Drip Irrigation systems in vertical and green roof gardens

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Drip irrigation is an ideal solution for irregular or small areas. Inline and in situ drip irrigation limits the potential for liability by reducing or eliminating overspray on buildings, walkways, roadways, and other trafficked areas. Maintenance costs are often lower due to reduced overspray, runoff, erosion, compaction, water staining, and property damage. With no exposed emission equipment to get vandalized, stolen, damaged, misaligned, or worn out, material costs over the life of a project are substantially lower. A fertilizer injection (fertigation) system—for chemical or organic products—can be easily introduced to inline drip systems and distributed directly to plant root zones. This avoids human and animal contact and provides a more even distribution of material, minimizing material cost. Where water supply or irrigation scheduling is problematic, subsurface irrigation may be used to extend the watering window. Irrigation can be scheduled anytime, even during active use, without worry about increased evaporation during the day. Extending the watering window may allow lower flows, resulting in significant savings through reduced connection fees and materials costs.

Drip irrigation components include: control, valve, ET-Sensor, Filter, Zone control kits, Inline Drip Tubing, Pressure regulator, Laterals, Barbed fittings, Air/Vacuum Relief (AVR) Valve, Supply header, Exhaust header, Flush Valves and PLD Cap, etc. The paper gives a detailed account of various Drip Irrigation systems that are commercially and successfully used in Vertical gardens and Green roof gardens in different parts of the world.

Key words: Drip Irrigation, Vertical Gardens, Green Roofs, ET-Sensor, fertilizer injection.

INTRODUCTION

Drip irrigation can be traced back to the early Roman aqueduct period, when broken clay pipe distributed water along rows of plants. It was not until the formation of modern Israel, however, that the concept of placing a small amount of water only at the root zones when needed, and at an exact rate, began to be developed commercially. The Israelis were faced with an inadequate water supply, often of a saline nature, and a lack of prime agricultural land. They laid out lines of perforated polyethylene tubing. These early systems exposed many problems: plants close to the source received too much water, while plants at the end of the line wilted; the discharge orifices clogged easily; and elevation changes only complicated the obvious need for hydraulic engineering. Widely used in irrigated farming, the drip method is an important irrigation technique which, while conserving valuable resources -- water, land, labor, energy, and fertilizers -- promotes improved plant growth and productivity. Larger yields, better crops, and earlier production are important benefits to the grower whose livelihood depends on his irrigation system. The objective of drip irrigation is to continually provide even moisture only to the plant's root zone. Overhead sprinklers saturate entire areas followed by a drying out period. They are designed for lawns that need only shallow watering. Slow applications over long periods of time are required to get the deep water penetration required for deep-rooted vegetation.

Hundreds of thousands of acres of money-producing crops are now being irrigated exclusively with drip irrigation. Agricultural drip irrigation systems now have close to a forty year history since the early experiments
began in Israel. Now with the experience gained through agricultural use, it is now possible for homeowners to better irrigate trees, shrubs, flower and vegetable gardens, ground cover, potted and hanging plants. Drip irrigation is now found in an increasing number of homes, highway and street median strips, and freeway landscaping, to mention just a few. The use of drip irrigation has dramatically increased as the public has been faced with rising water costs and scarcity of water. Drip irrigation now provides homeowners with an exciting plant watering concept that not only conserves water, but also accelerates plant growth. Drip irrigation is very adaptable and is successfully used in a wide variety of climates, soil types, plants, and growing methods. Utilizing a drip irrigation system involves the installation of a permanent plant watering system that enables the homeowner to place water where it is wanted, and in the exact amount that is necessary for optimum plant growth.

Drip irrigation is a method of applying slow, steady, and precise amounts of water and nutrients to specific areas of trees, vines, ground covers, potted plants, or shrubs (Figure 1). At a slow application rate, water seeps into the soil and moves laterally by capillary action beneath the soil’s surface. An adequate section of the root zone of the plant is maintained with moisture close to soil capacity, providing a soil-to-water-to-plant relationship which is conductive to better plant growth. Thus, smaller quantities of water are used to the utmost efficiency. The Drip irrigation system is designed to minimize water consumption. It consists of automation-unit with equipment for control of nutrient injection and irrigation cycles. When a surface has a variation of sun exposures, the irrigation is divided into segments in order to program it specifically for each part. Within the multi-layered felt surface a drip-tube is integrated.

Drip irrigation systems range in size from a few plants to several thousand acres, and permits the cultivation of slopes previously thought unusable and land left idle. In fact, the more difficult the installation, the greater will be the advantages of drip irrigation. Of all the irrigation methods, drip irrigation is the most efficient. Sprinklers shoot water into the air, where much of the water is lost to evaporation and never reaches the plant.

Flood irrigation transports the water in open trenches to the soil where the planting gets about half of the water supplied. Sprinklers are more efficient than flood irrigation, with only about one fourth of the water lost, but drip irrigation results in losses of less than 10 percent of the supply.

With the water supply getting lower and lower throughout the country and the world, the conservation of this precious commodity by drip irrigation may eventually be the difference between adequate food and famine, or green yards and dirt. In short, drip irrigation is the slow and precise delivery of water to chosen plantings. This is achieved by the use of flexible polyethylene tubing or PVC pipe with devices for dripping water (emitters) and low-volume sprays, drip tape, Laser Soaker Line, or Porous Pipe systems.

The systems are easy to install, requiring no trenching and only shears for cutting polyethylene hose or tubing, and PVC pipe cutters for cutting PVC pipe. A hole punch is required for installing an emitter into the polyethylene hose. Drip irrigation can maintain near perfect moisture levels in the root zone of the plants, avoiding the too wet/too dry swings typical of overhead watering. Drip irrigation systems can be controlled manually or by the use of an automatic timer in conjunction with a tensiometer, and can be used to apply fertilizers directly to the roots of plants.

**DRIP IRRIGATION SYSTEM**

Drip, or micro-irrigation, technology uses a network of plastic pipes to carry a low flow of water under low pressure to plants. Water is applied much more slowly than with sprinkler irrigation. Drip irrigation exceeds 90 percent efficiency whereas sprinkler systems are 50 to 70 percent efficient. It is so efficient that many water utilities exempt landscapes irrigated with drip from restrictions during drought. Note that any irrigation system is only as efficient as the watering schedule used. If systems are set to water excessively, any system including drip can waste water. Low volume application of water to plant roots maintains a desirable balance of air and water in the soil.

Plants grow better with this favorable air-water balance and even soil moisture. Water is applied frequently at low flow rates with the goal of applying only the water plants need. Sprinkler irrigation results in a greater wet-to-dry fluctuation in the soil and may not produce optimal growth results. Micro-irrigation systems are more widely available and better designed for use in home gardens than ever before. Traditionally used for growing commercial vegetables, orchards, windbreaks, greenhouse and nursery plants, micro-irrigation systems are well-adapted for home use. Use them in landscapes, vegetable and flower gardens and for small fruits. They are well-suited to irrigate container plants as well. When combined with a controller, drip irrigation systems can be managed with ease. Micro-irrigation is ideal for berm plantings. Slopes are inefficient to irrigate because gravity pulls water downhill, causing runoff and water waste.

The slow rate of water applied through drip irrigation is more likely to soak in before it runs off. Quick Facts about Drip Irrigation System are:

- People interested in water wise gardening should consider drip irrigation.
- Odd-shaped and narrow areas are easily irrigated with drip systems.
- Drip irrigation stretches water supplies and may be exempt from water restrictions imposed during drought.
Drip irrigation equipment is readily available and can easily be installed by do-it-yourself. Common setup mistakes include not installing a filter or pressure reducer, use of overly long lengths of mainline and adding too many drip emitters. Drip systems can be easily changed over time as plants grow and needs change. Use goof plugs to plug holes in mainline that are no longer needed.

DRIP IRRIGATION SYSTEM DESCRIPTION

Placing Emitters

Drip irrigation emitters must be placed so that water reaches the roots of plants (http://extension.colostate.edu/docs/pubs/garden/04702.pdf). Roots will grow where conditions are favorable, primarily where there is the right balance of water and air in the soil. Design the drip system around the irrigation needs of the plant.

For new plantings, make sure emitters are placed over the root ball. Initial placement on perennials is often permanent unlike trees and shrubs that require emitters to be moved away from the trunk and others added as plants grow. Generally, larger plants have larger and more extensive root systems. A greater number of emitters are needed with larger plants and higher water using plants.

Fewer emitters of lower flow are needed with lower water-using plants or plants that will receive only occasional water following establishment. Drip emitter placement is also related to whether the soil is sand or clay. To compensate for variations in lateral movement of water in the soil, locate emitters 12 inches apart in sand, 18 inches apart in loam, and 24 inches apart in clay. If one to two emitters are recommended for a plant in a clay soil, two or three may be required in a sandy soil to wet a sufficiently wide soil area (http://extension.colostate.edu/docs/pubs/garden/04702.pdf).

Devices

There are two types of emitters: pressure sensitive and pressure compensating. Pressure sensitive emitters deliver a higher flow at higher water pressures. Pressure compensating emitters provide the same flow over a wide pressure range. More products made in recent years are pressure compensating. Turbulent flow and diaphragm emitters are non-plugging. Emitters can be attached into the mainline or placed on the ends of quarter inch micro-tubes. Because emitters are generally color-coded by flow rates, purchase all emitters from one manufacturer because color codes differ among manufacturers.

Emitter Tubing is useful for closely spaced plants. Turbulent flow emitters are manufactured into the mainline at pre-set spacings. Spacings in quarter inch tubing are typically 6, 12 or 24 inches. A wider range of spacings are available in half inch tubing, including 9, 12, 18, 24, 36 or 48 inches. The in-line emitters are self-flushing and clog resistant as long as system water filtration with 200 meshes filters is used. Emitter tubing irrigates evenly over its entire length. Laser tubing and soaker hoses have holes in tubes but do not contain emitter devices for precise metering of water; the amount of water released varies along their length making them less satisfactory for maintaining plants.

Bubblers are devices that emit higher flows of water in a circular pattern. They are useful for irrigating larger plants such as roses and shrubs, and for filling basins around newly planted trees or shrubs. Some can be adjusted for flows from 0 to 35 gph.

Micro-sprays emit large droplets or fine streams of water just above the ground. They are available with nozzles in full, half and quarter circle patterns that wet diameters varying from 18 inches to 12 feet. They should be placed on a separate zone from other drip devices because of their greater water use that can vary from 7 to 25 gph. Fewer micro-sprays can be placed on a zone.

![Figure 1: Drip Irrigation System of Vertical Garden.](Image)
than emitters due to their high flow rates. These devices are low pressure but share characteristics with high pressure sprinklers. Pop-up micro-sprayers are now available, eliminating a permanent irrigation riser in the garden. They are not as efficient as ground-applied water from drip emitters and care must be used to avoid overpressurization and misting. Misters and foggers are not recommended for landscape use.

**TYPICAL SYSTEM SETUP**

A drip system is easy to install for the do-it-yourselfer because the mainline does not need to be trenched into the ground as is the case in sprinkler installations. If tubing is not in the ground, the wire anchors holding the tubing in place may be forced out of the ground and require reinsertion. The point of connection to a water supply can be a pump from a well or pond, one valve among those in a high pressure sprinkler system, or a faucet (hose bib). It can even be a high pressure sprinkler head using a kit to convert it to drip. Keep in mind that other heads in that zone must be capped because sprinklers and drip cannot be mixed within the same zone. In permanent systems, the order of equipment is backflow prevention device, control valve, filter then pressure regulator. Valves are solenoid types generally automated with a controller. In add-on drip systems with a head assembly attached to an outside faucet or hose, a faucet valve Water quality is important for the proper operation of a drip system. Filtration to remove algae, sand and other materials is very important to drip systems. Elaborate filters and more frequent cleaning will be necessary with water from wells or ponds that may contain algae. In clay or loam soils, consider two 0.5 gph emitters at the base of a perennial flower to ensure watering if one fails. A 1 to 5 foot shrub and small tree less than 15 feet at maturity will initially require two, 1 gph emitters 12 inches from the base of the plant. Change to 2 and then 4 gph higher flow emitters if planting a larger sized tree and as the small tree grows. A 5 foot or larger shrub may require three 1gph emitters. A medium tree 15 to 25 feet may ultimately require four emitters two feet from the trunk. If planting a “whip”, it is possible to start with two 0.5 gph emitters and change to higher flow and more emitters as the tree grows. Begin with three, 2 gph emitters on a 1 inch caliper tree planting and three, 4 gph emitters on a 2 inch caliper tree at planting.

Trees larger than 25 feet at maturity may be impractical to irrigate with drip because of the extensive nature of tree root systems and mass of the trees. Increase the number of emitters and change them to 2 or 4 gph or larger flows as trees and shrubs grow. The valve is opened with a manual turn of a faucet handle or with a mechanical or battery operated timer attached to the faucet. The head assembly in this case would consist of a manifold of backflow preventer, filter and pressure regulator. A backflow prevention device is critical to preventing contamination of household potable water. Small antisiphon devices are available that screw onto a hose bib for add-on systems. Contact your government building department or water provider to find out what backflow prevention is required locally. A 150 to 200 mesh filter can be used for relatively clean municipal water. Filters with a higher mesh count have a greater screening capacity. Y or T filters are convenient because they don not require dismantling connections for cleaning as do in-line filters. A pressure regulator is essential for maintaining pressure that meets product manufacturer specifications. Take into account the pressure that will be needed for elevation changes. Add 5 psi to the operating pressure for every 10-foot rise in elevation above the point of connection to the water source. Pressure compensating emitters minimize low head drainage.

**DESIGN AND LAYOUT TIPS**

Use high quality components that will last for many years. A Y-connector is convenient on a drip system connected to a hose bib because a garden hose can be connected to the other side. Dedicate separate zones to drip irrigation. You cannot mix high-pressure sprinklers and drip on the same zone even if one sprinkler head is used with a conversion kit as a point of connection for the drip system. You can mix drip devices on the same zone to meet the needs of many different plants but don't mix micro-sprays with drip emitters. In this case, limit mainline to 200 feet in a single zone. Use ½ inch polyethylene mainline on small to medium properties where maximum flow per zone will not exceed 200 gph. On medium to large properties, choose ¾ inch tubing to increase maximum available flow rate to 480 gph per zone. If the source flow is less than mainline capacity, the source gallons determine the attachable components per zone. Add the flow rate of all emitters, emitter tubing and components used in a zone to make sure you have not exceeded the maximum flow for the zone. For example, fifty 2 gph emitters require 100 gallons of flow per hour (50 x 2 = 100 gph).

To evaluate source flow rate, run water full force from an outside faucet and note the number of seconds it takes to fill a bucket. Calculate the gallons of flow per hour (gph) by dividing the bucket size in gallons by the number of seconds required to fill it, and then multiply by 3600 seconds for gallons per hour. Bucket size (gallons) Seconds to fill x 3600 seconds per hour = flow in gph. The maximum flow is considered to be 75 percent of the flow rate. This is the largest number of gallons available for use at one time while operating a zone. Note that even though the source flow gallons may be higher than held by a ½ or ¾ inch mainline, the maximum line gallons limit the number of components per zone that can be attached to the mainline. Snake mainlines through the...
landscape to avoid straight runs and allow for expansion and contraction. Don not kink; use right angle connectors in tight corners. Use wire anchors every 3 feet to keep lines in place. Install mainline above weed fabric and under mulch to keep it out of sight and prevent a trip hazard. This will also minimize light exposure and maximize useful life. If source pressure is low, use drip components designed to operate at low pressures between 15 and 20 psi. Locate at least one drip emitter at the lowest point in the system or install a valve there so the lines can be drained for winter.

**Operating the System**

Systems are generally designed to operate for one hour of run time per week after plant establishment. Adjust emitter sizes and numbers accordingly. Watering twice per week may be required after planting on sandy soils or on plants requiring regularly moist soil. However, for native or xeric plants that does not grow well on regularly moist soils, operate the system weekly or every couple weeks on established plants and let soil dry out in between. Such plants include pinyon pine, Apache plume, Nepeta, Centranthus, most Penstemons, Artemesia and many types of Salvia. Irrigate Xeric perennials initially with 1 gallon per week. Extend the time between watering once established. Equip perennials and annuals using moderate amounts of water with emitters or emitter tubing to receive 2 gallons per week. A shrub the size of a plant growing in a 5 gallon nursery container should receive 4 to 6 gallons weekly. Add more emitters per plant for higher water using shrubs and reduce the emitter flow size for more xeric shrubs.

Large shrubs may require 10 to 12 gallons of water weekly. Monitor the soil moisture to check that you are not overwatering as too much water kills many newly planted plants.

Established trees may require up to 10 gallons weekly per inch of trunk diameter. For example, a tree with a 2-inch trunk diameter may require 15 to 20 gallons per week (2 in. diameter x 10 gals/diameter inch = 20 gallons). With a compact root ball at planting, amounts to water new trees are less than established trees with a wide-ranging root system. For a new-planted “whip,” 1 to 2 gallons per week are often sufficient. For a 1 inch caliper new-planted tree, 6 to 8 gallons weekly is an initial target amount. For a 2 inch caliper tree, consider 10 to 12 gallons weekly at planting. Use the above guidelines as a rough initial guide and then check the soil moisture at the rooting depth of the plant the following day. Adjust irrigation run times accordingly.

**Drip Irrigation Installation Steps**

It is highly recommended that the Vertical Garden/Green/Living Wall be watered automatically. One of hose-end timers (tap timer) is well suited for watering the system because it can be programmed down to minutes. This will allow you to work out the ideal maximum watering time that minimizes the amount of “waste” water from the system. With a little patience you will be able to program the precise amount of time required to keep the right amount of moisture in the pot mix. Regular watering will prevent the soil from drying out and will help to maintain vigorous plant growth.

Step 1: Begin the installation at the water source by attaching the 25 PSI (1.7 BAR) pressure regulator to the faucet (tap). If you decide to automate your system, first install one of Hose- end timers (tap timer) (not included), and connect the timer to the faucet. Insert the ¼” (6 mm) micro tubing into the ¼” (6 mm) compression side of the adapter by forcing the micro tubing in and wiggling it from side to side, and then thread it into the male side of the pressure regulator.

Step 2: Unroll the 1/4” (6 mm) micro tubing and lay it out to the location of the Green Wall mounting pots.

Step 3: The micro tubing serves as the primary line that runs water to all the pots. At the center of each pot, cut the 1/4” (6 mm) micro tubing and insert a 1/4” (6 mm) tee (soaking the micro tubing in hot water will ease installation). Connect a short 2” to 4” (5 to 10 cm) piece of micro tubing to the 1/4” (6 mm) tee. Leave the ends of the 1/4” (6 mm) micro tubing open, so you can flush the line before completion.

Step 4: Turn the water on, and flush the line for 10-20 seconds to clean out any debris inside the system.

Step 5: Insert a .3 GPH (1.1 l/h) PC drip emitter into the end of the micro tubing. Then insert one side of the 2’ (60 cm), 1/8” (3 mm) micro tubing into the dripper’s barbed side (color: gray).

Attach the stake to the end of micro tubing, and insert the stake into the pot near the crown of the plant. Repeat the steps for each pot and use the C clamp (included) to support the micro tubing where needed. Drip irrigation installation suggestions are as follows (Figure 2):

- If an automated system is preferred, install one of DIG’s hose end timers (tap timers). If installed, test the hose end timer (tap timer) and make sure that is working correctly.

The system can also start from a ½” sprinkler riser (see below). Drip Irrigation Installation Steps Drip Riser Installation If a sprinkler riser is used; begin your installation at the 1/2” riser that is closest to the area where the Vertical/Living Wall kit is located.

Remove the spray head or pop-up sprinkler from the 1/2” riser.

Connect the 1/2” adapter with the 1/4” (6 mm) barbed elbow to the riser.

Turn the water supply on and flush the line. After you flush the line, turn the water off and attach the sprinkler head to the adapter.

Connect the micro tubing into the adapter, barbed elbow, and lay it out to the vertical garden.
The irrigation kit is expandable up to 65 pots using \( \frac{3}{4} \)" (6 mm) micro tubing as the main line. If larger than 65 pots, the main line needs to be \( \frac{1}{2} \)" (16 or 17 mm). It is simple to add extra pots. Once you have the kit installed, use the same methods to add additional wall mounting brackets and pots, and expand the irrigation system.

The PC drip emitters discharge the same amount of water under a pressure range of 10 to 50 PSI (.68 - 3.5 BAR), allowing for higher uniformity and longer lateral runs within the vertical garden planting. This feature allows the number of drip emitters on a single line to be maximized while maintaining an even flow rate from each PC drip emitter along the line.

The .3-GPH (1.1 l/h) self-flushing PC drippers with built-in check valves, included in the kit, contain a silicon diaphragm that continuously adjusts to varying water pressures and, at the same time, allow particles to pass through the drip emitter's water passage providing reliable performance and a longer life. This method of flushing with a large flow path allows the drip emitter to operate at optimal flow rates under extreme conditions.

In addition, the pressure compensating drip emitters have a special water saving feature that eliminates water draining when the system is shut off at around 2.2 PSI (.15 bar). At this pressure the pressure compensating drip emitters shut off completely, preventing any water drainage from the lateral.

When the system is turned on again, the pressure compensating drip emitters simultaneously reopen at 4.3 to 4.5 PSI (.3 to .31 bar) for precise control of water flow over the length of the lateral.

When properly designed and managed, drip irrigation has many advantages over other irrigation methods, including: elimination of surface runoff, high uniformity of water distribution, high water usage efficiency, flexibility in fertilization, prevention of weed growth and plant disease.

Drip systems are also easily integrated in fertigation systems and automation. Traditionally, irrigation water is applied to the entire field, whether by sprinklers or by flood irrigation, resulting in a significant loss of water. Drip irrigation (or trickle irrigation) is a modern irrigation method in which water is delivered directly into the root zone of the plant.

This kind of system uses low pressure and low flow rates and water is applied only to specific zones in the field, where plants are grown. Typical drip emitter flow rates are 0.6 - 16 L/hr (0.16-4.0 gal/hr), and the most commonly used emitters are of 1-4 L/hr (http://www.smart-fertilizer.com/articles/drip-irrigation).

Advantages of Drip Irrigation

Reduced water use: Because drip irrigation brings the water to the plant root zone and does not wet the entire field, drip irrigation typically requires half to a quarter of the volume of water required by comparable overhead irrigation systems.

Joint management of irrigation and fertilization: Drip irrigation can improve the efficiency of both water and fertilizer. Precise application of nutrients is possible using drip irrigation. Hence, fertilizer costs and soluble nutrient losses may be reduced with drip irrigation. Nutrient
applications may also be better timed to meet plant needs. Reduced pest problems: Weed and disease problems may be reduced because drip irrigation does not wet the row middles or the foliage of the crops as does overhead irrigation.

Simplicity: Polyvinyl chloride (pvc) and polyethylene parts are widely available in several diameters and are easy to assemble. Many customized, easy-to-install connectors, end-caps, and couplers are available in different diameters. Cutting and gluing allows for timely repairs.

Low pumping needs: Drip systems require low operating pressure (20–25 psi at field entrance, 10–12 psi at the drip tape) compared to overhead systems (50–80 psi). Many existing small pumps and wells may be used to adequately irrigate small acreage using drip systems.

Automation: Drip-irrigation application may be simply managed and programmed with an AC- or battery-powered controller, thereby reducing labor cost.

Adaptation: Drip systems are adaptable to oddly shaped fields or those with uneven topography or soil texture, thereby eliminating the underutilized or non-cropped corners and maximizing the use of available land.

Production advantages: Combined with raised beds, polyethylene mulch, and transplants, drip irrigation enhances earliness and crop uniformity. Using polyethylene mulch also increases the cleanliness of harvested products and reduces the risk of contamination with soil-borne pathogens. Reflective mulches further help reduce the incidence of viral diseases by affecting insect vectors, such as thrips, whiteflies or aphids.

Disadvantages of Drip Irrigation

Drip irrigation requires an economic investment: Drip irrigation systems typically cost $500–$1,200 or more per acre. Part of the cost is a capital investment useful for several years, and another part is due to the annual cost of disposable parts. Growers new to drip irrigation should start with a relatively simple system on a small acreage before moving to a larger system.

Drip irrigation requires maintenance and high-quality water: Once emitters are clogged or the tape is damaged, the tape must be replaced. Water dripping from an emitter and the subsequent wetting pattern are hard to see, which makes it difficult to know if the system is working properly. Proper management of drip irrigation requires a learning period.

Water-application pattern must match planting pattern: If emitter spacing (too far apart) does not match the planting pattern, root development may be restricted and/or plants may die.

Safety: Drip tubing may be lifted by wind or may be displaced by animals unless the drip tape is covered with mulch, fastened with wire anchor pins, or lightly covered with soil.

Leak repair: Drip lines can be easily cut or damaged by other farming operations, such as tilling, transplanting, or manual weeding with a hoe. Damage to drip tape caused by insects, rodents or birds may create large leaks that also require repair. Drip-tape disposal causes extra cleanup costs after harvest: Planning is needed for drip-tape disposal, recycling or reuse.

Components of a Drip-Irrigation System

The type and sequence of components in a drip-irrigation system are typically the same for all field sizes. Yet, based on field size (and water need), component sizes (diameter) may vary. Larger components tend to be more expensive. The backflow-prevention devices—comprised of two check valves and the low-pressure drain, also known as “anti-siphoning device”—are the only components required by Florida law (FS 487.021 and 487.055 and Florida Department of Agriculture and Consumer Services Rule 5E-2.030) when fertilizer or chemicals are injected into the system. The actual selection of a specific component (with the exception of the backflow-prevention device) generally needs to be made on a case-by-case basis.

The following is a brief description of the main components of a typical drip-irrigation system (http://edis.ifas.ufl.edu/pdffiles/HS/HS38800.pdf).

Water Source

Common water sources for drip irrigation are surface water (pond, river, and creek), groundwater, and potable water (from municipality, county or utility company) (Figure 3). Use the water source that will provide the largest amount of water of greatest quality and lowest cost. Potable water is of high, constant quality, but is by far the most expensive.

Pumping System

The role of the pumping system is to move water from the water source to the field through the distribution system. Pumping systems may be classified as electric powered systems, gas/diesel powered systems, and gravity systems. Gas/diesel pumps offer the greatest versatility in isolated fields (Figure 4).

Distribution System

The role of the distribution system is to convey the water from the source to the field. Distribution systems may be
Figure 3: Common water sources for Drip irrigation are surface water, ground water and potable water.

Figure 4: Diesel Engines mounted on a trailer offer the greatest flexibility of use.

above ground (easily movable) or underground (less likely to be damaged). Pipes are most commonly made of PVC or polyethylene plastics. Aluminum pipes are also available, but are more difficult to customize, cut, and repair. The size and shape of the distribution system may vary widely from field to field and from farm to farm.

**Drip Tape** (or Drip Tube)

The drip-irrigation system delivers water to each plant through a thin polyethylene tape (or tube) with regularly spaced small holes, called emitters. Selection of drip tape should be based on emitter spacing and flow rate. The typical emitter spacing for vegetables is 12 inches, but 8 inches or 4 inches may be acceptable. Dry sections of soil may develop between consecutive emitters when a wider emitter spacing (18 inches) is used on sandy soils. Flow rates are classified into low flow (30 gal/100ft/hr). The risk of emitter clogging is generally higher with the lower-flow drip tapes. The following equivalent units are commonly used to report flow rates: gallons/100ft/hr or gallons/emitter/hr. For example, with a 12-inch emitter spacing, 24 gallons/100ft/hr = 24/100 = 0.24 gallons/emitter/hr. In the field, drip irrigation tape should be installed with emitters upward (looking up) to prevent clogging from sediment deposits settling in the emitters between irrigation events. Drip tapes are widely available from several manufacturers.

**Injectors**

Injectors allow the introduction of fertilizer, chemicals and maintenance products into the irrigation system. Florida law requires the use of an anti-siphoning device (also called backflow-prevention device) when fertilizer, chemicals or any other products are injected into a drip-irrigation system. Backflow-prevention devices ensure the water always moves from the water source to the field. The devices prevent chemicals in the water from polluting the water source. The most common injectors used with
small drip-irrigation systems are the Venturi (or Mazzei) injector and the Dosatron. Because Venturi injectors involve no moving parts and are less expensive, they are commonly used on small farms. The injector is typically located as close as possible to the irrigation zone, but before the filter.

**Filtration System**

Because drip-irrigation water must pass through the emitters, the size of the particles in the water must be smaller than the size of the emitter to prevent clogging. Nearly all manufacturers of drip-irrigation equipment recommend that filters be used. The manufacturer generally will not honor warranties unless filters are used. The filtration system removes "large" solid particles in suspension in the water. Different types of filters are used based on the type of particles in the water. Media filters (often containing angular sand) are used with surface water when large amounts of organic matter (live or dead) need to be filtered out. Screen filters or disk filters may be used with groundwater. A 200-mesh screen or equivalent is considered adequate for drip irrigation. When the water contains sand, a sand separator should be used.

Rapid clogging may occur when no filter or the incorrect type of filter is used. A filter needs to be cleaned when the difference in pressure across the filter (measured before and after the filter) is greater than 5–8 psi. A drip-irrigation system should never be operated without a filter even if the filter requires frequent cleaning. Failure to use a filter will result in clogged drip-tape emitters, often resulting in poor uniformity and sometimes in crop loss. The filter should be cleaned as often as needed. Efforts should be made to understand the cause of the rapid clogging, and remediation for the problem should be developed. The presence of the filter after the point of fertilizer injection means totally soluble fertilizers must be used. Otherwise fertilizer particles may contribute to filter clogging. Conventional growers may use two types of fertilizer materials: ready-to-use true solutions or dissolved granular fertilizer. Ready-to-use solutions are easily injected. However, granular fertilizers are sometimes coated with a thin layer of oil to prevent dusting. Upon dissolution of the fertilizer granules, an oily film may form at the surface of the solution. Injecting the oily film together with the fertilizer may contribute to filter and emitter clogging. Certified organic fertilizers are seldom true solutions (they may be suspensions or dilute colloidal solutions), and may also contribute to filter clogging. Consequently, the actual fertilizer rate applied may be reduced by the amount of fertilizer particles trapped by the filter. In both cases, small-scale trials may be needed to assess the clogging risk of each fertilizer material used.

**System Controls**

System controls are devices that allow the user to monitor how the drip-irrigation system performs. These controls help ensure the desired amount of water is applied to the crop throughout the growing season. Pressure regulators, installed in-line with the system, regulate water pressure at a given water flow, thereby helping to protect system components against damaging surges in water pressure. Pressure surges may occur when the water in the pipe has a velocity >5 feet/second ("water hammer") or when water flowing in the pipe has no avenue for release due to a closed valve or a clog in the pipe. Water meters monitor and record the amount of water moving through a pipe where the water meter is installed. When a stopwatch is used together with a water meter, it is possible to determine the water flow in the system in terms of gallons-per-minute. Pressure gauges monitor water pressure in the system and ensure operating pressure remains close to the recommended or benchmark values. Based on where the pressure gauge is installed, it will measure water pressure in a various ranges, from 0–100 psi near the pump to 0–20 psi at the end of drip tape. Pressure gauges may be installed at set points (near the pump, before and after the filter, near the field. They can also be mounted as portable devices and installed temporarily at the end of a drip tape.

**TIPS FOR DESIGN AND LAYOUT**

Irrigation engineers are trained and certified to properly design drip-irrigation systems. Relying on their expertise will pay off in the long run. Many small-scale growers abandon drip irrigation because of poor performance of flawed designs or inadequately modified designs. Do not hesitate to ask for professional help when designing your drip-irrigation system or when planning major modifications to an existing system.

**Designing a Drip Irrigation System**

The main components of a drip irrigation system include the mainline, valve, sub-main, backflow preventer, pressure regulator, filter, tubing adapters and fittings, drip tubing, emitters, and end caps (Figure 5). The mainline is the pipe that runs from the water Source—typically your outdoor faucet—to the valve; and the sub-main runs from the valve to the point where the drip tubing is connected. Generally, sub-mains are used only when there are multiple lines of drip tubing and zones feeding off of the same mainline water source. The combined length of the mainline and sub-main should not exceed 400 feet. The valve controls water flow into the system and can be set for either automatic or manual control. Backflow preventers are necessary to ensure that irrigation water does not flow back into the pipes and contaminate your main water source. Pressure regulators are only necessary if your water pressure is over 40 pounds per
square inch. If you do not know your water pressure it is a good idea to install one just in case. Filters keep dissolved substances in your water from clogging the emitters over time. Install filters either at the emitters or at the water source to protect both the valve and pressure regulator in addition to the emitters. It is best if the filter has at least a 150 mesh screen or higher. Tubing adapters and fittings are used to attach the drip tubing to the rest of the system. It is important that these are the right size for the tubing to prevent them from blowing apart under pressure.

**Drip Tubing and Emitter**

Drip tubing is a polyethylene tube with emitters placed along the plants. The emitters release the water from the drip tubing. Drip tubing and emitters come in various types and diameters depending on your needs. The length of a single drip tube should not exceed 200 feet from the point where water enters the tube. You will need to stake the tubing to keep it from moving. As a rule, do not bury the drip tubing and emitters, even if they are designed to be. This helps to prevent clogging and rodent damage.

**Emitter Spacing and Design**

Emitters can be spaced evenly for row crops, and this design is known as an emitter hose. Emitters can also be spaced intermittently for plants spaced farther apart, such as trees, shrubs and perennials. With an emitter hose, the emitters will generally be spaced about 18 inches apart. While watering trees and shrubs, there should generally be two emitters per plant. Emitters typically have a flow rate of 1 gallon per hour, though a flow rate of ½ gallon per hour may be better for maximum efficiency. The end cap is placed at the end of the drip tubing to prevent water running out the end.

**Basic Operation and Maintenance**

Drip irrigation can be set to run automatically, like sprinklers, or controlled manually. Manual operation allows you to take advantage of rainfall before applying unnecessary water. Because small amounts of water are applied slowly, drip irrigation is designed to run daily unless it rains. How long to run the drip irrigation system will depend on how much water your plants require per day and the flow rate of your emitters. Water is applied either once or twice a day. Early morning is the best time to water because there will be less evaporation. Watering in the evening increases the plant’s susceptibility to disease.

You should check filters and emitters on a regular basis to ensure they are functioning properly and not clogged. To prevent winter damage, you should take up the drip irrigation system at the end of each gardening season. Most suppliers/manufacturers of drip irrigation systems will provide specific design, installation, operation, and maintenance specifications and guidelines that should be carefully followed. The cost of a drip irrigation system will vary depending on the size of the area to be irrigated and the type of emitters and tubing used. However, regardless of the size of the area being irrigated there is an initial upfront cost for standard items such as the valve, pressure regulator, and backflow preventer. Typically, a drip system for a home garden area will cost between $200 and $600.

**Soaker Hoses**

Soaker hoses are another irrigation alternative. Soaker hoses require less equipment and are easier and cheaper to install than drip irrigation. A soaker hose is a porous hose that can be connected to an outside faucet, garden hose, or rain barrel and laid out along the base of the plants. The hose allows water to slowly seep out along its length. This system works well with plants that are close together, like ornamental beds with clumped flowers or round covers. However, a soaker hose should not be used to irrigate plants, trees, or shrubs that are
spaced far apart because the area in between the plants will be unnecessarily watered.

Planning

To aid planning and design, all systems should be sketched out. This will allow you to determine the length of tubing and the number of other parts that will be required to complete system. If the locations of the plants are marked, then deciding on how to lay out the system is much easier. Most home systems use less water than the hose bib or anti-siphon valve is capable of delivering. If, however, the system needs more that the hose bib can deliver at one time, divide the system into as many individual systems as necessary. You may also want to consider keeping certain plants with differing watering requirements on a separate system.

Keep in mind that, in the future, you may want to add to the system such as adding more emitters to a tree as it grows, or when you add more emitters because you’ve decided that it would be nice to have an area of color out by the spa in the backyard. In other words, don’t limit yourself. One of the many advantages of a drip irrigation system is the ease in which it can be changed or modified to suite your needs. Provisions should be made to utilize the drip irrigation system for the application of fertilizers and/or additives on a frequent, or better yet, continuous basis.

Fertilizers, micro-nutrients, additives, and system cleansers must be in liquid form when being used. There are many brands of liquid fertilizers already on the market that are premixed. All you have to do is pour them into the fertilizer injector. No mixing is required. These are totally water soluble fertilizers and can be premixed with water, at a rate of one pound (or small bag) of dry fertilizer to one gallon of water. In addition, a wetting agent can be dispensed to breakup compacted soils, compost tea which increases micro-organisms in the soil, micro-nutrients.

Head or Valve Assembly

There are several components that can be recommended to be installed into all drip irrigation systems:

- a backflow prevention device such as a pressure vacuum breaker, an anti-siphon, or atmospheric vacuum breaker is recommended for all watering systems that are connected to a drinking water supply. This eliminates the possibility of irrigation water backing-up into the drinking or potable water system;
- a fertilizer injector like the Add-It® allows for the application of liquid or any dry, totally water soluble, fertilizer,
- a filter to screen out small particles matter from the water and protects the small openings or orifices of emitters, micro-sprays, etc. from clogging. It contains a fine mesh screen or cartridge that can be rinsed and reused;
- and a pressure regulator which reduces the higher pressures found in home plumbing systems, usually 45-100 PSI, down to 10 to 25 PSI, depending on the drip irrigation system being installed. The lower pressure greatly reduces the possibility of leaks and blowouts.

Automatic Systems

The first component is an on/off valve, which has female pipe thread connections on both inlet and outlet. This means that it will require a male pipe thread connector, rather than a hose thread. Next in line is the 24 volt automatic valve which may already have a built-in vacuum breaker or anti-siphon. If not, then one must be installed separately. Then comes the fertilizer injector, which is followed by the ‘Y’ filter. The last item needed before you complete the head assembly is the pressure regulator. Most pressure regulators for this size of system have female pipe threads on both sides, allowing them to connect to the filter without the use of an adaptor. The pressure regulator is placed on last so that the pressure going out to the lines is at the desired level. PVC pipe or poly tubing is connected to the pressure regulator. The regulator should be placed ahead of the ‘Y’ filter and fertilizer injector if you have pressures that exceed 60 PSI. Depending on the parts you decide to use, you may find that connections will need to be made between incompatible fittings. There are adaptors available to solve this problem. Sometimes a canister filter and an adjustable pressure regulator are installed on the supply line leading to more than one automatic valve with each control valve controlling a separate circuit. Be sure that the casing of the filter is strong enough to take full, constant water pressure, and use an adjustable brass pressure regulator. Also, if installing a fertilizer injector before of a manifold of valves, a reduced-pressure vacuum breaker is usually required. If you have any questions regarding what backflow requirements are in your area, give your local water company a call. You will also want a shut-off valve upstream (ahead) of the entire head assembly to facilitate working on the individual electric valves should they require maintenance, or to facilitate draining and filling the fertilizer injector.

Size Limitations

Pressure variations occur in all systems. Two factors affect pressure: elevation and friction. Elevation can add to the pressure if the tubing is running downhill or reduce it, if the tubing is running uphill. If the highest point in the system is not more than 10 vertical feet above the control valve, and pressure compensating emitters are used, then the pressure difference is within the acceptable range. With friction, pressure is always lost as water travels through the tubing. Friction is greater at high flow rates and in smaller diameter tubing. Tubing should be sized properly to keep pressure loss due to friction within
acceptable limits, while keeping the cost of the system down. There are many different sizes of polyethylene hose. The most common, however, is 1/2" (15 mm) which is used mainly as the supply line and can handle flow rates up to 200 GPH (or less than 3.5 GPM). 1/4" (4 mm) tubing is usually used to branch off the supply hose to carry water to any area that is too hard to reach with the supply hose. Because of its small size, it should not be asked to handle more than 8 GPH (or (8) 1 GPH emitters). Most drip irrigation systems require little in the way of design beyond the most practical or aesthetic considerations. Remember that you can add to a system if flow rates allow. If not, dividing the system into two or more sections is also relatively simple. No matter how large or small your system is, the scale drawing is crucial in determining your needs.

**ASSEMBLY OF A DRIP SYSTEM**

**Lines**

One of the advantages of using poly hose over PVC pipe is that the fittings require no glue or clamps. It comes in coils for easy handling and storage, and is resistant to the damaging effects of ultra-violet light so it can be laid on the surface. With either barbed or compression hose fittings, the tubing is pushed into place, and its elasticity and memory hold it securely. If many lateral lines feed off one main line, it is a good idea to use PVC pipe for the main line. Lateral lines are connected to the main lines with a tee fitting which splits the flow of water. At the end of each line is an end cap to facilitate flushing on a semi-annual basis. As the lines are laid out, the tubing may have to be staked down or secured in some fashion until it takes shape. Be sure to leave a little slack in the lines to allow for expansion and contraction due to temperature changes. This will also help prevent the emitters from moving out of place. Once the wet zone has been established beneath the emitter in the root zone, it is extremely important that the emitters are not moved, or else the water will fall on dry soil and will not penetrate when the system is turned on again (http://dripirr.com/services/system-guide/Drip_Irrigation_Design_Guide.pdf).

**Emitters**

Once the lines are in place and flushed the emitters (drippers) can be installed. There are two basic types, or styles, of emitters available; compensating and non-compensating. Most installations will require non-compensating emitters. The only time that you will need to consider installing compensating emitters is if you have drastic elevation changes of 10 feet or more. There are basically three ways that an emitter can be installed. The most common way is to make a hole on the top side of the hose with a hole punch, not a nail or sharp object, and insert or “pop” the barbed end of the emitter into the hole. If a hole is punched by mistake or in the wrong place, it can be fixed with a “goof” plug. Another way is to install a 1/4” barbed connector into supply hose, run 1/4” tubing from it to the location you wish to place an emitter, and insert an emitter into the end of the 1/4” tubing. A third way is to place the emitter into the poly hose and attach 1/4” tubing to the area to be watered. For control purposes, it is far better to have the emitter at the end of the 1/4” tubing if the distance from the supply hose to the emitter is over 10 feet.

Since a drip irrigation system should be designed starting from the plants and moving back to the source of water, start with how many emitters to use and where they should be placed. Two of the most important factors to remember are soil types, and the root structures of the plants. In sandy soil, where spaces between grains are relatively large, gravitation pulls water down into the soil. In finer soils such as clay, the horizontal water movement is much stronger so water will tend to move laterally before penetrating very deeply. An emitter in sandy soil may suffice for an area of 16 inches in diameter, while the same emitter in clay soil may wet an area 24 inches or more across. When designing your system, take care to see that a sufficient percentage of the root zone is watered. Shallow roots require closer spacing of emitters. Deep roots allow for a much wider spacing. In small systems with mixed plantings, it is best to play safe and design for fuller coverage. A soil test can be useful in making your decisions. This can be done by observing the effect of slow dripping of water on the soil from your garden hose. Be sure to dig down into the soil away from the obvious wet area on the surface to see the extent of coverage. Remember, you may only see a small wet area on top of the soil, but underneath, the water may be moving laterally further than you think.

**Mini-Sprays**

There are a wide variety of low volume sprays that can be used in a drip irrigation system. The smallest available is a “fogger” with a flow rate of 3 to 5 GPH. A “Spray-Stake” is simply a small spray on the top of a stake that sprays approximately 2 feet in a 120° pattern at 6 GPH. It is attached to the supply line with a 1/8” coupling and tubing. Many professional rose growers use these because they get the entire area around the rose wet, yet do not get the foliage wet, which could cause mildew. Also, this spray allows you to broadcast dry fertilizers and systemic, and to have them leached into the soil with the fine, low profile spray. “Micro-sprays” are a small fan type spray. A hose support stake can be utilized to hold the spray in an upright position. These sprays are available in many different flow rates and patterns. They are very useful for watering small areas of ground cover or slopes because erosion is virtually eliminated. The largest of all
sprays available for the drip irrigation system is what is called the Micro-Sprinkler. It is available only in 360° patterns, but will cover a very large area (up to 30’ in diameter).

It can also be used on slopes, large areas of wild flowers, or for watering large trees. It, too, must be mounted on a support stake.

The support stake can be attached directly to the side of the supply line, or can be attached with a 1/4″ coupling and tubing. A simple reminder for all sprays:

They all require more water flow than any of the emitters, so you cannot place as many on a single line. And, even if a “Mini-Spray” covers an area in the beginning, most plants grow taller in time. They could grow up and block the “Mini-Spray,” which means that the plants on the far side get no water.

Risers are available, however, to raise the “Mini-Spray” over the top of intruding plants.

Assembly Tips

Start the installation at the water source and work your way out to the laterals.

Be aware of the type of thread on the fittings which you use. Forcing a hose thread fitting onto a pipe thread fitting can result in stripped threads that can cause leaks. When pipe thread connections are made, wrap the male threads with two to three wraps of Teflon tape before making the connection.

Check for the correct direction of flow on valves and other components before making the final connections. Usually all pipe threaded components will have an “arrow” on them that points in the direction of the water flow. Hose threaded parts are even easier to work with. All inlets are female and all outlets are male. Do not over tighten plastic fittings by using a wrench or pliers. Hand tightening, or one half turn with a wrench, should be sufficient if Teflon tape is used.

Try to be as careful as possible in keeping dirt out of the lines when you are installing your system, even though you will be flushing out the entire system once you have it totally installed. Allow the tubing to “relax” or sit in the sun. This will make it easier to work with and assemble. If it’s cold outside when you’re installing your system, dip the end of the tubing into a container of warm water.
Do not stretch or pull the poly hose taut. Allow the hose to “snake” along the ground. This will allow for expansion and contraction due to weather conditions.

When punching a hole for an emitter, spray, or connector, be careful to hold the punch perpendicular to the tubing while supporting the back side of the tubing with your other hand. Flush all tubing lines before closing, removing any debris that may have gotten into the system during installation.

**Horizontal Hydroponics designed as Ebb and Flow system**

Typical horizontal hydroponics designed as ebb and flow system, referencing the relation to the rhythm of the tidal changes, requires a tray (http://agreenroof.com/wp-content/uploads/2013/06/Hydroponic-irrigation.pdf). The tray is segmented and elevates the grow blocks or containers so they are not sitting in water, a reservoir and a pump. The tray design is important; you cannot use just any tray. The bottom of the tray has to have raised areas to keep the roots from being submerged or sitting in water. This is exactly the same principle with the popular built up hydroponic walls! No aerobic activity equals disease and root rot. Typically the pump is on a timer moving water to flood the tray with fertilizer directly to the plant root zone and then through an overflow the water drains back into the reservoir for reuse. A hydroponic living wall will not require a tray. This is an important part to the success of a hydroponic living wall. There needs to be aerobic activity at the root level, the layers of material sandwich the plant roots creating an anaerobic environment. In a horizontal set up the tray allows for air flow and the roots can breathe never being submerged in water for more than a few seconds taking up nutrients as the water recedes back to the reservoir. Reservoir, Fertilizer and Pump Tray with grow blocks or pots

Hydroponic tray shown with channels that allows water and nutrients to flood the tray and recede back to the reservoir (Figure 7). The plant roots literally sit up and out of the water that is left in the tray preventing root rot due to anaerobic activity.

**Green Roof Irrigation Systems**

Green Roof System represents “A roof area of plantings/landscape installed above a waterproofed substrate at any building above a waterproofed substrate at any building level that is separated from the ground beneath it by a man by a man -made structure made structure.” – NRCA Green Roof NRCA Green Roof System Manual, 2007.

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**Sprinklers**

Used only on Intensive roof systems. If the roof depths are very shallow, supply pipe work is laid in the gravel margin, or in raised beds around the edges of the lawn. Traditional lawn type sprinklers of the pop-up type are then positioned around the outer perimeter of the grass area, spraying into the lawn area. These sprinklers have good coverage and can also be used to establish the grass when first laid. For lawns with greater soil depth the pop-up sprinklers can be fitted directly into the lawn area, and will operate in the same way as sprinklers in a traditional lawn.

**Drip Lines**

Extensive and some intensive green roofs are fitted with a drip line system which directly targets the root zone. This should be installed during the green roof installation. A specialist drip line is used, which is designed to go in the root zone – most ordinary drip pipes will clog if used in this way. The individual drippers also have a compensation device built-in to ensure that, regardless of the elevation on the roof, each dripper will provide the same amount of water. Drip lines are laid below the soil surface at root level. According to application, drip lines are laid across the roof in lines spaced 300-1000mm apart. In the case of pitched sedum roofs, two lines of drip line are usually installed at 2-3m intervals. On extensive roof gardens, where planters or shrub borders are included, these have to be dealt with using drip lines placed on the surface (or under a mulch) of the bed. If there are pots or urns in the roof area, these can be watered using individual drippers for each pot.

**Pressurization and Control System**

Because of the irrigation location ie: high level, a pressurized water supply will be required to ensure even watering. Water regulations require a type ‘A’ air break on all irrigation systems. This can be taken from a suitable pressurized supply within the building or a purpose made pressurization unit. The latter is pre-assembled and has a built in water storage tank with air gap, pressure pump and controller. This unit is usually located in a pump room at lower level. Copper or MDPE pipe work is taken from its location to the roof level. A mains water and 230v power supply is all that is additionally required. The
controller can be set to operate the irrigation automatically either daily, weekly or manually as required. An additional rain sensor can also be fitted if required - this will suspend watering if sufficient rainfall as occurred.

**Installation Roof level**

Depending upon the roof size, the roof irrigation is usually divided into zones. Each zone will have a separate pressurized supply pipe running to it. Depending on the roof make up, sprinklers and associated pipe work are usually installed before the soil is laid. For all but intensive roof planting, drip lines for substrate based roofs are usually laid on or within the substrate, held using plastic anchorage pegs and connected to a header pipe. This pipe connects to the zone supply pipe. For planters in intensive systems the drip line is laid on the soil surface. Sedum blanket panels on sloping roofs are usually only fitted with two lines of drip line, one on the top and one in the middle of the slope. The drip line is placed directly on the roof felt and the blanket panel laid on top. Because the water usage is less several large areas can be linked together and watered in one zone.

**Pressurization and Control Units**

The zone pipe work is connected to a control valve manifold. This will usually be located in a pump room at lower level. An individual solenoid valve is required for each zone. In the case of a pressurization unit the solenoid valves will be built onto the unit. If another water source is being used, then the valves may be wall mounted. A supply pipe from the pressurization unit or pressurized supply connects to the control valve manifold. The solenoid valves are electrically operated via the controller. Operating time for the system will vary according to application and will be specified in the design specification. Temporary Sprinkler Systems Irrespective of green roof type, overhead sprinklers must be used to first establish the grass or sedums. A temporary sprinkler system is used. This ensures that the roots grow into the soil medium. Temporary systems are designed to stand on the roof area and water regularly. Operation of the system using a battery timer adds to the efficiency, as it allows watering to be undertaken at dawn, when wind and evaporation levels tend to be at their lowest. Once the green roof has been established, the built-in irrigation system can take over and the temporary system moved to another site.

**Rainwater Recycling**

The irrigation on the green roof can be made to be self contained, catching extra run-off water from the green roof and traditional roof areas in times of rain, holding it in a rainwater storage tank, then re-using this water when irrigation is required. By using rainwater to irrigate, there are no restrictions on the irrigation of the green roof system, even during hosepipe bans or drought orders. The stored rainwater is normally held in an underground tank, where the water can be kept cool and away from light sources, best preserving its quality. Alternatively for very small schemes an above ground tank can be used. For existing buildings, where fitting underground tanks would be difficult, an above ground steel tank can be used.

Before the water enters the tank, it is important to filter the water of leaves of large debris. It is also important to try and keep the guttering and roof areas free of potential sources of contamination, such as diseased plants or dead birds etc. When the water is taken from the storage tank it will be passed through a further filtration system, before being put back onto the roof irrigation. The rainwater storage tanks need to be sized to ensure that there is water for irrigation during dry weather. If necessary, the system can have a mains water top up system, which will add small amounts of mains water into the tank, when the weather is very dry. When using recycled water, care needs to be taken to ensure any risks are minimized through comprehensive risk assessments.
Choosing the Right Irrigation Products for Green Roofs

Properly irrigating green roofs keep plants healthy and alive through periods of drought and help establish plants during the transplant process. Further, if the soil is kept moist the thermal energy that would have transferred into the building is consumed by active plant transpiration and evaporation processes, which result in energy savings for the building. Keeping the soil moist can also lead to better storm-water retention by reducing the hydrophobicity of overly dry soils (http://www.rainbird.com/specnews/documents/RightIrrigationProductsforGreenRoofs.pdf). Which type of irrigation products you use on green roofs will depend on the type of green roof, soil media and depth, slope, and plant type.

Green Roof Drip Irrigation during Winter and Spring Seasons

The irrigation system, whether drip or overhead spray, should be visually inspected at each visit to ensure that it is functioning properly. Check all valve locations and joints to look for signs of leaks or breaks in the piping. Visually inspect spray heads and drip emitters to ensure they have not become clogged. Check moisture levels on the roof and adjust run times on the controller if using an automatic system. Special care will be required to winterize and re activates the system (http://columbia-green.com/wp-content/uploads/2014/08/CGT_Maintenance_July2014.pdf).

Drip Irrigation: Winterization

Step 1: After the last frost danger has passed and you are ready to turn on the system in the spring, the first step is to flush it out. During the winter small insects may take up residence in the emitters, tubes and pipes. Open the ends of drip tubes and flush them out by turning on the water. Make sure that standing water doesn't drain back into the pipes, taking dirt back in with it.

Step 2: After flushing, check the system out by running it. Look for clogged emitters or nozzles, check for leaking valves and make any necessary repairs.

Step 3: Check the controller to ensure that it is properly programmed for each station. If it has a back-up battery replaces it with a fresh one.

Watering regimens for Green Roof Irrigation System will differ depending on location, solar exposure, building height, and roof pitch. Owner/Installer should consult the appropriate horticulture professionals in their area (as designated by growing zone and climate), or seek watering schedule information from a Rooftop Green specialist. Watering should be carried out via appropriate watering techniques including but not limited to: garden hose pressure of 40-50psi (typical residential exterior faucet, North America), watering can with diffused nozzle or “shower” apparatus, overhead sprinkler systems, or sprayer irrigation. Situational characteristics will affect the necessity and frequency of irrigation (http://growrooftopgreen.com/wp-content/uploads/2016/05/Rooftop-Green-Spec-Sheet.pdf).

Green roof systems installed adjacent to glass or reflective vertical surfaces are exposed to increased light and UV, requiring extra irrigation during dry periods.

Pitched roof applications drain faster than flat roof applications and often need to be watered during even mild dry events. Watering prevents vegetative lost and stabilizes effects of the plant growth. Many pitched applications exposed to wind and sun will dry faster than typical applications and will likely require an irrigation system.

Size matters. Rooftop Green recommends that facilities with green roofs larger than 250 square feet should be watered by multiple personnel or utilizes an automated system.

WEBSITES

Figure http://extension.colostate.edu/docs/pubs/garden/04702.pdf.