, it is common to see a soil moisture sensor be wired directly back to the controller. This will require the installation of new wires from the controller to the sensor location. This effort may take substantial time and expense to achieve but this will be necessary if only one sensor will be used for the entire sprinkler system. Many times the cost of installing the additional wires will be more than the sensor and its controls.

Multiple sensor systems

When a new sprinkler system is being installed, run additional wires from the field to the controller. Ideally it would be best to have a common wire for each hydrozone type, thereby controlling the irrigation for different planting zones independently while using the same controller. This will allow multiple sensors to be used, one for each program for example. The cost of doing this is minimal and allows flexibility for the future. Usually five correctly sized wires will be sufficient for even the more complicated sensors.

Another option would be to place a sensor and its control at each zone in the system. This is a good alternative when valves are spaced far apart and each sensor is only for a particular zone. Installation is easier, but costs increase because of the total number of sensors being used.

Figure 6-16
A multiple sensor system



Fortunately, in the last few years, many soil moisture-sensing systems have come onto the market that will allow the usage of the existing valve wires to also connect to the sensor. This will work well where running wires a short distance from the probe to a nearby valve box. Usually a different frequency is sent down the wire for the sensor which is different than that used to operate electric valve solenoids. The signal gets back to the moisture sensor controller and an irrigation decision is made before the valve can be actuated. These types of sensing systems will work extremely well in a retrofit situation on an existing landscape. The sensors typically are installed or wired to interrupt the common wire going to each of the valves of the system to preempt irrigation.

Minimize the distance from the controller to the sensors.

There are limits to how far a sensor can be from a controller. Distance from the controller to any soil moisture sensor should be less than 5000' as a general rule. The greater the distance, the greater potential for problems to occur, plus the greater the cost for wiring. The sensor wire connections and sensor locations should be clearly noted on all "as-built" irrigation plans for future reference.

Install sensor wiring below any possible turfgrass cultivation levels.

Check to ensure that wires from controllers to the sensors are buried below regular aeration depths for the turf. For instance, if deep time aeration equipment is used, wires should be below 12" depth. If shallow tined aerators are used, a 6" to 8" depth is sufficient.

Connect wires in a nearby valve box

The wire connections should always be installed in a valve box to assist with long-term maintenance. This allows for easy access and less digging down the road to test the sensors or to replace them. For multiple sensor systems, select a test area in close proximity to valve control boxes. Ensure that good quality waterproof connectors suitable for underground use are utilized.
If more wire is needed than supplied by the manufacturer, make sure it is approved for underground burial.

Sensor Features

Listed below are some important features when selecting a soil moisture sensor to control the sprinkler system:

- **Adjustable Moisture Level** the operator can set the sensitivity of how much moisture should be in the soil to meet the minimum needs of the grass.

- **Indicator Light** allows the operator to set the moisture level and receive immediate feedback from the sensor when current moisture level has been sensed. On some models the light comes on when water is needed and in other models the light remains on as long as there is adequate moisture.

- **Override position** will allow irrigation to take place even if the sensor would indicate that the soil is moist enough. This feature is useful when the site has just been fertilized or the system is being checked for correct operation

- **Sensor wire** should be UL approved for direct bury in the soil. Use waterproof connectors. Bury the wires deep enough that they won't be damaged by equipment used to manage turf such as aerators.

- **Special tools** when available will make sensor installation into undisturbed soil easier and the sensor can take over control of the sprinkler system more quickly. Some sensors can only be placed in a hole where the soil has been disturbed. Take care to compact the soil around the sensor to have the same bulk density of the undisturbed soil.

- **Track record** is important as well as service from the distributor after the sale. Choosing the soil moisture sensor system that will work best for your situation is perhaps the biggest challenge. There have been many companies come and go over the years, so finding one that has been around for a while and appears to be stable will give you some confidence that their sensor and system must be working.

Programming

After the soil moisture sensor has been properly placed and installed, a new approach to programming the controller will be required. Depending upon local ordinances or requirements there are several ways to approach programming.

- **Daily watering** is programmed by selecting each day of the week for watering to occur. However the total run time should be split up among several start times. For example twenty minutes a day could be programmed to be four start times for five minutes each. That way if the sensor sensed that the soil was dry enough for irrigation to occur, then it would allow five minutes of watering to happen. Then, when the next cycle should begin, if it sensed that it received adequate moisture from the first cycle, it would preempt the next three cycles from occurring. Schedule at least one hour of time between cycle starts so that the water can soak down towards the sensor. With this method, the watering should only occur when the sensor feels dry.

- **Programmed days** uses the same approach as above, but irrigation can take place only on selected days. This method accommodates mowing schedules or restrictions that allow watering only on certain days or during certain hours. Again using multiple cycle starts will maximize the benefit of using soil moisture sensors by only applying the amount of water that the soil can hold to meet the needs of the grass.

- **Set Point** is established for the appropriate or desired amount of moisture in the soil to keep the plants healthy. Usually this point is near field capacity. The soil moisture sensor monitors the amount of water in the soil in relation to the set point and makes a decision to allow or not the scheduled irrigation event. Having an understanding of soil types and corresponding soil water properties are useful in properly programming the system.

Optimizing

"Optimizing", describes the actions of observing and adjusting the controls to maximize the benefit of a soil moisture sensor system. This requires careful observation of how well the grass is doing as a whole and of the specific area where the sensor is located. After a period of time it might be determined that the sensor location is not as representative of the site as first thought. If the site overall looks dry, then either the other zones need additional run time for more water, or the sensor zone needs less run time. Balancing the run times for the various zones to be compatible with the sensor zone takes time and patience.

Once the sprinkler zones are balanced with the sensor zone, then further adjustment can be made to many of the systems. Most systems will have some type of control system that interfaces with the irrigation controller. This allows adjustment of the sensor sensitivity. If it is set for too wet then the sensor will allow more irrigation to take place than what the grass requires. If it is set for too dry, then the grass will become stressed. When this happens most people begin to lose confidence in the sensor, thinking that it is not working correctly. The sensitivity needs adjustment and a period of time to determine if it is set properly. Some sensors don't have a sensitivity adjustment and then the only option is to dig it up and change its location in the root zone to better meet the needs of the grass.

Acceptance of the sensor-controlled irrigation system comes as the owner of the property is satisfied by the overall appearance of the turfgrass. When the owner is happy, then the sensor is doing its job. For most people, the sensor will allow less irrigation than what the owner would do on his own. But that is the goal of sensor-based irrigation – to apply the right amount of water at the right time.

As a follow-up to see if the sensor is truly doing the job it is intended to do, there needs to be a way to measure how much water is being applied compared to what should be applied or has been in the past. Using past water records for similar periods of previous years will show if water is being conserved and money is being saved. If current ET information is available, then knowing how much water should be applied in inches or gallons can be compared to current meter readings or site catchments. Without measuring and comparing, then there is no way to know if the soil moisture sensor system is working correctly and saving water.

The above information is to help explain briefly and in very simple terms the types of technologies that can be used to measure soil moisture and control irrigation. This area is changing rapidly as advances in the technology are improving and becoming much more affordable.

Less expensive systems measure soil moisture using conductivity or resistivity of the soil as an electrical current moves between probes in contact with the soil. The more moisture there is the electrons can move easily and when it dries out then it becomes more difficult. These systems can be installed in line with the common wire if you are using one sensor to control the whole site or they can be installed on an individual zone control valve.
Systems that use AC voltage usually will have probes that last longer in the ground than systems using DC voltage. Many of the new systems use the existing valve wires also as the wires for the probes and will have an interface controller between the actual clock and the probe in the field. This has reduced the wiring during installation, meaning only a short length of wire needs to be installed from the probe to the nearest valve box, instead of back to the controller location. This is important on retrofit projects and is less of an issue on a new project where it is relatively easy to install extra wires.
These soil moisture-sensing systems only measure relative soil moisture; you do not have any actual values. You may have a dial to change the sensitivity of the probe to soil moisture so that the soil can be maintained wetter or drier to suit the plants but requires the landscape manager to make that change.
To achieve the best results with these controllers, create a schedule based upon the precipitation rate of the sprinklers so that each area will get an equal amount of water, and then divide the run times into four different cycles. If there is sufficient moisture after two cycles, then the sensor will eliminate the remaining two cycles and you will have just saved half of the water you were planning on applying. However, if the soil is still dry, it will allow irrigation to continue. This takes advantage of the cycle and soak

concept that is useful for deep irrigation. When possible make every day a potential irrigation day, but if designated watering days are required, this technique will work as well.

More sophisticated systems use more advanced technology for measuring soil moisture. These new systems can actually measure the volumetric amount of water in the soil, usually expressed as a percentage, and allows the landscape manager to set specific amounts of water that the soil should be maintained at for the plants to be happy. These new systems can be add-on units for existing controllers, or available as a controller, and can have multiple sensors attached to track the moisture in different hydrozones.

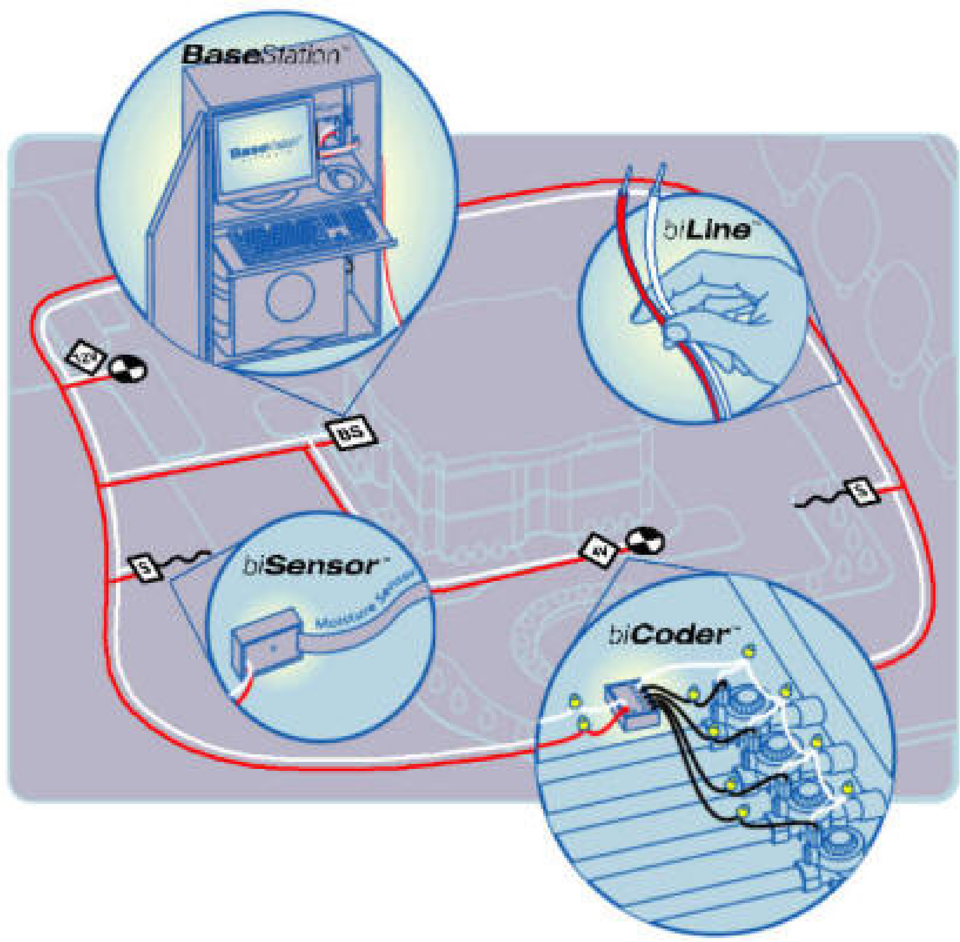


Figure 6-17
An example of a complete sensor system.

The systems have the ability to track the soil moisture over a period of time, creating a powerful management tool. Be sure to use cycle and soak with these types of soil moisture sensing system. Another advantage of soil moisture sensing systems is you don't need a rain shut-off device, because if the soil is wet from rainfall then irrigation will not take place.

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