Landscape Irrigation Design Standards

Conserve WATER

U.S. DEPARTMENT OF THE INTERIOR

City of Santa Fe
Water Division

Presented By:
City of Santa Fe's Water Conservation Office

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Preface

Excessive water use and high maintenance costs are the result from inefficient irrigation designs and poor water management. Limited water resources create the need for water conservation. The landscape industry is often the target of restrictions in times of drought because of its highly visible potential for water savings. Water conservation is a source of water supply and should not be just a short-term response to water shortages. The water industry should improve landscape water efficiency as a method of long-term water supply management.

Landscapes provide a quality of life. Continued drought, inefficient irrigation systems, and poor water management deplete water supplies and threaten this quality of life. Because of the expanding concern over water conservation, especially as it relates to outdoor watering, options for improving irrigation efficiencies in the landscape are needed. Irrigation systems will never be 100 percent efficient. However, irrigation systems today typically do not meet fair or achievable standards. Efficiency concepts are misunderstood in the industry. Inefficiencies stem from poor irrigation design, installation, scheduling, and maintenance.

There are sufficient sources of information related to irrigation efficiencies and water conservation as it relates to outdoor watering. Conversely, there is also bad and misleading information available. Irrigation manufacturers provide excellent educational materials and continue to develop new and innovative technologies that provide better tools for efficient watering. With these technologies and the need for changes come renewed interest in site development and redevelopment of landscapes. The Irrigation Association (IA) is a great resource for educating the professional contractors and supplying education materials.

Issues related to inefficient irrigation are numerous and options for addressing the problems include an increase in public awareness, industry training, and contractor certification. After extensive research and analyzing the information, recommendations in the form of this Landscape Irrigation Design Standards guideline were developed to address the issues connected to poor irrigation design, water management, and maintenance of irrigation systems. The guidelines provide information for all individuals involved with irrigation such as the irrigation designer, contractor or installer, water manager, and maintenance personnel. The guidelines include uniformity principles, irrigation efficiency, distribution uniformity, irrigation scheduling, water losses, and system maintenance.

As a result of improving irrigation efficiencies, landscapes will be healthier and our most precious resource, water, will be saved. This document provides a framework for guiding this development and redevelopment into the future.

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City of Santa Fe

Acknowledgments

The City of Santa Fe's Water Conservation Office wishes to acknowledge the Irrigation Association for their generous support and assistance in allowing us to use portions of their manuals and literature in the development of this standards guide. We would also like to thank Andy Mumma, Randy Sugrue, Willie West, Robert Wood, and Paul Zalesak who assisted in the review and revision of this project and/or contributed to the manuals content.

In addition, we would also like to acknowledge the Bureau of Reclamation's contribution of grant funding for the printing and preparation of this standards manual.

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Introduction

1.1. What are Landscape Irrigation Design Standards?

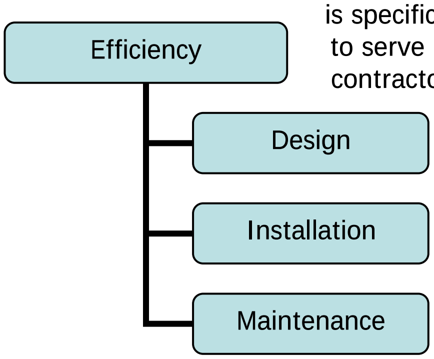
Landscape Irrigation Design Standards represent the findings of a study to research options for improving irrigation efficiencies. The issues related to inefficient irrigation were researched with the conclusion that the development of an efficiency guide (Landscape Irrigation Design Standards) for irrigation systems is needed to provide a framework to improve irrigation system efficiency with the goal to protect our water resources.

For the range of these documents, the term "irrigation system" refers to landscape irrigation systems. Objectives of these guidelines are to create a framework that:

- Establishes minimum standards for the design and installation of cost effective, reliable, and efficient irrigation systems
- Defines common industry practice to standardize all irrigation systems
- Improves consistency in the design and evaluation processes
- Defines administrative processes for reviewing and approving irrigation design
- Promotes consistency within the design and installation of irrigation systems
- Establishes a high level of quality for the consumer
- Helps to protect our water resources with the improvement of water efficiency
- Promotes certification of landscape professionals within the industry

This guide covers key aspects of irrigation design, installation, and maintenance to promote efficiency and establish a high level of quality irrigation systems that consumers have the right to expect.

The primary objective is to improve the design, installation, and maintenance of irrigation systems and to standardize all irrigation work by providing water resource information. Included is specific information for the City of Santa Fe. The intention of this guide is to serve as a resource for irrigation designers, landscape architects, contractors, developers, maintenance personnel, and water managers working for the improvement of landscape water efficiency in accordance with commonly accepted industry practice.



The focus of the guidelines is on new installations and redevelopment of irrigation systems. The expectation is that upgrades to all existing non-efficient irrigation systems will meet minimum standards by either retrofitting or replacement of the entire system.

Landscape irrigation systems are those that provide application of irrigation water by means of permanent aboveground, surface, or underground equipment under pressure. All irrigation system designs shall be site-specific, reflecting plant type, soil type, infiltration rates, slopes, microclimates, water pressure, and prevailing wind direction.

These guidelines apply to all permanent irrigation systems used on parks, industrial, municipal, commercial, multi-family, medians, streetscapes, and single-family residential development and do not apply to agriculture irrigation systems. They address design criteria, materials, installations, testing, inspections, and maintenance for such systems.

Efficient irrigation is a sophisticated process. Irrigation systems that deliver exactly the right amount of water at the right time to lawns, plants and trees, give assurance of environmentally sound and efficient results. The irrigation industry offers reliable options and affordable technology for water conservation and efficient water distribution to protect landscape investments.

Development of design criteria in this guide use standards in the industry and the 1997 edition Uniform Plumbing Code. Efforts have been made to ensure that data and information are accurate; however, the City of Santa Fe cannot accept responsibility for any errors or oversights in the use of material or in the preparation of landscape and irrigation plans. For the range of these documents, the term "City" refers to the City of Santa Fe, New Mexico.

1.2. Methodology

Research was conducted to understand the issues related to inefficient irrigation and water losses. First, four major factors that influence irrigation efficiency were identified:

1. **Poor irrigation design**. Without a high-quality design, the irrigation efficiency will start low and decline from that point.
2. **Poor irrigation system installation**. Even with a high-quality irrigation design, the installed system can suffer from poor installation practices.
3. **Poor irrigation system maintenance**. Over time, parts wear out and break, and incompatible components are installed, creating water loss; therefore, reducing efficiency.
4. **Poor water management**. Water managers over water their landscapes two or upward to ten times more than the landscape requirement; furthermore, you can have a very efficient irrigation system, and still be inefficient with scheduling.

Next, four options for improving irrigation systems through better design, installation, maintenance, and water management of irrigation systems were identified and prioritized. All of the following options are important; however, they are listed from least important to most important:

1. **Training**. Currently, there is not a sufficient amount of requirements or education needed to work in the landscape industry. Providing seminars and training is needed to increase the abilities and awareness of irrigation designers, installers, and water managers. This option is not a priority with the availability of training through associations, manufacturers, distributors, and private consultants; however, more affordable training is needed to reach more people.
2. **Certification**. Requiring contractors to become certified raises the level of a contractor's knowledge and professionalism. This option will take an enormous effort involving local and state governments with changes to local and state regulations.

3. **Public awareness**. It is important to educate the end user. The owner should be aware of the qualifications of a contractor before they begin a project. The contractor should be licensed, certified, and reputable. When the owner does his or her homework, everyone wins. This option should be a priority of city governments, manufacturers, and retailers of irrigation products.
4. **Irrigation efficiency guide**. With the type of information available to the public and contractors, which is either too basic or clear as mud, justifies the need for an efficiency guide for irrigation systems. The guidelines would provide a framework for high-efficiency irrigation systems.

The conclusion is that an efficiency guide for irrigation systems would be the most cost-effective and practical approach. With the data analyzed and conclusions drawn, recommendations were formulated and presented in the form of this Landscape Irrigation Design Standards efficiency guide.

Landscape Irrigation Design Standards may be copied or reprinted as needed. In order to maintain its integrity and consistency, the authors request that you do not modify or delete any part of this document without prior approval from the City of Santa Fe.

Note:

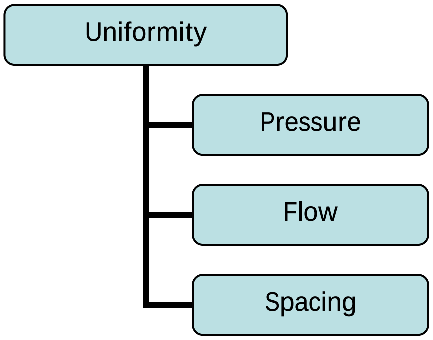
- “Should” means it is highly recommended.
- “Must” or “required” means law requires it: plumbing code, regulation, ordinance, or specified within this document and adopted by the City of Santa Fe.

II. Efficiency Concepts

2.1. Introduction

Although related, the concepts of efficiency and uniformity are different. Irrigation efficiency is a measure of the amount of water stored in the root zone that is available for plants to use, divided by the average amount of water applied during irrigation. Uniformity is the evenness of the water applied over a given area and result of appropriate design, installation, equipment, and maintenance. A system can have high uniformity, but have low efficiency due to poor water management.

New installations designed with optimum pressure, flow, and spacing will achieve a high uniformity. Thus, in existing irrigation systems, a high level of efficiency is harder to achieve when retrofitting poorly designed installations.

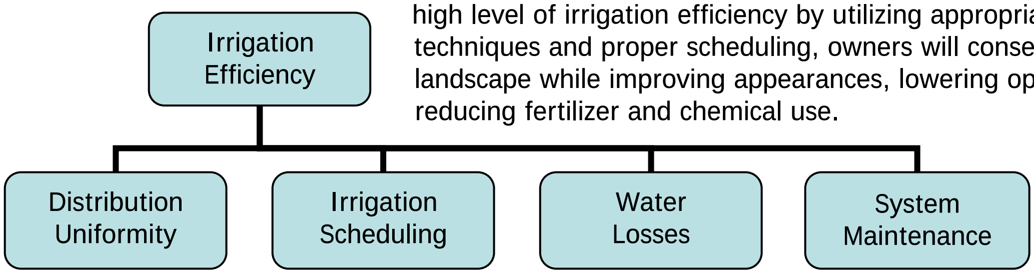


2.2. Uniformity Principles

Three components, pressure, flow, and sprinkler spacing influence uniformity. Any change of one of the three will change the uniformity. Changes in pressure relate to hydraulics of the system (e.g., pipe sizing and proper routing of pipelines). The hydraulics as well as nozzle selection influence the flow of a sprinkler. Irregular or uneven sprinkler spacing and spacing of the sprinklers further than the manufacturer's recommendations will lower uniformity.

2.3. Irrigation Efficiency

Irrigation efficiency includes the limitation of the system's distribution uniformity, irrigation scheduling, water losses, and system maintenance. The goal of the designer is to improve irrigation efficiency where most of the applied water will be available to the plants. Achieving a high level of irrigation efficiency by utilizing appropriate design techniques and proper scheduling, owners will conserve water in the landscape while improving appearances, lowering operating costs, and reducing fertilizer and chemical use.



2.3.1. Distribution Uniformity

Distribution uniformity (DU), which is the distribution (evenness) of the sprinkler system's application of water, must be uniform to avoid excessively wet or dry areas in the landscape. A common method of measuring a sprinkler system's application of water for uniformity of coverage in a specific irrigated area is by way of a statistical parameter called the lower quarter distribution uniformity (DU_{LQ}).

DU_{LQ} is determined through recognized landscape water auditing procedures, utilizing catch device tests to measure the water applied to the intended areas. A landscape irrigation auditor uses the catch device data to calculate the DU_{LQ}. The definition of DU_{LQ} includes the average water applied in the lower quarter, which is 25 percent of the area receiving the least amount of water regardless of location within the pattern, divided by the average water applied over the total area. In theory, a perfectly even application of water would have a DU of 100 percent; however, rain is not 100 percent efficient.

Why is DU important?

There is a direct relationship between DU and the plant water requirement.

Uniformity has a direct influence on the amount of water required by the landscape to keep everything green. A turf area with a water requirement of one inch per week will require the irrigation system to apply 3.33 inches at a low uniformity of 30 percent.

With a higher uniformity, the water savings will be greater and there will be a less chance of wasted water such as deep percolation and runoff due to longer run times.

Consider the words of Brent Mecham, "The measurement of DU is a report card for an irrigation systems performance" for each individual zone and an indication of overall performance.

2.3.2. Irrigation Scheduling

Proper irrigation scheduling is applying the right amount of water at the right time, before harmful stress occurs, to the depth of plant root zones without over watering by deep percolation and causing runoff. Each occurrence of irrigation should replace the depletion of water from the soil reservoir by evapotranspiration (ET). To achieve and maintain efficiency, the irrigation manager must adjust the watering schedule regularly to accommodate changes in the weather.

Developing effective and efficient irrigation schedules is the foundation of good water management. Schedules identify which days of the week to water, how many times a day to water, and how long to activate a station to water. When developing irrigation schedules, consider the interaction between weather, plants, and soils, and balance these changing requirements of the landscape within the capabilities of the irrigation system.

2.3.3. Water Losses

Water losses, (e.g. evaporation, wind drift, over spray, low head drainage, runoff, or deep percolation) reduce irrigation efficiency.

- High winds, high pressure, high temperatures, and low humidity increase evaporation and wind drift losses.
- Poor irrigation design, installation, and maintenance are responsible for over spray.
- Multiple cycles and slopes increase low head/line drainage.
- Excessive run times result in runoff and/or deep percolation.

2.3.4. System Maintenance

The irrigation manager's performance plays a significant role relating to irrigation efficiency and water savings. Uncorrected malfunctions of system components, incorrect replacement parts from repairs, and improper adjustments of sprinklers reduce irrigation efficiency and attribute to a large part of water waste.

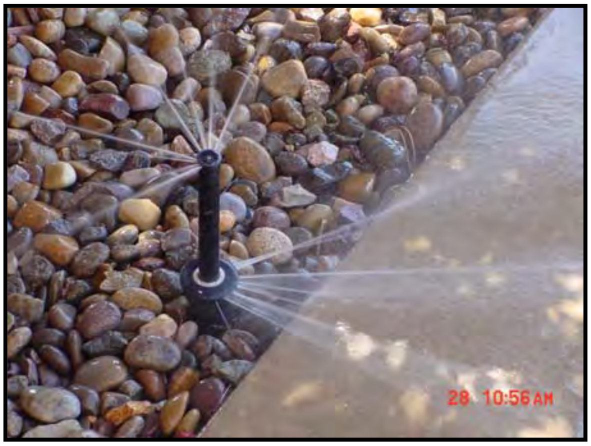


Figure 2-1: Sprinkler Leak

2.3.5. Emission Uniformity

Due to the low operating pressures of drip systems, the emission uniformity (EU) becomes a significant consideration. A small psi variation can have a significant impact on the flow of the emitters.

EU is a measure of how evenly water flows from the emitters within a zone, and calculated by comparing the output flow from the lowest 25 percent of emitters to the total average emitter flow. Factors that affect EU are psi, temperature, emitter type, and quality/consistency in manufacturing. A landscape irrigation auditor calculates the uniformity of the system from actual catch device data collected in the field.

Table 2-1: Estimated Distribution Uniformity (DU)

Sprinkler Type	Excellent (Achievable)	Good (Expected)	Poor (Avoidable)
Rotor	80%	70%	55%
Fixed Spray	70%	55%	40%
Bubbler	75%	65%	55%
Bubbler - PC	95%	85%	75%

Note: PC is the abbreviation for pressure compensating

Table 2-2: Estimated Emitter Efficiency (EU)

Emitter Type	Excellent (Achievable)	Good (Expected)	Poor (Avoidable)
Point Source Non - PC	85%	75%	60%
Point Source - PC	90%	85%	80%
Line Source Non - PC	90%	80%	65%
Line Source - PC	95%	90%	85%

Note: PC is the abbreviation for pressure compensating

Figure 2-2: Audit in Progress

2.4. Landscape Irrigation Audits

A landscape irrigation audit consists of a series of field procedures for collecting and compiling irrigation system data; then using this data to evaluate system performance characteristics, such as distribution uniformity and precipitation rates.

Landscape irrigation audits produce detailed information about actual irrigation system performance. With this information, the landscape irrigation auditor develops detailed irrigation schedules for each station throughout the year.

The water manager should implement landscape irrigation audits periodically to evaluate system performance and maintain a high degree of efficiency.

2.5. Landscape Irrigation Auditor

Landscape irrigation auditors gather water-use data and test landscape irrigation systems. They compile water records, perform water-use studies, measure irrigated sites, identify plant materials, determine irrigation water requirements, and estimate potential dollar and water savings.

Auditors are responsible for checking pressure and flow rates, conducting water distribution tests, and collecting data to determine irrigation uniformity and efficiency. They take soil samples, determine soil types, and root zone depths, which are vital in developing irrigation schedules.

At right (Figure 2-3) are basic tools used by a landscape irrigation auditor, (top to bottom, catch can, wind sensor, and pressure gage).

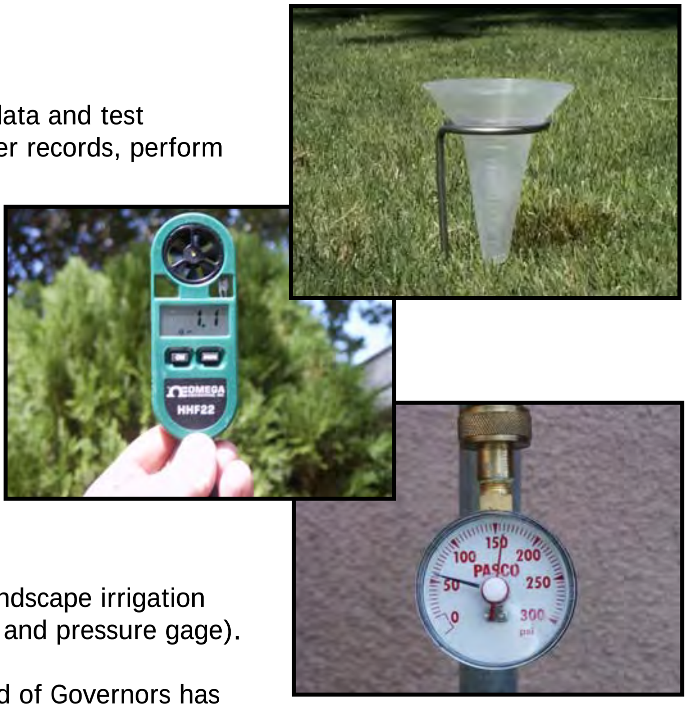


Figure 2-3: Audit Tools

The Irrigation Association (IA) Certification Board of Governors has established certification programs to achieve national recognition of irrigation auditors. For information about the IA or any of its educational and certification programs, members, and irrigation specialists visit www.irrigation.org on the Internet. To verify certification status, search under "Certification" and select "Certified Professionals."

THE IRRIGATION ASSOCIATION®

Certification as a Landscape Irrigation Auditor (CLIA) indicates that the successful applicant has:

- ✓ Participated in a required CLIA training course
- ✓ Successfully passed a written exam covering the principles and practices of auditing
- ✓ Agreed to follow a specific "Code of Ethics" established by the Certification Board
- ✓ Yearly educational activity required to maintain active status and to keep current with the industry

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www.irrigation.org

2.6. Irrigation Audit Guidelines

The Irrigation Association (IA) developed Irrigation Audit Guidelines to conduct irrigation audits intended to function as recommendations in the evaluation and performance of landscape irrigation systems. They aid landscape professionals in fieldwork procedures and in irrigation performance calculations and techniques.

The current edition of the IA Certified Landscape Irrigation Auditor Manual and IA Irrigation Audit Guidelines can be downloaded at http://www.irrigation.org/certification/default.aspx?pg=draft_guidelines.htm&id=25.

2.7. Design Coverage Analysis

Before the computer age, designers lacked the tools to determine uniformity of a system before installation. With computer modeling, the designer now can determine the uniformity of the irrigation design and observe the results of an irrigation design before actual installation of the system.

The Center for Irrigation Technology (CIT) offers a computer software program called SPACE Pro (Sprinkler Profile and Coverage Evaluation) to aid designers in the sprinkler selection and spacing process. SPACE Pro is a design tool to evaluate sprinkler performance which can be used to choose the optimum spacing, pattern, and operating pressure that can be achieved when considering several different sprinkler products.

The software can evaluate rectangular and triangular spacing of up to 120 feet between sprinklers. The designer can weigh against different irrigation system configurations by evaluating sprinkler coverage for almost any kind of landscape plan from residential yards to golf courses. The computer can "model" a sprinkler and spacing design by using data from a single leg test or from a full grid catchments pattern of a single sprinkler. The designer can also enter data from his or her own tests allowing for applications that are more specific.

The goal for the designer is to create an irrigation system design with the highest possible level of uniformity. The realization is that after the installation and over time, the irrigation system will lose efficiency. That is why it is important to start with the highest possible uniformity; it is easier to retain a high level of efficiency than it is to retrofit and repair a poorly designed system and only achieve a lesser level of uniformity.

There are several ways to evaluate how a sprinkler and nozzle distribute water. These include single leg profiles, grids, densograms, and histograms.

2.7.1. Single Leg Profiles

Single leg profiles are graphs showing the distribution of water along its radius of throw. These distributions of sprinklers affect the performance of an irrigation system. Typically, the design of a single sprinkler does not distribute water evenly across a given area. Because the profile of a typical sprinkler pattern resembles a triangle, it is important to design the sprinkler system so that individual patterns overlap in order to provide a reasonable level of uniformity. When spacing is not consistent, the uniformity of the sprinkler system will be lower.

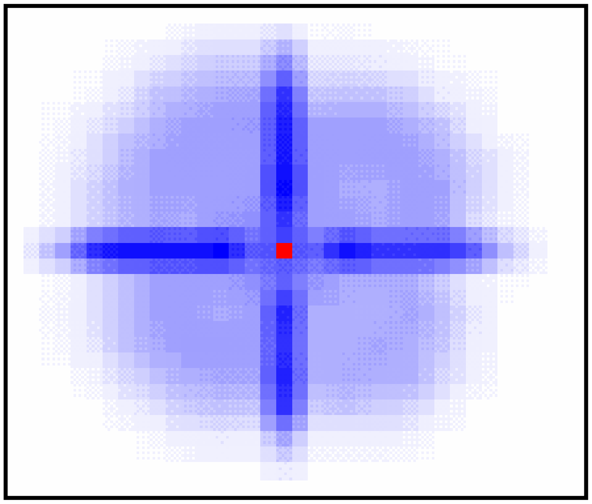

Figure 2-4: Full grid data file (360°)

2.7.2. Grid Patterns

Grid patterns are tests conducted for fixed spray heads. A grid test is performed with catch cans placed every square foot or every two square feet. The collected data input into the computer results in a diagram that shows the areas of coverage. The darker areas shown in Figure 2-4 represent a heavier application of water and the lighter areas represent a lighter application of water.

2.7.3. Densograms and Profiles

The computer creates a densograms when it “runs” the sprinkler zone to see how a combination of sprinklers will apply water to a given area. A densogram is a graphical image of the sprinkler overlap pattern. Densograms and sprinkler profiles are a valuable tool for designers to use to help estimate a system's uniformity.

The darker areas shown in Figures 2-5, 2-6, and 2-7 represent heavier application rates, and lighter areas represent lighter application rates. Although it is not possible, a sprinkler layout with perfect uniformity would be solid blue. These visual displays of uniformity allow designers to see wet and dry areas as well as uniformity along the radius of a particular sprinkler. For example, Figures 2-5, 2-6, and 2-7 represent a section of coverage using the same four sprinkler heads except at different spacing. Note that Figure 2-7 at 82 percent DU is relatively solid. Figure 2-6 at 58 percent DU is showing dry spots along the edges, and Figure 2-5 at 30 percent DU represents very poor uniformity.

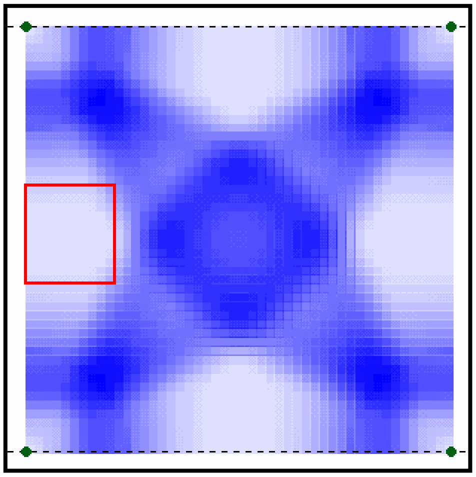

Figure 2-5: Densogram - 30% DU

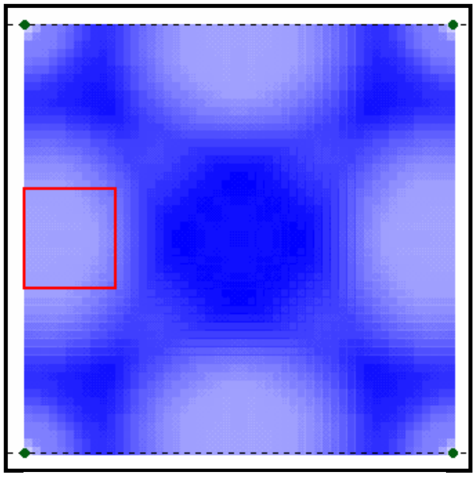

Figure 2-6: Densogram - 58% DU

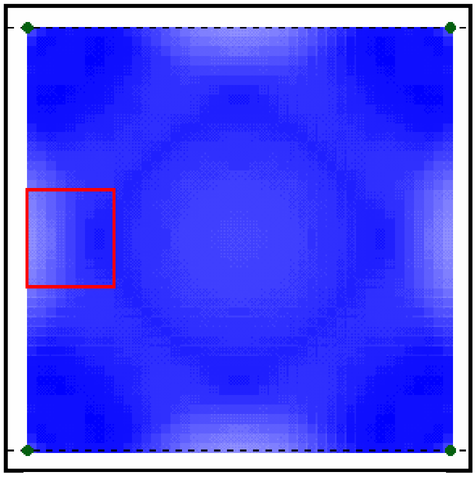

Figure 2-7: Densogram - 82% DU

2.7.4. Histograms

Histograms show graphically how much of the site by percentage is receiving precipitation, from zero to twice the mean application rate. It can help focus on how much of the site would receive less than the average precipitation rate and how much of the site would be over irrigated causing wet spots.

For more information about CIT, SPACE Pro, or any of its educational and software programs, visit http://cati.csufresno.edu/cit on the Internet or contact:

Center for Irrigation Technology
California State University, Fresno

5370 North Chestnut Avenue
Fresno, CA 93740-0018
Phone (559) 278-2066 - Fax (559) 278-6033

2.8. Design Uniformity Testing

Minimum efficiency requirements for design uniformity testing should be 70 percent or better DU for all fixed spray systems and 80 percent or better DU for all rotary systems with a goal to achieve the highest level of efficiency.

III. Design Criteria

THE IRRIGATION ASSOCIATION®

Certification as an Irrigation Designer (CID) indicates that the successful applicant has:

- ✓ A minimum of three years of irrigation-related experience and/or education
- ✓ Successfully passed a series of written examinations covering both general irrigation subjects and specialty areas
- ✓ Agreed to follow a specific "Code of Ethics" established by the Certification Board of Governors
- ✓ Yearly educational activity required to maintain active status and to keep current with the industry

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3.1. Introduction

The purpose of this section is to establish minimum standards for the design of an irrigation system that is reliable, efficient, and uniformly distributes the water. It is encouraged to meet the highest standards whenever possible.

The practice of irrigation design varies considerably depending on the geographic location, soil conditions, and type of plants or turf irrigated. The information contained herein is for providing general guidance to the irrigation designer.

The following standards apply to all expansions or major renovations and to all new development. All irrigation system designs should be in conformance with all provisions of this article. For the range of these documents, the term "plan" refers to the irrigation design and the term "designer" refers to the irrigation designer or landscape architect.

This section applies to all irrigation systems with a focus on overhead (spray and rotor) irrigation systems. Section V expands on the unique design parameters and components related to drip irrigation.

3.2. Irrigation Designer

Irrigation designers prepare irrigation plans, details, specifications, and appropriate irrigation schedules to meet the needs of a particular project. They select the most effective irrigation equipment or materials for the application and utilize the information in such a manner to produce efficient and cost-effective irrigation designs, which meet the watering requirements of irrigated plant material.

It is recommended to hire a qualified irrigation designer with related experience, education, and certification.

A qualified designer:

- Has experience with the same type, content, and scale of the proposed irrigation design.
- Engages in on-site observation of the installation to ensure that design intent is fulfilled and discussion with the end user regarding system use, particularly as it relates to scheduling and maintenance concerns.
- Has working knowledge of general irrigation theory, including hydraulics, soil-plant-water relationships, plant water requirements, and the principles of electricity.
- Has a thorough knowledge of all irrigation equipment including its selection, use, restrictions, and installation methods.

3.2.1. Certified Irrigation Designer

The IA established a certification program to distinguish tested irrigation designers from others doing design work. A CID is an experienced professional who designs irrigation systems and prepares comprehensive installation plans. For information about the IA or any of its educational and certification programs, members, and irrigation specialists visit www.irrigation.org on the Internet. To verify certification status, search under "Certification" and select "Certified Professionals," or contact:

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Water sources:

City, well, and surface water are the three main types of water sources and will have different methods of calculating the capacity for each.

The most common source for residential and commercial use is the city water supply.

3.3. Water Supply

The first design step is to determine the type of water supply (e.g., city, well, effluent, harvested, and surface water) and the capacity (e.g., pressure and flow).

A. The water supply must be adequate from the standpoint of volume, flow rate (gpm), and quality to meet irrigation requirements of the irrigated area, as well as other demands, if any, both at the time of system design and for the expected life of the system.
B. The capacity of the water supply must be adequate to provide sufficient energy (water pressure) to carry the flow to operate the irrigation system properly.
C. Consider daily, seasonal, and long-term fluctuations in the supply pressure when developing a safety factor to rate flow and pressure.
D. Review all potential water supply sources as part of the irrigation system design and advise the owner concerning cost and suitability of each, (e.g., potable, effluent, harvested, etc.).
E. Incorporate alternative water sources in the irrigation design where practical and allowed by law (e.g., rainwater harvesting, and gray water).
F. Indicate the location and source of the water supply on the plan.

3.4. City Water Supply

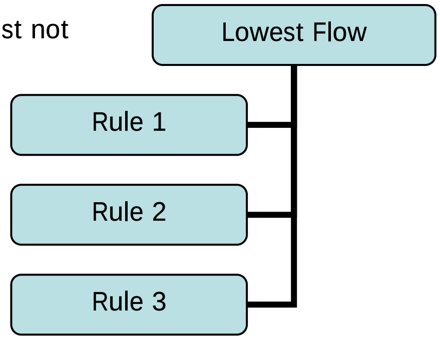
Maximum Available Safe Flow:

The water meter size, pressure, service line size, and type determine the maximum available safe flow. Three rules govern available safe flow. Select the lowest flow out of the three rules to be the maximum for any zone on the design. Refer to Appendix E for pressure loss through water meters and pipe.

Rule 1: The maximum allowable loss through the meter must not exceed 10 percent of the inlet pressure at the meter.

Rule 2: The maximum flow (gpm) through the meter must not exceed 75 percent of the maximum safe flow through the meter.

Rule 3: The velocity of water flow through the service line supplying the meter must not exceed seven feet per second (fps).



A. Measure the available pressure and available flow at the site before selection of sprinklers and zoning.
B. When a pressure test is not available, calculate the pressure from the hydraulic grade line zone and site elevation.

C. Indicate meter size and location, size and type of service line from the main to the meter, and the calculated or static pressure and source of the test on the plan.

3.5. Well Water, Cisterns, & Surface Supply

A. Determine capacity (flow rate) and total dynamic head (TDH) from pump performance data (pump curves) before selection of sprinklers and zoning.
B. If pump data is not available, a physical measurement is required.
C. Shared well water systems with other water usage will affect zone pressure and performance; therefore, consider this usage with respect to scheduling irrigation times when demand is lowest and that the pump will operate at designed pressures and flows.
D. The water supply from a pond or lake must be an irrigation only source; therefore, do not use the pump supplying water to the irrigation system for any other purpose.
E. If the source is well water or cistern, note complete data including pump motor horsepower, pump capacity, discharge pressure, electrical power source, pump location, etc. on the plan.
F. If the source is surface water, note complete data including pump motor horsepower, pump capacity, discharge pressure, electrical power source, pump location, length of suction line required, height of suction lift, type of suction intake, etc. on the plan.

What is Total Dynamic Head (TDH)?

In pump selection, an important factor, TDH is energy (pressure) that is expressed in feet. The TDH is proportional to the work performed by the pump. This work consists of lifting water, pressurizing it, and overcoming friction and inertia, and its value is the summation of the suction lift, discharge head, friction head, and velocity head.

- ✓ One foot of head is equivalent to a pressure of 0.433 psi or one foot of elevation. To convert head to psi, multiply the feet of head x 0.433.
- ✓ 2.31 feet of head is equivalent to a pressure of one psi or 2.31 feet of elevation. To convert psi to feet of head, multiply the psi x 2.31.

3.6. Pump Selection

The flow rate of a pump will not be constant. A pumps flow and pressure are linked together; when one changes so does the other.

A pump will produce less water at a higher pressure and more water at a lower pressure. A zone requiring high-pressure will have a smaller flow rate than a zone with a lower pressure requirement. In other words, each zone depending upon flow (gpm) can have a different pressure at the pump.

3.6.1. Flow Rate

A. The irrigation pump should meet the irrigation system's requirements for flow (gpm) and pressure (psi).
B. Zone the irrigation system to meet requirements of the pump's performance curve.
C. Do not exceed manufacturers' recommendations for flow.

3.6.2. Efficiency

An important factor in pump selection is the efficiency, which is the conversion of mechanical energy to hydraulic energy, measured as a percentage. It is a means to determine horsepower consumption for a given pump, as well as proper operating points.

A. Use manufacturer's data to select a pump that operates as near its best efficiency point as possible.

3.6.3. Water Quality

A factor to consider when selecting a pump is the quality of the water. Abrasives such as sand or silt, debris in the water, and solid size are factors to consider when selecting a pump.

A. Select a pump that effectively handles the application and prevents premature wear or misapplication.

3.6.4. Pressure Tank

In an average domestic water system, the pressure tank will be set to turn the pump on at 30 psi and off at 50 psi. The storage tank prevents the pump from turning on and off very rapidly every time any water is used. This short cycling of the pump and motor will cause motors to fail very quickly.

A. Determine that the pressure tank will support flow requirements without cycling the pump and motor.

3.7. Protecting the Water Source

Backflow is the unwanted reverse flow of water or mixtures of water with any other substance, into the distribution of pipes of a potable supply of water. Backflow can occur any time there is an imbalance of the hydraulic forces in a potable water system, which causes contaminated water to be forced or drawn into a potable water system. The cause of backflow can be by backpressure or back-siphonage.

A. All irrigation systems require a city approved backflow prevention device as described in Section IV, 4.12 to keep any irrigation water from re-entering the water source.
B. Private potable water supplies (e.g., wells, cisterns, lakes, and streams) require the same backflow protection that is required for a public potable water supply.

3.8. Dedicated Irrigation Meter

An important part of water management and scheduling is to measure the amount of water actually applied and an accurate accounting of all water use.

A. Provide a dedicated irrigation meter on all irrigation systems, metered separately from domestic usage for all commercial applications; an exception would be for single-family residential installations.

3.9. Sprinkler Selection and Layout

As described in Section II, sprinkler selection and spacing during system design will influence the uniformity.

A. Obtain uniform distribution of water from sprinklers by selecting the best combination of nozzle size, sprinkler spacing, and pressure.

Key elements involved in sprinkler selection and spacing depend upon:

- Sprinklers: nozzle selection and features
- Site conditions: wind, slopes, obstructions, soils, size, and shape including activities taking place on the area
- Water source: water available (gpm), and available pressure (psi)

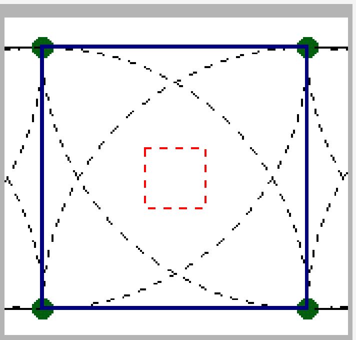
3.9.1. Sprinkler Spacing

Small and odd shaped areas where over spray is not wanted are best suited with spray heads. Spray heads typically cover small areas from a three-foot radius to a seventeen-foot radius and the precipitation rate can vary from 0.75 inches to two or more inches per hour. Due to the high precipitation rate, spray heads are not recommended for use on slopes.

Spray heads typically have a recommended operating pressure range between 20 psi and 40 psi. The operating pressure for optimum performance is about 30 psi for most brands.

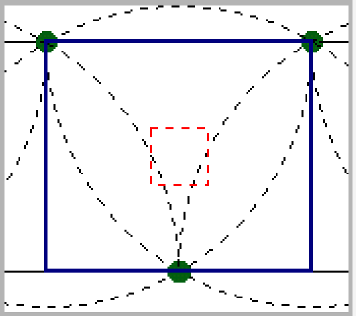
Rotors typically operate at higher pressure and cover larger areas than spray heads. Rotors apply water at lower precipitation rates, generally from 0.2 inches to 0.6 inches per hour.

A. Determine sprinkler spacing considering the irrigation requirements, hydraulic characteristics of the soil, and water quality with its effect upon plant growth, sidewalks, buildings, and public access areas.
B. Use design parameters for sprinklers from near the middle of the performance charts found in manufacturers' catalogs; specifically, always stay within the recommended range.
C. Do not exceed a manufacturer's suggested sprinkler spacing recommendations.
D. Space sprinklers equidistant from one another for the given lengths and widths of the area to achieve uniform coverage.
E. Sprinkler placement is critical to prevent over spray onto adjacent property, non-irrigated areas, walks, roadways, or structures.
F. Do not use spray irrigation in areas less than ten feet in any dimension.



Square Spacing:

Square spacing is preferable in areas with defined borders where protection from overthrow of the sprinklers is required. This style is useful with the City's regulations against wasting water.



Triangular Spacing:

Triangular spacing is often preferred because its water distribution uniformity is sometimes higher. The triangular spacing method is a good choice for large turf areas where overthrow of the sprinklers is not an issue. However, this method is rather hard to apply in small areas.

G. The maximum recommended sprinkler spacing using square spacing with no wind equals the design spray radius for their working pressure, which is 50 percent of the diameter of coverage.
H. The maximum recommended sprinkler spacing using triangular spacing with no wind is 55 percent of the diameter of coverage.

Spray Head Nozzle Selection:

- Use fixed arc nozzles whenever possible (i.e., 90°, 120°, 180°, 240°, 270°, and 360°); only use adjustable arc nozzles when odd arcs are required, and use special pattern nozzles with considerable caution.
- Where operating pressure is over 40 psi, use pressure-compensating screens/devices to reduce radius as needed or to control high pressure on systems.
- Where slopes and elevation changes are a factor, use pressure-compensating, screens/devices to control pressure variation.
- Select nozzles with the closest practical radius to the design spacing; do not allow for adjustment of more than 20 percent reduction in radius to prevent distortion of the spray.

Rotor Nozzle Selection:

- Where rotors are connected to the same control valve, select nozzles that have matched precipitation rates where the radius of throw is maintained constant, regardless of the pattern of spray.
- Select nozzles with the closest practical radius to the design spacing; do not allow for adjustment of more than 20 percent reduction in radius to prevent distortion of the spray.

3.9.2. Wind

Wind affects the sprinkler pattern by causing distortion, wind drift, and evaporation losses. There is more distortion from the wind with smaller drop sizes.

A. Incorporate minimum operating pressures to minimize misting.
B. Incorporate sprinklers with lower discharge trajectory angles to help offset the affects of wind.
C. Rotate or close in the spacing patterns laterally to the prevailing wind direction.
D. If wind velocities normally exceed five mph during irrigation, reduce the spacing by 1 percent for every one mph of wind speed as shown in Table 3-1.

Table 3-1: Recommended maximum spacing of the spray pattern diameter adjusted for wind

Wind Speed	Square Spacing % of Diameter of Coverage	Triangular Spacing % of Diameter of Coverage
0-5 mph	Pattern diameter x 0.50	Pattern diameter x 0.55
6-10 mph	Pattern diameter x 0.45	Pattern diameter x 0.50
11-15 mph	Pattern diameter x 0.40	Pattern diameter x 0.45

3.9.3. Sloped Surfaces

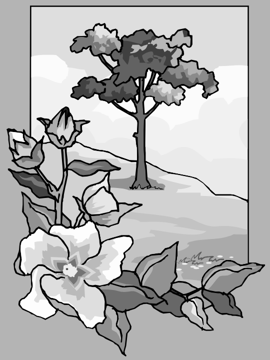
Slopes and changes in elevation create a challenge with the selection, location, and operation of sprinklers. Consider land slope, soil type, plant type, and infiltration rates when specifying application rates. On a 2:1 slope, a properly adjusted sprinkler will throw about 80 percent of its radius above the head and 120 percent of its radius below the head. Thus, the radius of throw lost uphill approximates to the radius of throw gained downhill.

A. Increase the spacing between the bottom of the slope and the first row of heads to compensate for the increase in the downhill spray pattern.
B. Reduce the spacing between the last row as it interfaces with the top of the slope.
C. Compensate for changes in slope by reducing the vertical spacing (from top to bottom) along the slope 1 percent for every 1 percent increase in slope (grade) beyond 10 percent.
D. The horizontal spacing (heads at the same elevation) along the slope is not changed.
E. Sprinklers should have a radius that will cover the actual linear distance of the zone and not the distance shown on the plans.
F. Use sprinklers with built-in pressure compensation to allow for changes in elevation.
G. Use sprinklers with check valves to eliminate low head drainage.
H. Use sprinklers where the application rate does not exceed the soil infiltration rate as shown in Table 3-2; the recommended sprinkler for slopes is a low precipitation rate rotor.
I. If spray heads are used, reduce the operating times and use scheduling practices that avoid runoff and permit uniform water application.

3.9.4. Obstructions

Blockage of the spray pattern by plant material creates a challenge for the designer.

A. Do not place sprinklers close to trees or shrubs where the stream of water can strike hanging branches/foliage and can cause damage.
B. Do not place sprinklers closer to trees than one-half of their radius of coverage.
C. Do not place sprinklers close to tree trunks, shrub masses, or other obstructions where too much of the sprinkler's coverage of the turf can be blocked.
D. Position sprinklers to irrigate at least three sides of trees or shrubs to allow for blockage.



Slope:

Percent for a slope (grade), equals vertical rise in feet per 100 feet of horizontal distance.

Determine the percent of a slope by dividing the rise by the run. Rise is the vertical distance in elevation between two points and run is the horizontal distance between two points. A 4:1 slope equals a four-foot horizontal distance per one foot of vertical change, thus a 4:1 slope equals a 25 percent slope.

The actual linear distance of the slope is longer than the distance shown on the plans. For example, on a 2:1 slope, the distance from top to bottom might measure 30 feet on the plans but the actual linear distance is 34 feet.

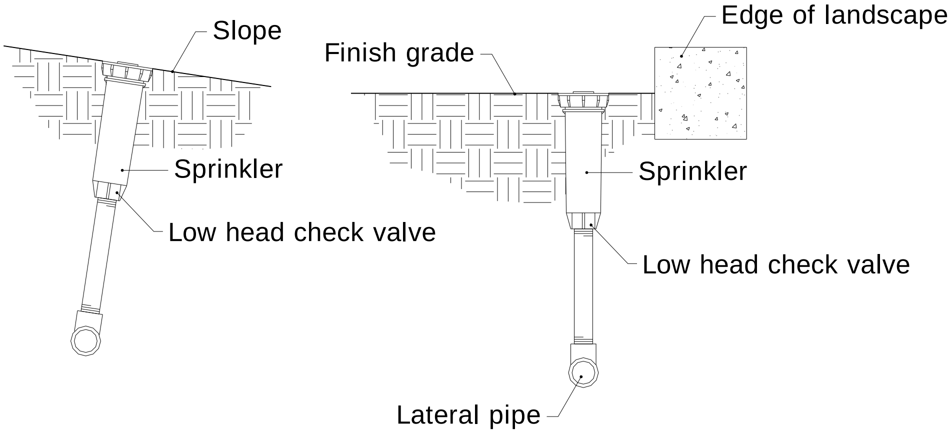


Figure 3-1: Low head check valves

3.9.5. Soil Infiltration Rate

The United States Department of Agriculture suggests the maximum precipitation values listed in the table below. Note that these are average values and may vary based on actual soil and ground cover conditions.

Table 3-2: Maximum precipitation rates for slopes (inches per hour)

Soil Texture	0 to 5% slope		5 to 8% slope		8 to 12% slope		12% + slope	
	Cover	Bare	Cover	Bare	Cover	Bare	Cover	Bare
Course sandy soils	2.00	2.00	2.00	1.50	1.50	1.00	1.00	0.50
Course sandy soils over compact subsoil	1.75	1.50	1.25	1.00	1.00	0.75	0.75	0.40
Uniform light sandy loams	1.75	1.00	1.25	0.80	1.00	0.60	0.75	0.40
Light sandy loams over compact subsoil	1.25	0.75	1.00	0.50	0.75	0.40	0.50	0.30
Uniform silt loams	1.00	0.50	0.80	0.40	0.60	0.30	0.40	0.20
Silt loams over compact subsoil	0.60	0.30	0.50	0.25	0.40	0.15	0.30	0.10
Heavy clay or clay loam	0.20	0.15	0.15	0.10	0.12	0.08	0.10	0.06

3.10. Bubbler/Stream Spray Selection and Layout

Typically, bubblers have an operating pressure between 20 psi and 50 psi with flows between 0.25 and 2.0 gpm. Flood irrigation is a method of watering individual plants and small plantings beds. The movement of water on top of the soil affects uniformity with flood irrigating. Consider this movement when spacing flood bubblers with respect to application rates, soil type, and slope.

3.11. System Zoning

3.11.1. Sprinklers

A. Group the sprinklers so the total gpm on a zone does not exceed the available safe flow. (Section III, 3.4)
B. Group spray heads that have matched precipitation rates (all nozzle sets, every radius, and pattern), to guarantee application of water at the same rate.
C. Group rotors that have matched precipitation rates where the radius of throw is maintained constant, regardless of the pattern of spray.
D. On slopes, group sprinklers from side to side across the slope and not up and down the slope.

3.11.2. Valves

A. Valve the irrigation system so application equipment for which the manufacturer specifies flow rates in gallons per minute (gpm) do not share a zone with equipment for which the manufacturer specifies flow rates in gallons per hour (gph).

Valve the irrigation system where all application equipment is compatible:

- Do not group fixed sprays on the same zone with rotors.
- Do not group drip emitters on the same zone with micro sprays, fixed sprays, rotors, or bubblers.
- Do not group stream sprays on the same zone with bubblers.

B. Group zones with consideration to plant root depths and type of vegetation irrigated (e.g., turf, shrubs, trees, and native plants consistent with hydrozones).
C. Group zones with consideration to microclimates.
D. Locate control valves near the middle of the zone to balance pressure loss from the valve to the end of the circuit.
E. Incorporate separate zones for slopes from top to bottom or in some cases, multiple zones: top, middle, and bottom.

What is a Microclimate?

Different conditions within a single landscape that can vary significantly define microclimates. Driveways, buildings, walls, pavement, trees, and structures influence these conditions. These microclimates affect zoning and scheduling.

- ✓ A "low" microclimate condition is an area in the landscape that is shaded and/or protected from wind.
- ✓ An "average" microclimate condition is an area in which buildings, pavement, slopes, shade, and reflection do not influence the landscape.
- ✓ A "high" microclimate condition is an area in which heat-absorbing, heat-reflecting surfaces or high wind conditions influence the landscape.

What is a Hydrozone?

An area containing plants with similar water requirements irrigated by a zone valve using the same irrigation method defines a hydrozone.

3.12. Controller

A. Locate controllers nearest source of electrical power and available supply with easy access.
B. Do not locate controllers within an irrigation spray pattern.

3.13. Pipe Location

A. Place lateral lines horizontally across slopes, rather than vertical with the slope; when installing lateral lines, make sure they follow the contours of the slope whenever possible.
B. Avoid piping through heavy and numerous tree roots, shrubbery, and ground cover areas whenever possible.
C. Avoid odd angles, curves, and cross trenching; specifically, do not exceed the radius of pipeline curvature allowed by the manufacturer.
D. Locate mainline piping in a separate trench than lateral piping.
E. Show the exact location of all piping on the plan.
F. The location of all piping should be clear in the irrigation design; subsequently, the clarity will affect the estimation of the system as well as the installation.

3.13.1. Sleeve Pipe

A. Sleeve all piping installed under sidewalks, roadways, parking lots, etc., in a class PVC pipe with a 200 psi or better pressure rating, two sizes larger than the sleeved pipe.
B. Place wire in a separate sleeve from that of the pipe crossing; use 1¼ inch or larger class 200.
C. For sleeves under non-paved roads, use schedule 40 PVC pipe or better.
D. Tees, ells, or turns in sleeve pipe are not allowed.

3.14. Sizing Components

3.14.1. Pipe Sizing

A zone with significant pressure variation can cause changes in sprinkler head flow; thus, creating serious uniformity problems. The operating pressure within a zone between the first and last head should be within certain limits for proper performance. When sprinkler pressure varies 20 percent, gpm varies by up to 10 percent, and when pressure varies by 30 percent, gpm varies by 15 percent, etc.

A. Design the irrigation system with appropriate pipe sizing so that there will not be more than 10 percent variation in operating pressure between heads within the station zone.
B. Design the irrigation system where pressure at the base of all sprinklers within a zone does not vary more than 10 percent of design operating pressure to insure a uniform water application.
C. Size all pipelines and use proper routing to limit pressure variations so that the operating pressure at all points in the irrigation system will be in the range required for uniform water application.
D. Size all lateral lines for overhead irrigation three-quarter inch in diameter or larger; one-half inch lateral pipe is not allowed.
E. Indicate pipe sizes on the drawing at all tees and changes in size; charts are not acceptable as a replacement.

3.14.2. Velocity Limit Technique

The most common method used to size pipe is the velocity limit technique where the designer sets a limit on the velocity of the water moving in the pipe. The velocity of flow affects the pipe friction losses. Pressure losses will increase as the velocity of flow increases. Use a friction loss chart for the type of pipe to determine the maximum flow through the different sizes of pipe with the proper velocity.

A. Do not exceed five feet per second (fps) based on gpm when selecting pipe diameters.
B. Do not design the working pressure to exceed 72 percent of the pressure rating of the pipe with the pipeline water velocity limited to five feet per second (fps).

3.14.3. Friction Factor Method

Friction factor is a method of sizing pipe that allows the designer to predetermine the amount of pressure variation in the lateral piping. It allows the designer to select pipe sizes that will not exceed the allowable pressure variation over the length of a sprinkler lateral and/or mainline. This method calculates a limit of loss per 100 feet of pipe allowing the designer to stay within set parameters and not exceed that loss per 100 feet on any size of pipe.

Friction Factor Formula:

$$F_f = \frac{P \times \Delta p}{L}$$

Where:

F_f = Friction factor
P = Sprinkler operating pressure
Δp = Allowable variation (decimal)
L = Length of pipe per 100'

- Sprinkler operating pressure is the pressure the sprinkler requires to have the nozzle perform correctly in the design.
- The allowable variation is the variation in pressure between the extreme ends of the critical length of pipe, and should not vary more than 10 percent (0.10).
- The length of pipe is the critical length over which the percent variation is measured and is expressed in hundreds of feet.

3.14.4. Valve and Valve Box Sizing

A. Size control valves based on the design flow rate through the valve following the manufacturer's recommendations with emphasis on friction loss; an acceptable loss through a valve is between two and five psi.
B. When automatic valves are in a manifold, size isolation valves to equal the largest valve in the manifold
C. Size valve boxes to allow a minimum distance of four inches between any control valve, manual valve, filter, or union and the valve box to allow for maintenance of enclosed components without excavation.

3.15. 24-Volt Control Wire Sizing

There are different methods of sizing electrical control wire. Use the valve manufacturer's recommendations for wire sizing. Locate operating and electrical characteristics for individual valve types and controllers in any manufacturer's catalog.

3.16. System Hydraulics

Hydraulic principles are a part of the design and function of an irrigation system. The main goal of determining system hydraulics is to assure there is sufficient water pressure available to irrigate all parts of the landscape. The designer should follow sound design principles in order to insure the proper operation of the system for the least possible cost. Good hydraulics of a sprinkler system will produce efficient designs and minimize wasted water and power. The total system pressure requirement is the accumulation of all losses incurred between the point of connection with the city main and the most distant sprinkler on a lateral.

Dynamic pressure is the pressure when water is flowing in the system. There are several ways to calculate dynamic pressure in a system (e.g., flow tests, pressure, gauges, or by calculation). For design purposes, the dynamic pressure can be calculated with static pressure at the point of connection, adjusting for elevation change and subtracting for friction losses in pipe, fittings, valves, meters, etc.

When calculating dynamic pressure loss use the following factors:

- Pressure loss due to friction loss in the pipe: calculate the friction losses for the worst-case head on the worst-case zone of each different type of watering method (e.g., sprays, rotors, drip, etc.)
- Pressure loss due to elevation change: calculate friction loss or gain for elevation loss or gain by multiplying 0.433 by the height of elevation change; for every one foot of elevation change there will be a corresponding change of pressure of 0.433 psi.
- Pressure loss due to friction loss in fittings: calculate fitting losses in terms of equivalent loss in feet of pipe, or take 10 percent of the mainline and lateral pipe losses and use this as fitting losses.
- Pressure loss in valves, meters, etc.: these losses are determined by the manufacturer and listed in product literature or technical charts.

3.17. Irrigation Requirements

Local Jurisdictions require restrictions on watering at certain times of the year and during drought conditions. It is the responsibility of the designer to keep current with all local ordinances.

A. The irrigation system should have the capacity to water at a rate that will satisfy the peak water demand of the "fully mature" landscape within these time constraints.

3.17.1. Watering Restrictions

The City of Santa Fe Comprehensive Water Conservation Requirements Ordinance section 25-2; the following is a summary of the watering restrictions that apply to all citizens, businesses, and governmental entities within the corporate limits of the city.

A. The following requirements for outdoor irrigation of landscaping are in effect from May 1, through October 31, each year; all outdoor irrigation must occur between 6:00 p.m. and 10:00 a.m.

For more information on water conservation requirements visit http://www.santafenm.gov on the Internet, search "Government" drop down menu, select "City Clerk," select "Ordinances," select "Santa Fe City Code (1987)," select "City of Santa Fe," select "City Code," select "Chapter XXV Water" and select "25-2 Comprehensive Water Conservation Requirements" or contact:

City of Santa Fe
Water Conservation Office
PO Box 909
Santa Fe, NM 87504-0909
Phone: (505) 955-4225

3.18. Design Regulations

The City of Santa Fe Landscape and Site Design Regulations Ordinance, SFCC 1987 Section 14-8.4; the following is a summary of the design regulations that apply to all citizens, businesses, and governmental entities within the corporate limits of the city:

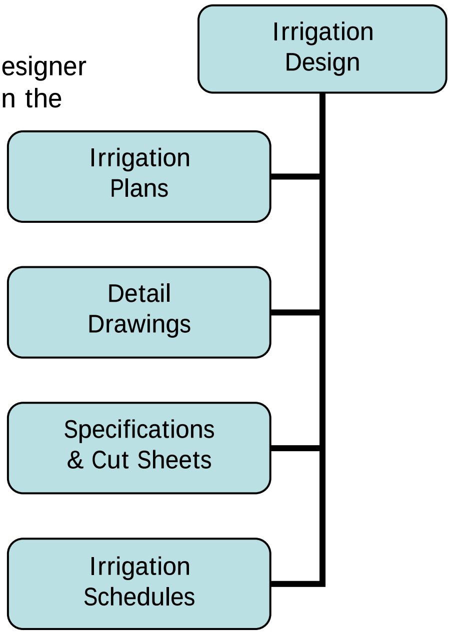
- A permit is required for all new irrigation system installations.
- A permit is required for major renovation of existing irrigation systems, which includes the installation of backflow prevention devices and the installation of additional zones.
- A Uniform Plumbing Code approved backflow prevention device is required for all irrigation systems connected to the city water system including existing irrigation systems. Atmospheric vacuum breakers are the minimum required standard for above grade systems such as those connected to hose bibs and frost-free hydrants.
- An automatic, digital multi-programmable controller is required for all irrigation systems installed in commercial, industrial, and multi-family residential development with an irrigated landscaped area larger than 1000 square feet.
- Irrigation system operation information including recommended monthly and seasonal irrigation schedules and water budgets based on gallons used for landscape plantings for year one and year three shall be included on the irrigation plan or with attached documentation.
- Irrigation systems shall be designed for the site-specific topography, site orientation, microclimate, prevailing winds, and soil type to prevent runoff, minimize evaporation, and promote infiltration.
- Irrigation systems shall be designed to prevent water waste, over-watering, and to prevent over spray or drainage of water onto any paved or unplanted surface.
- Irrigation systems shall be zoned by levels of water use; group plants with similar water use requirements together for the most efficient water use.
- Separate zones are required for permanent and temporary irrigation lines.

- Overhead spray irrigation is prohibited for watering trees and shrubs; it is allowed for turf and ground cover plants and for temporary irrigation systems for re-vegetation with drought tolerant plant species.
- Spray irrigation is prohibited in areas where any dimension is less than 10 feet.

For more information on landscape and site design regulations contact:

City of Santa Fe
Land Use Department
200 Lincoln Avenue
Santa Fe, NM 87504
Phone: (505) 955-6585

3.19. System Documentation



When it is necessary to deviate from these guidelines, the designer should submit in writing to the appropriate agency stating on the system drawings the nature of the deviation, reason for the deviation, possible outcome of the deviation, and the justification for the standard used. The irrigation design will not be complete without the appropriate support material to make the drawing clear and understandable.

A complete design includes documentation that covers:

- Irrigation plans
- Detail drawings
- Specifications
- Product cut sheets
- Irrigation schedules

3.19.1. Irrigation Plans

A. Irrigation plans should be to scale, preferably 1 inch = 10 feet or 1 inch = 20 feet for large projects.
B. The scale of the plan should be large enough to determine fittings and location of all equipment, sprinkler head placement, and for clarity.

Include in the design drawings but not limit:

- Date, revisions, and legend
- Point of connection (POC) or water source
- Static water pressure
- Meter location and size (where applicable)
- On-site pump station location and pumping capacity (where applicable)
- Backflow prevention device location, type, size, and installation specifications or detail
- The manufacturer, model number, size, and location of each control valve including master valves

- Flow in gallons per minute (gpm) and design operating pressure through each valve on plan
- The manufacturer, model number, radius, required operating pressure, gallons per minute (gpm), and location of irrigation heads (bubbler, spray, or rotor)
- The manufacturer, model number, type, required operating pressure, gallons per hour (gph), and location of drip system components
- Piping type, size, location, and depth of bury
- Power supply/electrical connection point and line location
- Plan scales and north arrow on all sheets
- Irrigation installation details, notes, and specifications
- The manufacturer, model number, type, and location of automatic controller
- Control wire routing detail and wire size
- Major or pertinent landscape features

3.19.2. Detail Drawings

A. Provide a complete set of installation details, notes, and specifications for the irrigation system.
B. Show on the detail drawings the installation of all assemblies without any questions for size or type of materials to use for said irrigation system.
C. Include in the detail drawings, manufacturer's name, model number, size of all equipment, and be job specific.
D. Include size and brief description of pipe, fittings, nipples, and appurtenances.
E. The detail drawings need not be to scale but should be accurate and be of sufficient size to show clarity.
F. Include in the drawings, notes that are specific to the installation.

3.19.3. Irrigation Schedules

Include an irrigation schedule for twelve months including runtimes per station, cycles per day, and days per week for each station. (See Section VI, Irrigation Schedules)

3.20. Reclaimed Water Specifications

Dispensing of reclaimed water for application to any area on an ongoing basis, rather than temporary or intermittent, requires a ground water discharge permit, pursuant to the New Mexico Water Quality Control Commission Regulation 3104. Permits can be obtained by contacting the NMED Ground Water Quality Bureau at 827-2900

3.20.1. System Identification

A. Provide the industry standard purple color and/or marked "Caution: Reclaimed Water Do Not Drink" and "Peligro: Agua Impura No Beber: on pipes, valves, valve boxes, and sprinkler heads when a site has reclaimed water available or is in an area that will have reclaimed water available as irrigation water.
B. Locate signs with careful consideration to sign placement depending on the size and configuration of the use area, access points, public exposure, and the general use of the area.

3.20.2. System Separation

A. Meter the back-up groundwater supply.
B. Backup supply water is only for emergencies when reclaimed water is not available. Protect the backup water supply with an approved backflow prevention device. (see section IV, 4.12)
C. Maintain at all times a minimum 10-foot out-to-out horizontal separation between reclaimed water mains and potable water.
D. Protect all drinking fountains located within an approved reclaimed water use area by re-sitting or isolating them with a protective structure from contact with reclaimed water, whether by windblown spray or by direct application through irrigation or other approved uses.
E. Do not install reclaimed water irrigation systems near food establishments or public facilities such as picnic tables, cooking areas, and play equipment.
F. Do not install hose bibs on a reclaimed water system regardless of style, construction, or identifications.
G. Operate the irrigation system between the hours of 9:00 p.m. to 6:00 a.m.
H. When using effluent water, do not use control valves that have an external manual bleed.
I. Use quick couplers discretely; their intended use requires a separate plan review from the Department.
J. Provide quick couplers with the approved color and identification.
K. Eliminate conditions that directly or indirectly cause run-off of reclaimed water outside of the approved reclaimed water use area; cause ponding of reclaimed water; or permit windblown spray to pass outside of the approved use area, whether by design, construction practice, or system operation.
L. The use of reclaimed water is limited to those uses permitted by Federal and State law and to those uses approved by the City for the reclaimed water service area.

3.21. Materials

A. Any material specified by name/or model number in the specifications or on the irrigation drawing or detail drawings is deemed to be used for the purpose of identifying the materials and insuring the specific use of that material in the construction of the system.
B. The engineer and the designer of the system will not allow substitutions without prior written approval.
C. All materials must be new and without flaws or defects of any type and be the best of their class and kind.
D. All materials require a minimum guarantee of one year against material defects or defective workmanship.
E. Furnish sufficient descriptive literature and material samples to establish substitute material as an equal substitute, and include reasons for desiring substitute materials.

3.22. Irrigation Design Checklist

Water Source

☐ Meter size & location
☐ Pump size & location

Point of Connection

☐ Size & type of pipe
☐ Isolation valve size & location

Backflow Prevention Device

☐ Meets local code
☐ Proper size
☐ Enclosure
☐ Location on plan

Automatic Control Valves

☐ Master valves
☐ Zone valves
☐ Size & location on plan
☐ Flow rate for each zone valve
☐ Zones numbered on plan

Valves

☐ Isolation valves
☐ Air relief valves
☐ Pressure regulating valves
☐ Quick coupler valves
☐ Size & location on plan

Mainline/Laterals/Sleeve Pipe

☐ All pipe sized on plan
☐ Type of pipe indicated
☐ Depth of cover specified
☐ Thrust blocking if applicable
☐ Location on plan

Supporting Information

☐ Legend
☐ North arrow
☐ Scale (1" = 10' or 1" = 20')
☐ Complete irrigation schedules
☐ Date of design
☐ Manufacturer & model numbers indicated

Control System

☐ Type of controllers
☐ Location on plan
☐ Power source
☐ Grounding
☐ Lightning protection
☐ Moisture Sensor
☐ Rain Sensor
☐ Wind Sensor

24-Volt Control Wire

☐ Wire routes & size on plan
☐ Waterproof connections

Winterization

☐ Freeze sensor
☐ Backflow protection
☐ Manual drain valves

Total System Requirements

☐ Static pressure
☐ Maximum available flow
☐ Sprinkler operating pressure
☐ Friction loss calculations

Sprinklers/Bubblers

☐ Each sprinkler type has different symbol
☐ Radius, flow & pressure indicated

Detail Sheets

☐ Point of connection
☐ Backflow preventer
☐ Master valve
☐ Control valves
☐ Sprinklers
☐ Bubblers/stream sprays
☐ Controller
☐ Drip components
☐ Wiring requirements
☐ Thrust blocking
☐ Quick couplers
☐ Miscellaneous

IV. System Components

4.1. Introduction

The purpose of this section is to establish minimum irrigation design standards for the specification and selection of system components that guarantee equipment compatibility, quality, and effectiveness.

The following standards apply to all expansions or major renovations and to all new development. All irrigation system designs should be in conformance with all provisions of this article. For the range of these documents, the term "plan" refers to the irrigation design.

4.2. Valves

4.2.1. Automatic Control Valves

A. Provide automatic control valves with a manual flow control for downstream flow adjustment and manual closing.

B. Include in all valve manifolds schedule 80 PVC unions downstream of each control valve for easy removal and repair.

Include on the plan:

- Manufacturer
- Model number
- Size and location of each valve including master valves
- Flow in gallons per minute (gpm), design-operating pressure through each valve, and zone number

Prepare a detail-drawing showing:

- Installation
- Depths of bury for main and lateral lines
- Required fittings
- Valve box installation as specified in these documents

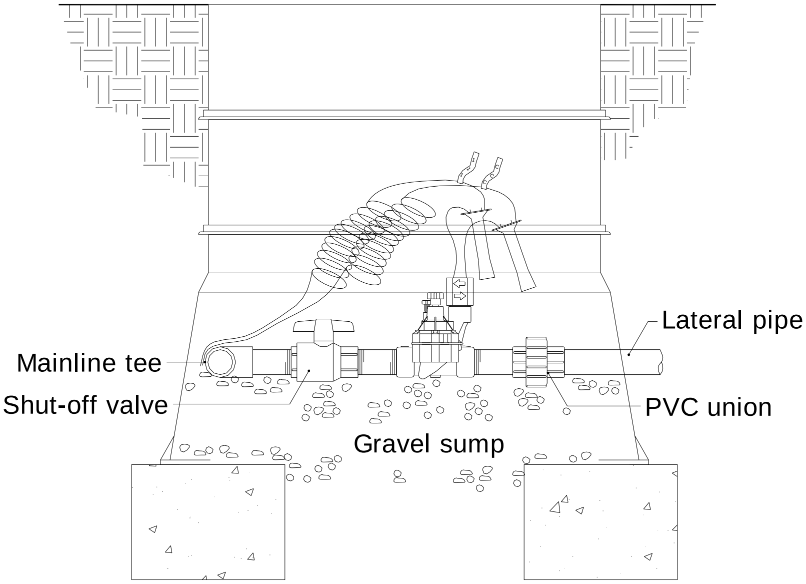


Figure 4-1: Automatic control valve assembly with isolation valve and union

4.2.2. Isolation Valves

A. Where systems have master valve assemblies, provide an isolation valve in the valve manifold upstream of the master valve as shown in Figure 4-1; the recommendation is a ball valve.
B. If the irrigation system does not have a master valve or the master valve is more than 10 feet from the point of connection (POC) then include an isolation valve at the POC; the recommendation is a ball valve.
C. Where systems have a single automatic control valve in the manifold assembly in a single valve box, provide an isolation valve for each valve as shown in Figure 4-1.
D. Where systems have multiple automatic control valves in the manifold assembly in a single valve box, provide a minimum of one isolation valve in the manifold upstream of the control valves as shown in Figure 4-2.
E. For looped mains, provide a minimum of two isolation valves.
F. Install isolation valves the same depths of bury as the mainline.
G. Where piping is 2½ inches or less, use globe or ball type isolation valves.
H. Where piping is three inches or larger, use push-on ring and gasket isolation valves.

Include on the plan:

- The manufacturer and model number
- Size and location of each isolation valve

Prepare a detail-drawing showing:

- Size and type of connecting pipe
- Fittings needed
- Valve box installation as specified in these documents

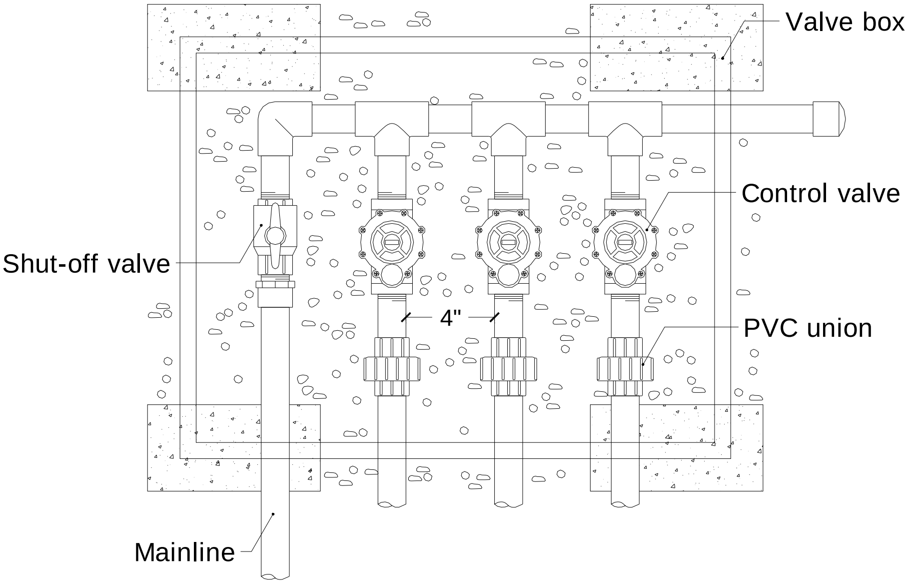


Figure 4-2: Isolation valve with valve manifold

4.2.3. Pressure Regulating Valves

A. Where the static pressure is greater than 80 psi, an adjustable brass pressure-regulating valve should be installed.
B. Where systems require a pressure-regulating valve, install the valve at the point of connection before the backflow preventer.
C. Assemble the pressure-regulator assembly in accordance with the manufacturer's instructions and the latest edition of the Uniform Plumbing Code.
D. Locate the pressure-regulator where there is sufficient side clearance for testing and maintenance within the pressure-regulator assembly.
E. The pressure-regulating valve may be installed in any position (i.e., horizontal or vertical).

Prepare a detail-drawing showing:

- Size and type of connecting pipe
- Fittings needed
- Valve box installation as specified in these documents

4.3. Valve Boxes

A. The construction of valve boxes should be able to withstand traffic loads common to the installation area.
B. Marking on covers should read "Control Valve".

4.4. Automatic Controllers

A. Use automatic controllers that have an adequate number of stations and power output per station to accommodate the irrigation system design, current, and future.
B. Where systems have independent water needs for each significantly different hydrozone and zones that require independent day schedules such as spray heads or rotors for turf areas, drip irrigation, bubblers for trees and shrubs, micro sprinklers, etc., select a controller that is capable of programming separate (multiple) water programs that will accommodate the design’s intent.
C. Use automatic controllers that are capable of programming a minimum of three start times to allow repeat cycles to avoid runoff.
D. Use automatic controllers that are capable of programming run times in one-minute increments per station and have LED read out.
E. Use automatic controllers that have non-volatile memory "total program memory retention" to hold the program and battery backup to keep current time during power failures.
F. Use automatic controllers that have a rain delay setting with auto resume.
G. Use automatic controllers that are UL listed and properly grounded according to manufacturer's recommendations and local electric codes.
H. A controller housing or enclosure is required that protects controllers from hazards of the environment at the installed location and should be vandal resistant.
I. Show the power supply/connection point and line location.

Include on the plan:

- Manufacturer
- Model number
- Type and location of each controller

Prepare a detail-drawing showing:

- The installation
- Required fittings
- Mounting height as specified in these documents.

4.4.1. Weather-Based Controllers (ET)

Weather-based irrigation controllers are an effective technology to reduce outdoor water use. Standard automatic irrigation timers water at set intervals regardless of plant water requirements; conversely, a weather-based irrigation controller uses weather data and site information to adjust watering times and frequency. This technology provides more efficient watering, reduces water run-off, and improves the health of the landscape.

Weather-based controllers estimate or measure depletion of available plant soil moisture in order to operate an irrigation system, replenishing water as needed while minimizing excess water use. A properly programmed controller requires initial site-specific set-up and will make irrigation schedule adjustments, including run times and required cycles throughout the irrigation season without human intervention.

4.5. Spray Heads

A. Where spray heads are specified in turf areas, use a minimum of a four-inch spring-loaded pop-up.
B. Where spray heads are specified in ground cover areas, use a minimum of a six-inch spring-loaded pop-up.
C. All spray heads should have filter screen devices to prevent clogging.
D. Where spray heads are specified along sidewalks, driveways, or in areas where damage from foot traffic or vandalism can occur, use flow shut-off devices.

Include on the plan:

- The manufacturer
- Model number
- Radius
- Required operating pressure
- Gallons per minute (gpm) for each sprinkler head nozzle
- Exact location of all sprinklers

Prepare a detail-drawing showing:

- The installation
- Depths of bury for lateral lines
- Required fittings of all sprinklers as specified in these documents

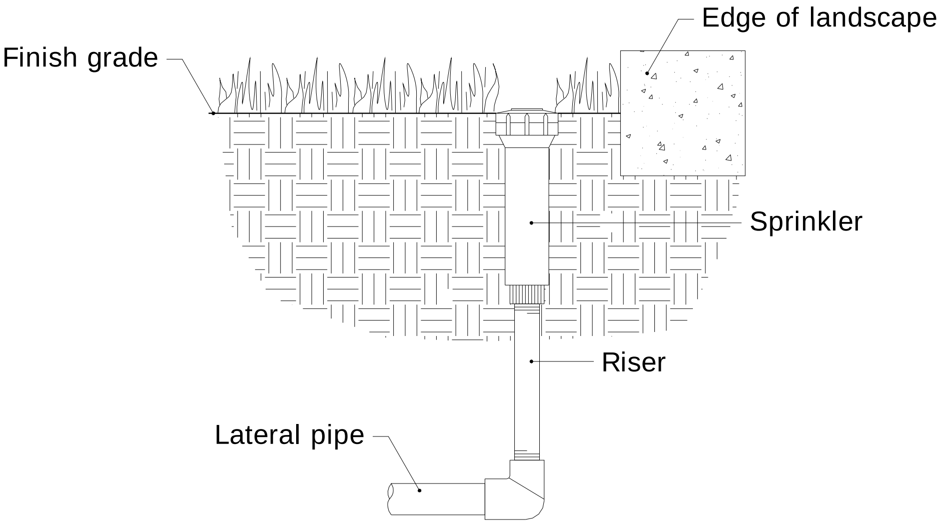


Figure 4-3: Typical sprinkler installation

4.6. Rotors

A. Impact sprinkler heads are non-matched precipitation heads and do not meet the pop-up height requirement; therefore, impact sprinklers should not be used.
B. Where rotors are specified in turf areas, use a minimum of a four-inch spring-loaded pop-up.
C. Where rotors are specified in ground cover areas, use a minimum of a six-inch spring-loaded pop-up.
D. Where rotors are specified along sidewalks, driveways, or in areas where damage from foot traffic or vandalism can occur, use flow shut-off devices.
E. All rotors should have filter screen devices to prevent clogging.

Include on the plan:

- The manufacturer
- Model number
- Radius
- Required operating pressure
- Gallons per minute (gpm) for each sprinkler head nozzle
- Exact location of all sprinklers

Prepare a detail-drawing showing:

- The installation
- Depths of bury for lateral lines
- Required fittings of all sprinklers as specified in these documents.

4.7. Stream Sprays & Bubblers

A. Where stream spray or bubbler nozzles are specified in areas where damage from foot traffic or vandalism can occur, use pop-ups with flow shut-off devices.
B. Use fixed flow pressure compensating flood bubbler nozzles that match the water requirement of the plant material when watering individual plants.

Include on the plan:

- The manufacturer
- Model number
- Radius
- Required operating pressure
- Gallons per minute (gpm) for each sprinkler head nozzle
- Exact location of all sprinklers

Prepare a detail-drawing showing:

- The installation
- Depths of bury for lateral lines
- Required fittings of all sprinklers as specified in these documents

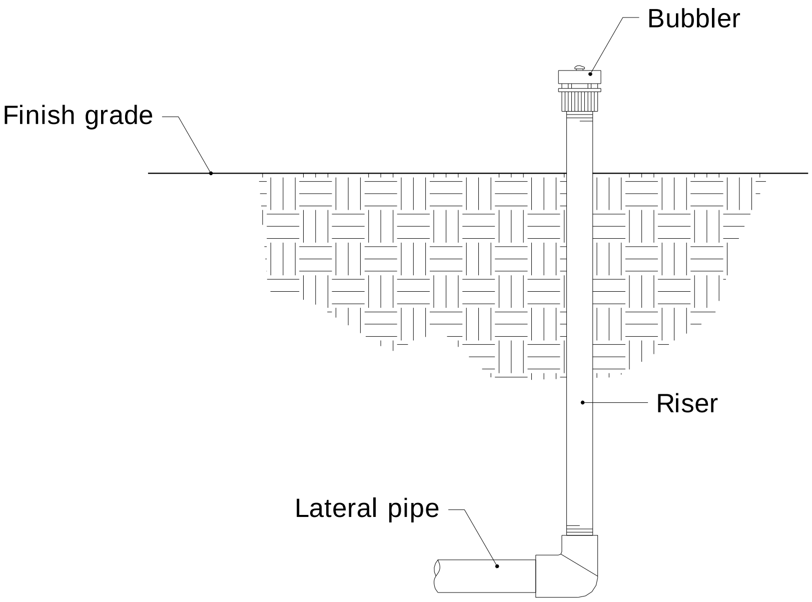


Figure 4-4: Typical bubbler installation

4.8. Swing Joints & Risers

The use of swing joints allows for easy adjustment of sprinklers to proper height and position.

A. Where systems are designed for large turf areas, sports fields, and areas where heavy maintenance equipment is used, use swing joint assemblies.
B. Use schedule 80 PVC risers for all sprinklers not requiring swing joints.
C. Galvanized risers are not recommended.
D. Use PVC schedule 40 riser extensions when necessary.
E. Cut-off risers and/or cut-off extensions are not recommended.

4.9. Pipe

4.9.1. Materials

Letters represent the kind of material used for the manufacture of plastic pipe, and four digits code thermoplastic pipe. The first two digits identify the type and grade of material; the last two indicate the hydrostatic design stress in units of 100 psi. PVC pipe will always have a code, such as PVC 1220. Either then it will have a designated class, such as class 200, or a schedule, usually schedule 40 or schedule 80.

Four elements make up the code: the materials, the type of compound, the grade of the compound, and the designed stress of the material; therefore, the code (PVC) (1) (2) (20) translates to: PVC materials, type 1 compound, grade 2 compound, and a design stress of 2,000 pounds. Do not confuse design stress with working pressure; it refers to the material strength only.

Example: PVC 1220

PVC = Poly Vinyl Chloride
1 = Type 1
2 = Grade 2
20 = 2000 psi hydrostatic design stress

Note that the first two digits are not indicative of quality. They are assigned in sequence as new compounds are submitted to the PPI for acceptance and classification.

4.9.2. Mainline

A. Where mainline pipe is 2½ inches in diameter or smaller, use schedule 40 PVC solvent weld pipe.
B. Where mainline pipe is 2½ inches in diameter or smaller, use schedule 40 PVC solvent weld type fittings.
C. Where mainline pipe is three inches in diameter or larger, use PVC pipe with a 200-psi or better pressure rating that has rubber gasket joints.
D. Where mainline pipe is three inches in diameter or larger, use push on, ring and gasket type fittings.
E. The use of PVC female threaded fittings on the mainline is not recommended.

Table 4-1: Thrust at fittings in pounds at 100 psi

Pipe Size	90 Bends	45 Bends	22-1/2 Bends	Dead End
1 ½"	415	225	115	295
2"	645	350	180	455
2 ½"	935	510	260	660
3"	1395	755	385	985
4"	2295	1245	635	1620
6"	4950	2710	1385	3550
8"	8300	4500	2290	5860
10"	12800	6900	3540	9050

Table 4-2: Safe bearing loads of various soils

Soil	Safe bearing load lbs per sq. ft.
Mulch, Peat, etc.	0
Soft Clay	1000
Sand	2000
Sand and Gravel	3000
Hard Shale	10,000

F. Indicate size of mainline on plan at all tees and changes in pipe size; specifically, charts are not acceptable as a replacement.

4.9.3. Spray Irrigation Lateral Pipe

A. Use PVC solvent weld pipe with a 200-psi or better pressure rating for all spray irrigation lateral piping; specifically, polyethylene pipe should not be used.
B. Use schedule 40 PVC solvent weld type fittings for all spray irrigation lateral piping.
C. Indicate size of lateral piping on plan at all tees and changes in pipe size; specifically, charts are not acceptable as a replacement.

4.10. Thrust Blocks

A. Thrust blocks must be used on all lines with rubber gasket joints.
B. Size thrust blocks based on the maximum line pressure, pipe size, and type of soil. Refer to Table 4-1 for thrust at fittings for a pressure of 100 psi. To determine total thrust for 150 psi multiply by 1.5.
C. To determine the bearing area to thrust blocks, refer to Table 4-2 for the safe bearing load of the soil and divide the total thrust by this safe bearing load.

For example, assume a 4000-pound total thrust was computed. The soil condition is sand. The required bearing area of the thrust block is 4000 pounds divided by 2000 pounds or two square feet.

Locate thrust blocks at all:

- Changes in direction, as at tees and bends
- Changes in size, as at reducers
- Stops, as at dead ends
- Valves, where thrusts may be expected

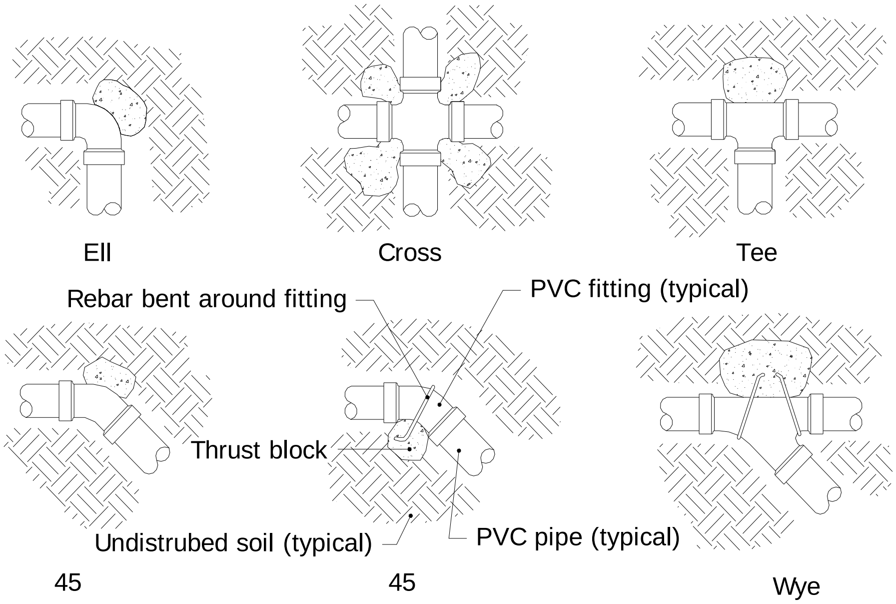


Figure 4-5: Typical thrust block installation

4.11. 24-Volt Control Wire

A. All 24-volt wire from controller to automatic valves should be type UF, solid copper, single conductor, PVC insulated; UL approved underground feeder wire direct burial in ground.
B. All 24-volt common wires should be white.
C. Include a separate common wire from the controller to each hydrozone to allow for sensor-based control of each hydrozone.
D. Show all wire routes and size on plan.

4.12. Backflow Prevention

A. Provide backflow prevention at all cross connections with water supplies in accordance with current Uniform Plumbing Code.
B. Locate backflow prevention before any outlets from the irrigation system and in locations that allow for inspection, testing, and servicing.

Potable water supplies to systems having no pumps or connections for pumping equipment, and no chemical injection or provisions for chemical injection, the following type of device must protect the potable water supply:

- Atmospheric vacuum breaker
- Pressure vacuum breaker
- Reduced pressure backflow preventer

Where sprinkler and irrigation systems have pumps, connections for pumping equipment, auxiliary air tanks, or are otherwise capable of creating backpressure, the following type of device must protect the potable water supply if the backflow device is located upstream from the source of backpressure:

- Reduced pressure backflow preventer

Where systems have a backflow device installed downstream from a potable water supply pump of a potable water supply pump connection, the following type of device must protect the potable water supply:

- Atmospheric vacuum breaker
- Pressure vacuum breaker
- Reduced pressure backflow preventer

Where systems include a chemical injector or any provisions for chemical injection, the following type of device must protect the potable water supply:

- Reduced pressure backflow preventer

Where systems have City potable water to supplement a reclaimed water supply, the following type of device must protect the potable water supply:

- Airgap separation

Where systems have reclaimed water and there is no interconnection with the potable water system, the following type of device must protect the reclaimed water supply:

- Reduced pressure backflow preventer

Where systems have City potable water to supplement a rainwater harvest supply, the following type of device must protect the potable water supply:

- Airgap separation
- Reduced pressure backflow preventer

4.12.1. Minimum Standards

The minimum required standard for irrigation systems connected to hose bibs and frost-free hydrants is a listed atmospheric vacuum breaker.

A. No backflow prevention device will be installed in any water supply piping when the diameter of the inlet or outlet of any such device or its connecting piping is less than the diameter of such water supply piping.
B. Size the backflow prevention device for the maximum flow of the system. Refer to the manufacturer's charts for the device where the installation of such device will not produce an excessive pressure drop; the charts will show the pressure losses for the range of flows for which the device is designed.
C. Provide metallic piping (e.g., galvanized or copper) for all vertical piping and all piping/fittings above grade.
D. If applicable, include freeze protection installation.

Include on the plans:

- The manufacturer
- Model number
- Size and location of each backflow prevention device
- Installation height as required by the highest outlet of all down stream piping

Prepare a detail-drawing showing:

- The installation
- Depth of bury for mainlines
- Required fittings
- Valve box installation as specified in these documents

4.13. Non-acceptable Backflow Prevention for Irrigation Systems

4.13.1. Double Check Valve (DC)

The double check valve consists of two spring loaded check valves connected in line. The double check is considered a low hazard device, because both check valves can become fouled without any visible signs and is not acceptable backflow prevention for irrigation systems.

4.13.2. Combination Valve/Vacuum Breaker

AVB:

AVB's consist of a body, a checking member, and an atmospheric opening. The AVB's air inlet valve closes when the water flows in the normal direction. However, as water ceases to flow the air inlet valve opens, thus interrupting the possible back-siphonage effect.

4.14. Approved Backflow Prevention for Irrigation Systems

4.14.1. Atmospheric Vacuum Breaker (AVB)

Application:

- Use an AVB to protect against either a pollutant or a contaminant, and only to protect against a back-siphonage condition.
- This assembly may not have valves or obstructions downstream, which includes gate valves, solenoid valves, quick coupling valves, and manual drain valves.
- The AVB may not be under continuous pressure.
- Do not use an AVB for more than twelve out of any twenty-four hour period.

Design Requirements:

- Locate the AVB downstream from all shut-off valves.
- Include one AVB downstream of each zone valve.
- Locate the AVB where the installed height is a least six inches above the highest piping or outlet downstream.

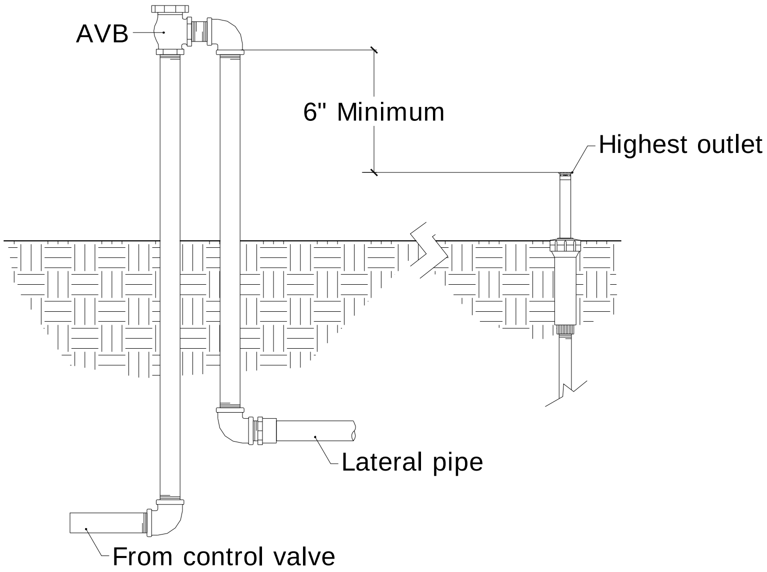


Figure 4-6: AVB assembly showing installed height above highest outlet

4.14.2. Pressure Vacuum Breaker (PVB)

Application:

- Use the PVB to protect against a pollutant or contaminant, and only to protect against back-siphonage; it is not acceptable protection against backpressure.
- Use where area being irrigated is lower than the backflow prevention assembly.
- The PVB may be under continuous pressure.

Design Requirements:

- Locate valves downstream after the assembly.
- Locate the PVB where the installed height is a least 12 inches above the highest piping or outlet downstream.
- Include unions a minimum of four inches above grade on each leg of PVB assembly.
- Include freeze protection; insulation from freezing using heat tape and heated protective enclosures are methods of freeze protection.

PVB:

PVB's include a check valve, which closes with the aid of a spring when flow stops. It also has an air inlet valve, which opens when the internal pressure is one psi above atmospheric pressure so that non-potable liquid may not siphon back into the potable water system. This assembly includes resilient seated shut-off valves and test cocks.

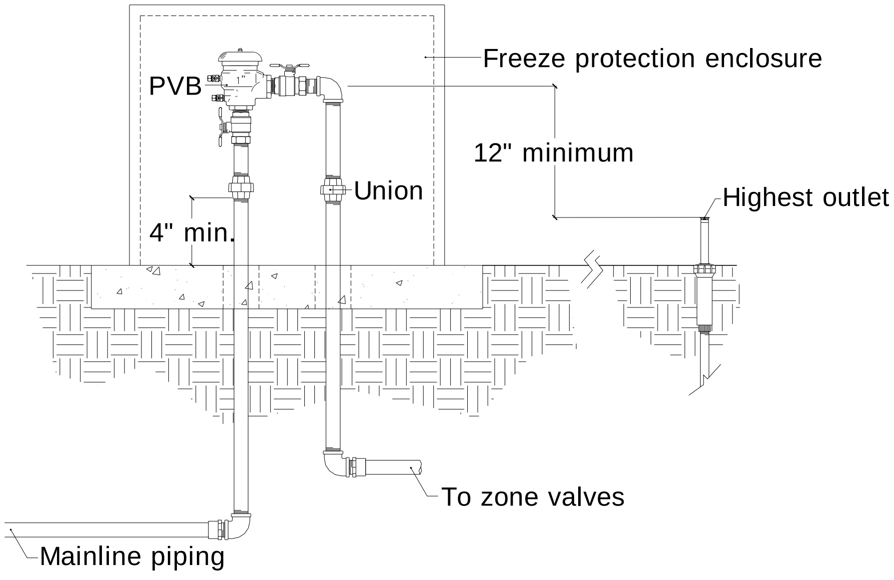


Figure 4-7: PVB assembly showing installed height above highest outlet

RP:

RP's consist of two internally loaded independently operating check valves and a mechanically independent, hydraulically dependent relief valve located between the check valves. The design of this relief valve is to maintain a zone of reduced pressure between the two check valves at all times. The RP also contains tightly closing, resilient seated shut-off valves upstream and downstream of the check valves along with resilient seated test cocks.

4.14.3. Reduced Pressure Assembly (RP)

Application:

- Use this assembly for the protection of the potable water supply from either pollutants or contaminants and use to protect against either back-siphonage or backpressure.
- Required when fertilizer or chemical injectors are used.
- Required when area being irrigated is higher than water source.

Design Requirements:

- Locate RP upstream of all valves.
- Include unions a minimum of four inches above grade on each leg of RP assembly.
- Locate fertilizer or chemical injectors after the RP.
- Include freeze protection; insulation from freezing using heat tape and heated protective enclosures are methods of freeze protection.

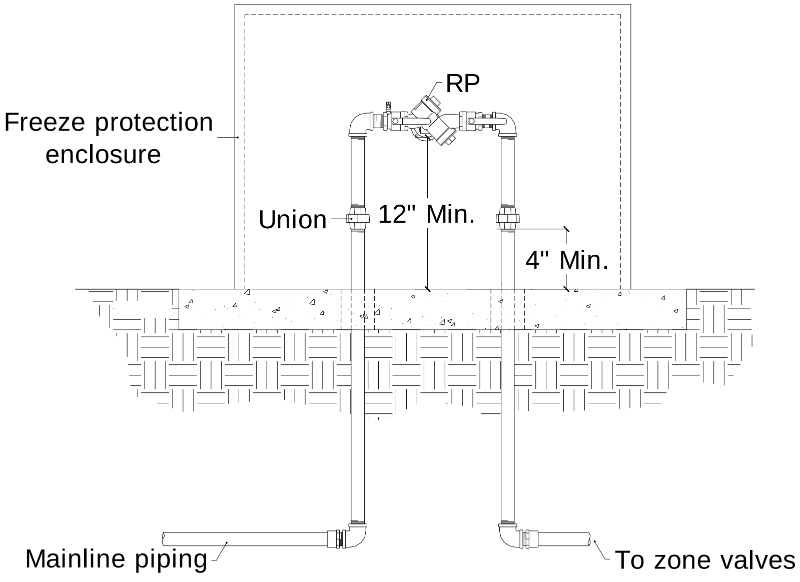


Figure 4-8: RP assembly

4.15. Freeze Protection (PVB, RP)

4.15.1. Heated Enclosures

A. Provide manufactured, heated, and insulated enclosure above ground.
B. Provide access panels to allow easy access for operations, maintenance, and testing of the backflow prevention device without removal of assembly.
C. Provide drain openings designed to remain closed except when the device is discharging water; the design of the openings must accommodate the maximum discharge of the backflow prevention device.

4.15.2. Heating Equipment

A. Include heating equipment for the enclosure designed and furnished by the manufacturer to maintain an interior temperature of +40° F with an exterior/outside temperature of -30° F and a wind velocity of 15 mph.
B. Provide an electric power source for heat and accessories, G.F.I. protected with at least six inches minimum clearance above any water discharge point and near the pipe riser on the enclosure access side or per local code.
C. For boxes using self-regulating tape heat source, secure tape to valve with wire ties or electrician's tape; no covering is necessary.

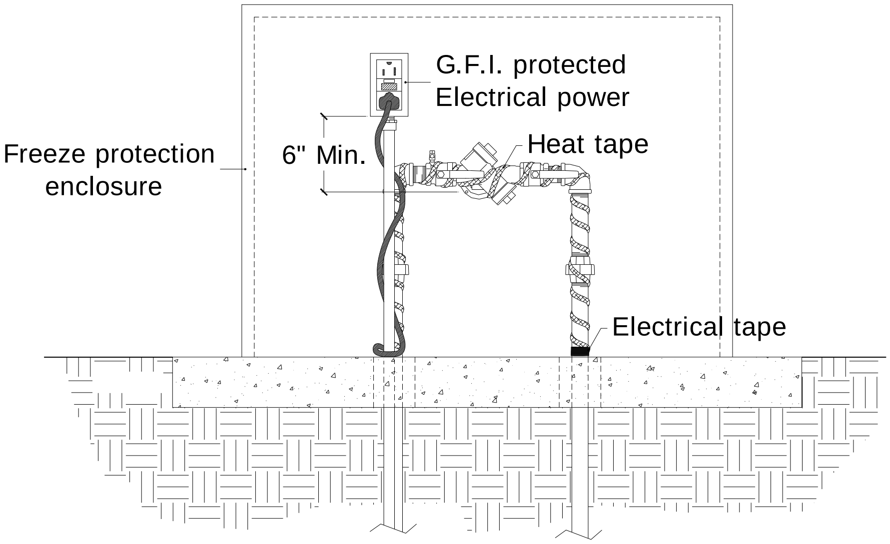


Figure 4-9: Heat tape

4.16. Automatic Drain Valves

Automatic drain valves will drain every time the irrigation system shuts off, thus wasting water. Freeze sensors may be an alternative by preventing irrigation systems from watering in freezing temperatures.

A. Automatic drain valves located in lateral piping should not be used.
B. Automatic drain valves on piping that is under constant pressure should not be used.

4.17. Drip Components

4.17.1. Drip Control Valves

Standard automatic control valves are typically used for drip systems. (See section III, 3.2.)

A. Control valves used on drip systems should open and close properly based on the design flow (gpm).
B. Pressure regulating control valves should regulate pressure when operated both electrically and manually.

4.17.2. Drip Controllers

Most standard controllers can be used for drip systems. (See section III, 3.4.)

A. Drip controllers should be capable of programming run times in both minutes and hours.
B. Where systems have independent water needs for each significantly different hydrozone and zones that require independent day schedules, select a controller that is capable of programming separate (multiple) water programs that will accommodate the design’s intent.

4.17.3. Drip Pressure Regulators

Pressure regulators are a required component. The drip system should operate at an acceptable range, typically between twenty and thirty psi. Excessive pressure will decrease uniformity and increase chances of equipment failure.

A. Include pressure regulators on all drip systems.
B. Large systems may require pressure regulators at key locations to deal with specific elevations in pressure.
C. Regulate pressure for each valve section to the manufacturer's recommended range for the drip emitters.
D. The pressure regulator can be a pressure-regulating valve or a separate device. The recommendation is to use a separate pressure regulator that is preset.
E. Size the pressure regulator to the correct flow according to the design flow (gpm) with consideration to future expansion.
F. Locate the pressure regulator downstream of the electric control valve and filter.

4.17.4. Drip Filters

Filters are a required component on every drip system. The most common problem with drip is clogged emitters and the filter acts as an insurance policy.

A. Provide a filter on every drip system regardless of the water quality.
B. Size the zone filter according to the total zone flow (gpm).
C. Select filter mesh size based on site water quality.
D. Provide one filter per zone.
E. Refer to manufacturer's recommendations for required mesh filtration of selected emitters.
F. Locate the filter downstream of the electric control valve.

4.17.5. Flush Valves

A. Design systems with sufficient pressure to flush the tubing in each run; as a rule, the system should have at least 10 psi to 15 psi of water pressure for flushing.
B. Design all systems with the capability of flushing out accumulated particulate matter.
C. Design system to provide a means for servicing such flushing requirements with a minimum of erosion or disruption to the surrounding landscape.
D. Provide manual flush valves (e.g., ball valves, manual drain valves, or flushable end caps) at the ends of all irrigation laterals.

4.17.6. Manifold Installation Order

A. Assemble drip components in the order: (1) Electric Valve, (2) Filter, and (3) Regulator.
B. Show the exact location of all drip components or assemblies.

Include on the plan:

- The manufacturer
- Model number
- Type of all drip components

Prepare a detail drawing showing:

- The installation
- Depth of bury for lateral lines
- Valve box installation
- Required fittings of all drip assemblies as specified in these documents

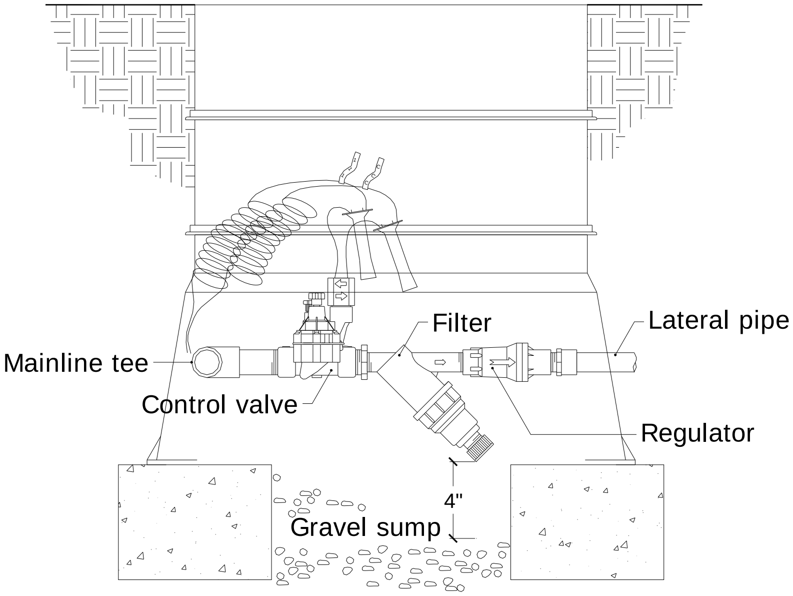


Figure 4-10: Drip valve and filter assembly

4.17.7. Drip Lateral Pipe

Drip main is typically three-quarter inch for commercial systems and one-half inch for residential. PVC is recommended when there are significant distances between the valve and the plant location where drip is required. Drip laterals are typically one-quarter inch.

A. Pipe for micro-irrigation may be PVC or polyethylene pipe (PE).
B. Use fittings manufactured specifically for the type and dimensions of the pipe used.

4.17.8. Fertilizer Injectors

Drip irrigation offers an advantage with fertilizer injectors where fertilizers and other chemicals can be applied uniformly and directly to the root zone.

A. Size and locate fertilizer injectors according to manufacturer's recommendations.
B. Locate fertilizer injectors downstream from an approved reduced pressure backflow prevention device.
C. Locate fertilizer injectors upstream of filters.

4.18. Monitoring Devices

Monitoring devices are recommended to maximize efficiency.

4.18.1. Soil Moisture Sensors

The automatic controller will be truly automatic with the use of soil moisture sensors. The irrigation controller is only as good as the program put into it. Soil moisture sensors wire into the irrigation system to prevent watering when adequate soil moisture is present, which saves water and reduces leaching of fertilizers.

In addition to saving water, soil moisture sensors offer turf managers labor savings opportunities. The sensors turn off the system automatically instead of having crews spending time turning controllers off or adjusting the run times.

Several critical factors need to be taken into consideration when deciding where to locate the sensors and how many to use. These factors include the varieties of plant material, sun exposure, topography, soil type, and irrigation method. The more variables present, the more sensor locations needed. Use soil moisture sensors to control individual valves or to override the whole irrigation controller.

Why use sensors?

Often water applied for irrigation results in runoff or deep percolation. With the need to conserve water and keep the landscape green, the designer should look for better ways to prevent wasted water.

The use of sensors added to the controller can prevent wasted water by turning off the controller when conditions are not favorable. In most cases, the devices will pay for themselves in just a short time.

Features and benefits:

- Adjustability to the point at which the sensor prevents irrigation
- Override switch for manual operation
- Works with all 24-VAC controllers

4.18.2. Rain Sensors

In a rain event, rain sensors shut off irrigation systems compensating for rainfall that occurs. When the sensor dries out, it will automatically reset. Rain sensors will save water with no more embarrassing moments when the sprinklers are on in the middle of a rainstorm.

Features and benefits:

- Adjusts to actuate at various rainfall quantities
- Works with all 24-VAC controllers
- Easy mounting
- Can add bypass switch
- Can be used in conjunction with other sensors

4.18.3. Freeze Sensors

Freeze sensors prevent irrigation systems from activation when the outdoors temperature drops to a near freezing level. When the temperature rises above that set point, the system resets to its regular cycle. Freeze sensors will prevent ice on driveways, sidewalks, and roadways plus the landscape.

Features and benefits:

- No adjustment necessary
- Can add bypass switch
- Can be used in conjunction with other sensors

4.18.4. Wind Sensors

Wind sensors prevent irrigation systems from activation during periods of high wind. They have adjustable shut down points and then automatically reset the system to operate when conditions are more favorable. Wind sensors will save water and only operate at the times that the water will reach its intended destination.

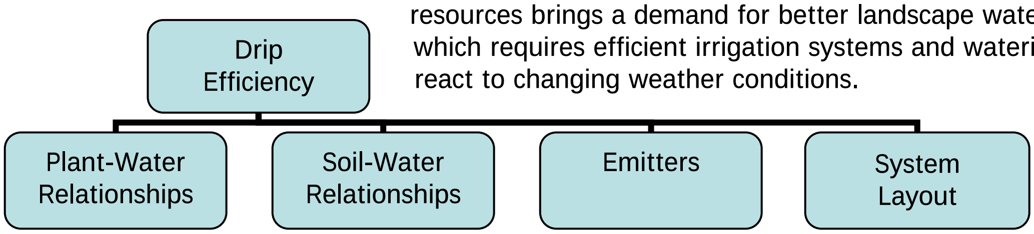
Features and benefits:

- Adjusts to actuate at various wind speeds
- Indicator light shows system shut down
- Two types of operation, normally open or normally closed
- Can add bypass switch
- Can be used in conjunction with other sensors

V. Drip Irrigation Design

5.1 Introduction

Drip irrigation systems are those that apply water to plant material at a slow application rate. When correctly designed, installed, and maintained drip systems operate with a high uniformity of water application where all plants receive the correct amount of water. The elimination of water transmission losses, runoff, and reduced evaporation contributes to a much higher efficiency than conventional spray irrigation systems. However, most installed drip systems are inefficient because the designer does not take into consideration plant-water relationships, soil-water relationships, emitters, and system layout. The growing concern over limited water resources brings a demand for better landscape water management, which requires efficient irrigation systems and watering schedules that react to changing weather conditions. The potential water savings using drip irrigation are the reductions in surface runoff, transmission losses, and in evaporation from the soil. These savings depend as much on the user of the equipment as on the equipment itself. Drip irrigation is not a substitute for other proven methods of irrigation; it is just another way of applying water.



This section applies to drip irrigation systems used on landscapes and does not apply to agriculture irrigation systems. The purpose of this section is to establish minimum design standards for the selection of drip system components that guarantee equipment compatibility, quality, and effectiveness.

The practice of drip irrigation design and installation varies considerably depending on the geographic location, soil conditions, and type of plants or turf irrigated. The information contained herein is for providing general guidance to the irrigation designer. Thus, specific conditions could require a deviation from these guidelines.

The planting scheme will determine the use of point source or line source emitters. Individual emitters generally irrigate individual plants that are sparsely spaced, which is a point source emitter system. Dense planting beds and closely spaced plants may require a line source, emitter system in which the entire bed is watered. In addition, some beds may require a combination of the two methods. Turf may require a line source, emitter system (subsurface irrigation) as an alternative to conventional irrigation.

The focus of this section is on point source irrigation for trees, shrubs, and ground cover. Turf and dense planting beds that require line source, emitter systems should adhere to manufacturer's design guidelines and recommendations.

5.2 Design Process

There is a major difference between the design processes of drip when compared with conventional overhead sprinkler systems. Almost the entire design is completed on a piece of paper and a calculator will be a requirement. It is not necessary to draw in every single emitter on the plan.

This section will cover:

- Plant-water relationships
- Soil-water relationships
- Emitters
- System layout

The irrigation designer should have a solid understanding of the soil-plant-water relationship. To get started, it is essential to produce an accurate scaled landscape design showing all locations of plant material to be watered and a plant list either from the landscape plan or from the field. A sample worksheet (Figure 5-1) is shown to help collect and organize site data. A full-size, reproducible blank worksheet is included at the end of this section.

Evapotranspiration				
Reference Month	July		Hydrozone	Middle Planter
Reference Period	31	days	Soil Type	Sandy Loam
Reference ET	4.51	in./period		

Landscape Coefficient (K_L) Ks x Kd x Kmc		Plant Root Zone (sq. ft.) d^2 x .7854			Emitters per Plant (A x 0.75) / A_s			Emitters per Plant Table 5-6	
Qty.	Plant Material	Species factor (Ks)	Density factor (Kd)	Climate factor (Kmc)	Landscape Coefficient (K_L)	Plant dia. (ft.) (d)	Root zone (sq. ft.) (A)	Emitter flow rate (gph)	Emitters per plant (n)
18	Blue Woolly Speedwell	0.5	1.0	1.3	0.65	1.5	1.77	1.0	2
5	Curlicue Sage	0.3	1.0	1.3	0.39	2.0	3.14	1.0	2
10	Elfin Pink Penstemon	0.5	1.0	1.3	0.65	1.4	1.54	1.0	2
7	Firewitch Garden Pink	0.5	1.0	1.3	0.65	1.5	1.77	1.0	2
7	Jupiter's Beard	0.5	1.0	1.3	0.65	3.0	7.07	1.0	2
9	May Night Meadow Sage	0.5	1.0	1.3	0.65	1.5	1.77	1.0	2
8	NM Hummingbird Mint	0.5	1.0	1.3	0.65	1.5	1.77	1.0	2
6	Poppy Mallow	0.5	1.0	1.3	0.65	2.6	5.31	1.0	2
6	Rocky Mnt. Penstemon	0.5	1.0	1.3	0.65	3.0	7.07	1.0	2
4	Walker's Low Catmint	0.5	1.0	1.3	0.65	2.0	3.14	1.0	2

Figure 5-1: Plant data worksheet

5.3 Plant-Water Relationships

5.3.1 Evapotranspiration

Plant water use (evapotranspiration) is composed of transpiration from the plant and evaporation from the soil. Plants use water to transport nutrients through the plant for cell development and temperature control. Most of the water used by plants in the desert southwest is for cooling. The job of the water manager is to keep the landscape healthy and green by replacing the used water. This is accomplished by managing the irrigation system to provide the right amount of water at the right time to meet the changing needs of the landscape.

Evapotranspiration (ET) is defined as the amount of water lost to the atmosphere by the combination of evaporation and transpiration of the plants growing in the soil and is typically expressed in inches of water per hour (in./hr.) or day (in./day). The rate of ET from the plant depends on the type of plant, stage of growth, moisture content of the soil, location, root depth, and the weather.

For example, to obtain potential ET (in./day) for the Santa Fe area for design purposes, refer to appendix A and reference the month of July, then divide by 31 to determine daily ET. This is just one method to determine daily ET. To produce accurate irrigation schedules, ET information for each month will be required.

5.3.2 Gallons per Plant per Day

The Gallons per Plant per Day Formula calculates how many gallons per day to apply to an individual plant. This formula helps the designer understand the plant water requirements for the landscape as well as differences in plant water requirements between plant types.

Gallons per Plant per Day Formula:

$$GPD = 0.623 \times A \times K_L \times ET$$

Where:

GPD = Gallons per plant per day
0.623 = Conversion factor
A = Plant root zone area (square feet)
K_L = Landscape coefficient
ET = Reference ET (inches per day)

5.3.3 Plant Root Zone Area (A)

Estimate the plant root zone area by using the canopy diameter or radius of the plant. Design the drip system for the mature size of irrigated plant material. This will reduce the need for future revisions and establish the maximum flow requirements of the piping system.

Plant Root Zone Area Formula:

$A = D^2 \times 0.7854$ or
$A = R^2 \times 3.1416$

Where:

A = Plant root zone area (square feet)
D = Canopy diameter (feet)
R = Canopy radius (feet)

5.3.4 Landscape Coefficient (K_L)

Landscape Coefficient Formula:

$K_L = K_s \times K_d \times K_{mc}$

Where:

K_L = Landscape coefficient
K_s = Species factor
K_d = Density factor
K_{mc} = Microclimate factor

What is a landscape coefficient?

To calculate the water requirement of an individual plant, the ET_r will require adjusting to account for specific conditions and the needs of the plant. The adjustment factor is the landscape coefficient (K_L).

The landscape coefficient varies with the combination of a plant species factor, density factor, and microclimate factor. The landscape coefficient for a given plant species will change as the density and microclimate change.

Evaluate each factor and assign it a numeric value to estimate the landscape coefficient.

It is very important to list each plant in the hydrozone and accurately identify factors that affect the hydrozone to match the varying plant water requirements.

Table 5-1: Species factor (K_s)

Vegetation	High	Medium	Low
Trees	0.8	0.5	0.3
Shrubs	0.7	0.5	0.3
Ground Cover	0.8	0.5	0.3

Table 5-2: Density factor (K_d)

Vegetation	High	Average	Low
Trees	1.3	1.0	0.5
Shrubs	1.1	1.0	0.5
Ground Cover	1.1	1.0	0.5

Table 5-3: Microclimate factor (K_{mc})

Vegetation	High	Moderate	Low
Trees	1.4	1.0	0.5
Shrubs	1.3	1.0	0.5
Ground Cover	1.2	1.0	0.5

Species Factor (K_s) is a value given to differentiate plant species to account for their varying evapotranspiration rates. For practical purposes, a category of high, medium, or low will define all ornamental plants. High water use plants will require about 70 percent to 80 percent of reference ET, medium water use plants about 50 percent, and low water use plants less than 30 percent. Native plants that are established may require no supplemental irrigation. Values for species factors are sometimes available through local sources. When available, this data tends to be more accurate.

Density Factor (K_d) is a value given to a planting area to account for the vegetation density. Newly planted and sparsely planted landscapes often have less leaf surface area than mature, dense landscapes and typically would use less water. Sparsely planted landscapes typically use less water and a dense planting will he higher.

Microclimate Factor (K_{mc}) is a value given to a planting area to account for environmental conditions. A high microclimate condition is one in which wind, heat-absorbing surfaces, or heat-reflecting surfaces affect the landscape. A low microclimate condition is one in which shade or protection from wind affect the landscape. An average microclimate condition is one in which any of these factors do not influence the site.

5.4 Soil-Water Relationships

Drip irrigation systems depend upon the soil to move and store water. Soil properties determine how much water the soil can hold and how much of that water will be available to the plants. Consider the soil as a reservoir for water and the amount of water available to plants depends upon the depth of the roots in this reservoir. A fundamental prerequisite for the designer is understanding soils and soil-water relationships, which greatly affects the irrigation design and irrigation schedule.

5.4.1 Available Water

The amount of water available for the plant depends on soil properties. A sandy soil has a low value for available soil moisture, whereas a clay soil has moderately high available soil moisture. A loam soil has the highest available soil moisture of any soil. In other words, sand has the smallest tank and loam has the largest tank. Soil water holding capacity is measured by inches of water per inch of soil.

5.4.2 Wetting Patterns

Wetting patterns show the relationship between vertical and horizontal movement of water in the soil up to the maximum wetted diameter. Once the maximum wetted diameter is reached, water movement is downward.

Unlike conventional irrigation, drip irrigation only wets part of the soil root zone. The wetting patterns, which develop from dripping water onto the soil, depend on discharge and soil type. Figures 5-2 and 5-3 show the effect of changes in discharge on two different soil types, namely sand and clay.

Sandy soils typically result in limited lateral water movement and rapid downward water movement. Therefore, the wetting pattern will be deep, with little lateral spread. Clay soils will typically result in a broader lateral water movement and of moderate depth. Compacted clay soils will experience a wetted zone that is wider and shallow.

Water movement in soils is affected by the condition of the topsoil, the permeability of the subsoil, layers of soil with varying properties, and the presence of compacted layers within the soil profile as well as the application rate.

Wetted Area:

Gravity and capillary action act upon water when applied to the soil. The effects of these forces working together produce a wetted pattern influenced by both soil type and application rate.

A higher application rate will produce a wider zone of saturation under the emitter. Light sandy soils require water application at higher rates to widen the wetted pattern. Heavy clays and clay loams require water application at lower rates to avoid surface ponding and runoff, and promote deeper water penetration.

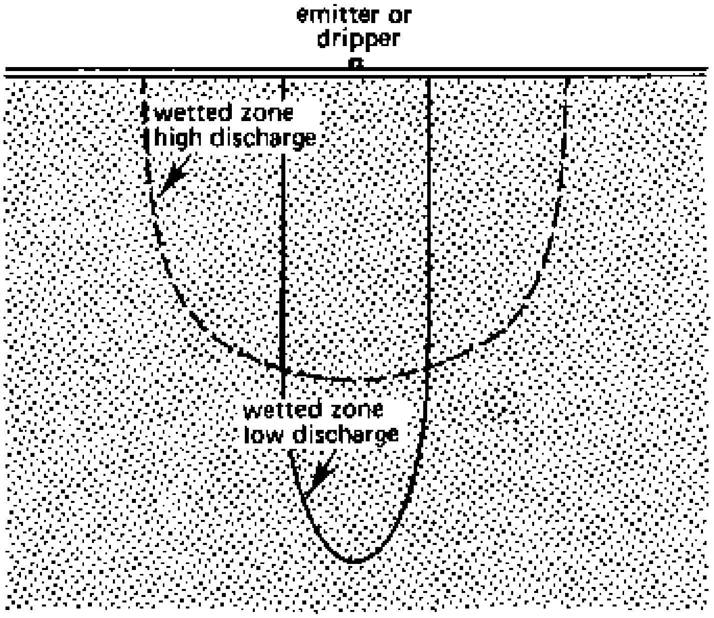


Figure 5-2: Wetting patterns for sandy soils with high and low discharge rates

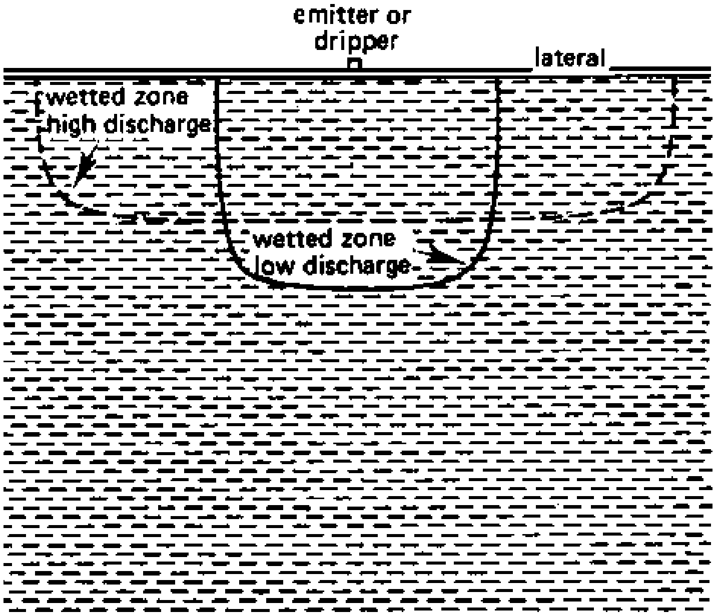


Figure 5-3: Wetting patterns for clay soils with high and low discharge rates

5.4.3 Soil Types

Soil is made up of sand, silt, and clay particles. The percentage of each of these three particles is what determines the actual soil type.

A simple way to determine the soil type is to take a sample from a representative part of the site and place the moistened soil sample in your hand and squeeze. Table 5-4 lists the general characteristics of the three main soil types.

Table 5-4: Determining the soil type

Soil type	Characteristics
Course (Sand)	Soil particles are loose. Squeezed in the hand when dry, it falls apart when pressure is released. Squeezed when moist, it will form a cast, but will crumble easily when touched.
Medium (Loam)	Has a moderate amount of fine grains of sand and very little clay. When dry, it can be readily broken. Squeezed when wet, it will from a cast that can be easily handled.
Fine (Clay)	When dry, may form hard lumps or clods. When wet, the soil is quite plastic and flexible. When squeezed between the thumb and forefinger the soil will form a ribbon that will not crack.

The jar test method is another method for determining soil types.

Supplies needed:

- 1 quart “Mason” jar with straight sides and a tight lid
- 2 cups of a representative sample of soil
- Water
- Ruler

What to do:

- Put the soil into the jar
- Fill the jar with water
- Shake until the soil particles are suspended in the water

What to expect:

- The sand will settle in the bottom of the jar in about one minute
- The silt layer will settle on top of the sand in two to three hours
- The clay layer will settle on the silt in about twenty-four hours
- Some clay particles and organic matter may not settle at all

After approximately 24 hours, measure each layer (sand, silt, and clay) and determine the percent for each layer. Use the chart below to determine the soil type. For example, a soil with 40 percent sand, 40 percent silt, and 20 percent clay is classified as medium loam.

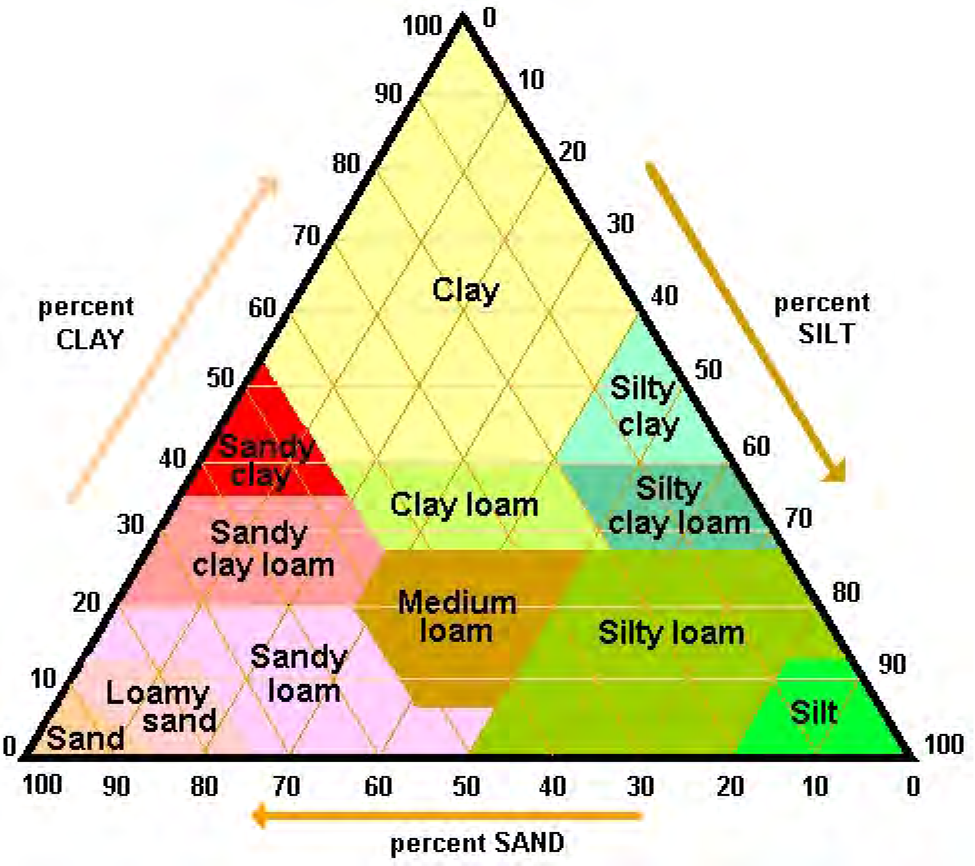


Figure 5-4: Soil triangle

5.5 Emitters

Emitters are the most important component of a drip system.

5.5.1 Emitter Selection

The local irrigation supply store will have several emitter types and flow rates in which to choose. Two import factors to consider are pressure compensating vs. non-pressure compensating. For the experienced designer, non-pressure compensating emitters work well on moderate, uniform terrain. Likewise, pressure compensating emitters are required for systems with lateral distances of more than 150 feet, slopes, and rolling terrain.

Conversely, a novice designer should consider using only pressure compensating emitters to guarantee uniform coverage and avoid the “Law of Diminishing Returns.” Diminishing returns in the landscape simply implies that with a poorly designed drip system, there is a gradual reduction in plant growth in relation to the distance that the plants are from the water source; (i.e., the greater the distance from the water source results in lower pressure and reduced water flow to the plant). This is because of hydraulic constraints and pressure loss throughout the irrigation system.

The selection of emitter by flow rate (gph) is dependant on the soil type. Sandy soils require water application at higher rates. Thus, 0.5 gph emitters are not recommended. Clay soils, on the other hand, often benefit from a lower water application rate. A low rate avoids surface ponding and runoff and promotes deeper water penetration.

5.5.2 Emitters per Plant

Because only part of the root zone is wetted with each emitter, it is important to design the irrigation system with the correct number of emitters per plant. Determining the number of emitters required per plant is part science, part math, and partly a judgment call by the designer. The recommendation is to give each plant a minimum of two emitters.

The incorrect way to assign emitters per plant is the "rule of thumb" of one emitter for a 5-gallon plant, two emitters for a 10-gallon plant etc. This does not allow for the mature size of plant material. In other words, some plants will receive too much water and the rest will not receive enough resulting in a very inefficient system.

A common problem with drip irrigation is installing a system with the incorrect number of emitters and trying to over compensate by increasing the watering time. Because of soil properties, "once the maximum wetted diameter is reached, water movement is downward," water infiltrates past the active root zone. Additionally, the amount of the water that a soil can hold is limited. Therefore, the increased watering time infiltrates water past the root zone wasting water. The result is restricted plant root zones, unhealthy plants, wasted water, and a high water bill.

A. Provide and space emitters to wet a minimum of 75 percent of the root zone for irrigated plant material at all stages of growth.
B. Determine the number of emitters per plant; divide the square footage of the emitter-wetted area (Table 5-5) by 75 percent of the square footage of plant root zone.
C. Use emitters with same flow rate throughout zone to achieve maximum efficiency.
D. Do not use emitters with different flow rates for the same plant.

Emitters per Plant Formula:

$$\text{Emitters per plant} = \frac{A \times 0.75}{A_s}$$

Where:

A = Plant root zone area (square feet)
0.75 = 75% of plants root zone
A_s = Emitter wetted area (square feet)

For example, determine the number of emitters for a plant with a nine-foot diameter in loam soil using one-gph emitters. In the formula, the plant diameter (9') is squared and multiplied by 0.7854 to find the plant, root zone area (sq. ft.) and then multiplied by 0.75, which equals 4.77. The next step is to divide 4.77 by the emitter-wetted area from Table 5-5. For this example, we are conservative and use 20. The result is 2.39 in which we round to two.

$$\text{Emitters per plant} = \frac{(9^2 \times 0.7854) \times 0.75}{20}$$

Table 5-6 shows the number of emitters per plant using average area (sq. ft.) from Table 5-5.

Table 5-5: Wetting pattern of emitters

Soil Type	Emitter Flow (gph)	Wetted Area	
		Diameter (ft.)	Area (sq. ft.)
Sandy	0.5	2.0 – 3.0	3 - 7
	1.0	3.0 - 3.5	7 - 10
	2.0	3.5 – 4.0	10 - 13
Sandy Loam	0.5	3.0 - 4.5	7 - 16
	1.0	4.5 – 5.0	16 - 20
	2.0	5.0 – 5.5	20 - 24
Loam	0.5	3.0 – 5.0	7 - 20
	1.0	5.0 – 6.0	20 - 28
	2.0	6.0 – 7.0	28 - 38
Clay Loam	0.5	4.0 – 6.0	13 - 28
	1.0	6.0 – 7.0	28 - 38
	2.0	7.0 – 8.0	38 - 50
Clay	0.5	5.0 – 7.0	20 - 38
	1.0	7.0 – 8.0	38 - 50
	2.0	8.0 – 9.0	50 - 64

Table 5-6: Number of emitters per plant by soil type

Plant Dia. (ft.)	Area (sq. ft.)	Sandy Soil			Loam Soil			Clay Soil		
		0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0
1	1	Not Recommended	*1	*1	*1	*1	*1	*1	*1	*1
2	3		*1	*1	*1	*1	*1	*1	*1	*1
3	7		*1	*1	*1	*1	*1	*1	*1	*1
4	13		*1	*1	*1	*1	*1	*1	*1	*1
5	20		2	*1	*1	*1	*1	*1	*1	*1
6	28		2	2	2	*1	*1	*1	*1	*1
7	38		3	2	2	*1	*1	*1	*1	*1
8	50		4	3	3	2	*1	*1	*1	*1
9	64		5	4	3	2	*1	2	*1	*1
10	79		7	5	4	2	2	2	*1	*1
11	95		8	6	5	3	2	2	2	*1
12	113		9	7	6	4	3	3	2	*1
13	133		11	8	7	4	3	3	2	2
14	154		13	10	8	5	4	4	3	2
15	177		15	11	9	6	4	5	3	2
20	314		26	20	17	10	7	8	5	4
25	491		41	31	26	15	12	13	8	6
30	707		59	44	38	22	17	18	12	9

*Recommend minimum of 2 emitters per plant

Emitter Placement:

An important factor in the performance of the irrigation system is the placement of the emitters. The location of the emission device in relation to the plant will affect germination and early growth, establishment of the root system, efficient utilization of water and nutrients, and the effects of salinity on the plant.

Salts present in the soil or in the irrigation water will be concentrated at the perimeter of the wetted zone formed around the emission device. The placement of the emitter will determine whether harmful salts are pushed out and away from the root zone or concentrated within it.

5.6 System Layout

5.6.1 Emitter Placement

A common and very poor practice used by contractors is to locate all emitters at the trunk of the plant. This practice of placing one or more emitters at a plant's base is responsible for the "Drip Junkie" in which roots are not encouraged to grow beyond the root ball. Figure 5-5 shows a cutout view of correct emitter placement and resulting wetting pattern.

A. Emitter placement on moderate, uniform terrain: obtain optimal wetting of the root zone by spacing the emitters in a circle, three-quarter of the way between the trunk of the plant and its dripline.
B. On a slope, moisture in the soil will percolate downhill, resulting in more water application at the bottom of the slope; thus, place emitters on slopes by adjusting the spacing of the emitters towards the top of the slope.
C. On a slope, space rows normally at the top two thirds and gradually increase the spacing in the bottom one-third.
D. When elevation change is 10 feet or more, zone the bottom one-third of the slope separately.

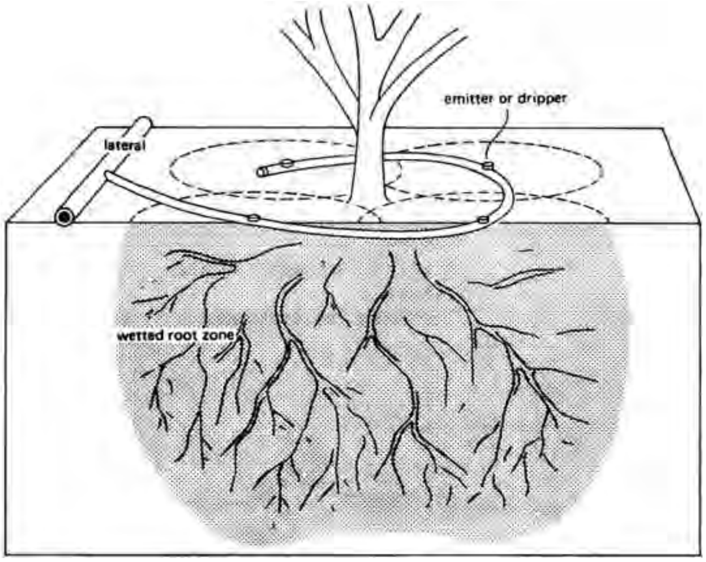


Figure 5-5: Emitter layout and wetted pattern

5.6.2 Hydrozones

A hydrozone is the grouping of plants in an area served by one control valve or zone. All the plants in the hydrozone will be irrigated on the same schedule.

5.6.3 Connecting the Dots

The irrigation designer should have a good understanding of the soil-plant-water relationship. This understanding is very important for the next step, tying the drip system together and making the hydraulics work, as well as developing proper irrigation schedules, which also requires common sense and a little bit of effort.

Considerations for grouping plants in a hydrozone are:

- Limitations with different plant water needs
- Hydraulic constraints
- Economic considerations
- Root zone depths
- Microclimates
- Soil types

Typically, drip irrigation literature recommends that “System layout is easy. Once you determine the type, numbers, and spacing of emitters required for each plant, ***SIMPLY*** determine the most economical way to connect the various emission devices to the water source.”

But Hold On, this is where you will make a very important decision, either to follow their recommendation and fail if the goal is an efficient drip system or succeed with designing an efficient and effective drip system by taking into consideration microclimates, plant types, and plant root zones.

For example, a typical watering schedule for the month of July, with sandy soil, 1 gph emitters, ET – 5.05 in./month, and a moderate microclimate looks something like this:

- Medium water use trees – 5 days per month @ 170 minutes
- Medium water use ground cover – 16 days per month @ 15 minutes
- Low water use shrubs – 5 days per month @ 51 minutes
- High water use shrubs – 11 days per month @ 54 minutes

The example above demonstrates why it is necessary to zone the different plant types separately. Both low and high water use shrubs show approximately 50-minute watering times; however, the low water use shrubs only need to be watered half as often. Likewise, low water use shrubs and medium water use trees require five days per month; however, the trees require a longer run time.

Now take into consideration microclimates in which the same type of shrub located in two different microclimates will have different water requirements and require separate zone valves. Additionally, a site with more than one soil type will require separate zone valves. Therefore, a hydrozone should only include similar plant types and watering depths, one soil type, emitters with the same flow rate, and one microclimate.

5.6.4 Sectioning

Different irrigation methods should be separated. Sprinklers, bubblers, microsprays, drip, and subsurface irrigation should be operated off separate valves.

Separate valves should be assigned to:

- Plants on slopes
- Different soil types
- Different microclimates
- Trees and shrubs
- Plants with different water needs

5.7 System Hydraulics

Section III, Design Criteria covers system hydraulics, sizing components, and friction loss. System hydraulics in drip irrigation systems is a critical step in the design process due to the low operating pressures. The operating pressure throughout the irrigation system should remain constant to maintain efficiency.

5.7.1 Pressure Loss Calculations

Pressure loss calculations from the point of connection and the valve are identical for both conventional irrigation and drip irrigation. Pressure loss calculations for drip laterals will require the total flow of the hydrozone.

A. The total flow is the sum of all emitters in the zone.
B. Convert gallons per hour (gph) to gallons per minute (gpm) by multiplying gpm by 60.
C. Keep the flow rate through each lateral (1/2 inch) less than 4 gpm (240 gph) to meet the less than five feet per second (fps) rule.
D. Do not exceed 500 feet for drip laterals when using one-half inch polyethylene tubing.

5.7.2 Flow per Zone

Flow per Zone Formula:

$$\text{Flow per zone} = \frac{\text{Number of emitters x gph}}{60}$$

Where:

Flow per zone = total gallons per minute (gpm)
Number of emitters = total number of emitters per zone
Gph = gallons per hour flow of one emitter

5.8 Maintenance

In a low-volume system, maintenance is more detail-oriented. Clean filters on a regular basis. Site reviews require scrutiny for signs of plant stress caused by a clogged emitter.

Installation:

- During installation, make sure components are placed for easy access.
- Completely flush the system prior to operation to remove all debris.
- During first month, inspect and clean all filters.
- Establish a cleaning schedule based on the amount of debris found during inspections.
- During first month, perform walk-through inspections for signs of plant stress; turn system on and carefully check each emission device for proper operation.

Regular Maintenance:

- Every two to four months flush all lines; examine water sample for signs of debris and suspended matter, and flush until water runs clear.
- Every two to four months examine and clean all filters, and replace filters if necessary.
- Perform a walk-through to look for signs of plant stress.
- Check all emission devices for location and flow; adjust, clean, or replace emission devices as required.
- Inspect the irrigation controller to make sure it is working and that the watering schedule is properly set.
- Ensure all emitters are visible and above finished grade.
- With the system on, visually inspect for leaks or damage to emitters, connectors, or tubing.
- Plug emission points where plants have died and not replaced.

5.9 Blank Site Data Worksheet

Evapotranspiration

Reference Month			Hydrozone	
Reference Period		days	Soil Type	
Reference ET		in./period		

Landscape Coefficient (K_L) Ks x Kd x Kmc		Plant Root Zone (sq. ft.) d^2 x .7854			Emitters per Plant (A x 0.75) / A_s			Emitters per Plant Table 5-6	
Qty.	Plant Material	Species factor (Ks)	Density factor (Kd)	Climate factor (Kmc)	Landscape Coefficient (K_L)	Plant dia. (ft.) (d)	Root zone (sq. ft.) (A)	Emitter flow rate (gph)	Emitters per plant (n)

VI. Irrigation Schedules

6.1. Introduction

The objective of proper irrigation scheduling is to apply the right amount of water before harmful stress occurs and to apply enough water at that time to replenish the amount of water used since the last irrigation without over watering. A schedule defines the day(s) of the week, the time(s) of the day, and how long a station or circuit is activated to apply water.

The irrigation designer should prepare irrigation schedules in response to plant water needs as created by the plant's response to current weather conditions. The schedule should reflect that plants will require more water when it gets hotter and different plants use water at different rates. Soil types, different watering methods, and combinations of plant materials added to the mix will complicate the process. The designer should take into account all of these factors on a zone-by-zone basis.

When developing irrigation schedules, it is very important to consider the interaction between weather, plants, soils, and irrigation systems. The designer will determine the water needed by weather, efficiency, and type of plant. The soil type will influence the frequency of water application.

Soil properties determine how much water the soil can hold and how much of that water will be available to the plants. Consider the soil as a reservoir for water and the amount of water available to plants depends upon the depth of the roots in this reservoir. The designer should know how the water moves into the soil and the amount of water that the soil will store for the plants to use.

The goal is to sustain the soil moisture content near field capacity when there is a good balance between soil moisture tension and aeration. Field capacity is a measure of water held by the soil against the influence of gravity. A soil is usually at field capacity when allowed to drain for 24 hours after being saturated by rainfall or irrigation. Saturation is when 100 percent of the pore space is filled with water and all oxygen is displaced. Conversely, permanent wilting point is the soil moisture content at which the plant wilts and remains in a wilted state and dies.

6.2. Base Schedules

Irrigation schedules are developed based on certain reference periods. A base schedule represents each reference period over the course of the year, typically for each month of the year. The schedule should be able to function within the limits and capabilities of the controller.

A. Develop a new base schedule at each point during the season the irrigation frequency changes.
B. Develop a base schedule for each month of the growing season where the frequency can be raised or lowered during that month without changing the station runtimes.

Provide a seasonal (twelve month) watering schedule for the mature landscape per each station including:

- Runtimes per station
- Cycles per day
- Days per week or frequency

If applicable, provide an additional watering schedule for new plant material and/or turf.

- The schedule should reflect recommended watering practices to establish new plant material for the time of year the installation is to be completed.

When application rates exceed soil infiltration rates:

- Determine how long a station can operate before run-off occurs, and divide the run time necessary to meet the plant water requirements by this factor.

Provide laminated schedules for the proper operation and maintenance of the irrigation system:

- Provide and install in each of the controller vaults on the project, a waterproofed irrigation schedule laminated in plastic.
- When applicable, replace watering schedules with updated versions to include all changes in the installed irrigation system and results from landscape irrigation audits.
- Provide copies of the irrigation schedules and diagrams in the operations and maintenance manual.

To Water or Not!

Low water use plants normally can survive on rainfall; however, supplemental irrigation will be required for one to two growing seasons to promote establishment. Once established, (approximately 2-3 years) some irrigation may be required in hot summer months and during periods with less than normal rainfall to maintain acceptable appearance and plant health.

“Water Deep & Infrequently”

Frequent watering creates shallow, weak root systems and poor plant health. Watering beyond the active root zone and frequent irrigations waste water. The soil should be allowed to dry between irrigations. Soil texture and plant rooting depth determine the length of time and frequency of the irrigation schedule.

Therefore, watering deep means watering to the depth of the plant’s active root zone (e.g., turf-6,” shrubs-12,” and trees-18”), and watering less frequent means allowing the soil to dry out (approximately 50 percent) between irrigations.

What is Evapotranspiration?

Evapotranspiration (ET) is the sum of water lost to the atmosphere by the combination of evaporation from the soil surface and transpiration of the plants growing in the soil. Many factors affect the rate of ET, including plant species, weather factors, and the amount and quality of water available to the plant.

What is Reference Evapotranspiration?

The calculation of reference evapotranspiration is a useful way to quantify weather data. It can be based on alfalfa (ET_r) or turf (ET_O). ET_O is defined as the ET of well watered, 4-to-6 inch tall cool season grass. ET_r is the reference evapotranspiration for alfalfa.

6.3. Irrigation Scheduling

The following discussion follows each line of the Base Schedule Worksheet located at the end of this section to show the process of developing a schedule step-by-step. (These letters correspond with the letters on the Base Schedule Worksheet).

6.3.1 (I.) Plant Water Requirement

A. Plant Material

- The two major classifications of turf grass found in landscapes are cool season grass and warm season grass; water requirements will vary depending on the plant material.
- The classifications of plants found in landscapes are ornamentals (e.g., trees, shrubs, and groundcovers); water requirements will vary depending on the plant material (e.g., high, medium, or low water use).

For example, a low water use shrub.

B. Reference Period

The reference period is a management decision. Typically, base schedules are developed for each month of the year. For monthly schedules, the reference period would be the number of days in the actual month.

For example, 31 days for the month of July.

C. Reference Evapotranspiration (ET_r)

Plant water use (evapotranspiration) is composed of transpiration from the plant and evaporation from the soil. Plants use water to transport nutrients through the plant, for cell development and temperature control. Most of the water used by plants in the desert southwest is for cooling. The job of the water manager is to keep the landscape healthy and green by replacing the used water. This is accomplished by managing the irrigation system to provide the right amount of water at the right time to meet the changing needs of the landscape. The rate of Evapotranspiration (ET) from the plant depends on the type of plant, stage of growth, moisture content of the soil, location, root depth, and the weather.

ET is expressed in terms of a depth of water per unit of time, such as inches per day, week, month or year. Reference ET (ET_r) is a useful reference point for irrigation water use calculations because it represents a specific rate of use in response to the local weather conditions. The designer should use local ET information whenever possible to determine the plant water requirement.

For example, the reference Evapotranspiration (ET_r) for the month of July in Santa Fe is 5.68. To produce accurate irrigation schedules, ET information for each month will be required.

Reference evapotranspiration can be obtained from a number of sources:

- The Cooperative Extension Service is the educational outreach arm of New Mexico State University's College of Agriculture and Home Economics in Las Cruces. Visit http://www.cahe.nmsu.edu/ces/ on the Internet for the nearest extension office.
- For New Mexico weather information, visit http://weather.nmsu.edu/.
- Visit the National Climate Data Center at http://www.ncdc.noa.gov/
- Visit the Western Regional Climate Center at http://www.wrcc.dri.edu/.
- A source of ET is an average of weather over a thirty-year period. Appendix A has historic ET information in monthly intervals if local information is not available.

D. Landscape Coefficient (K_L)

To calculate the water requirement of an individual plant, the ET_r will require adjusting to account for specific conditions and the needs of the plant. The adjustment factor is the Landscape Coefficient (K_L).

The Landscape Coefficient (K_L) varies with the combination of a plant Species Factor (K_s), Density Factor (K_d), and Microclimate Factor (K_{mc}). The landscape coefficient for a given plant species will change as the density and microclimate change. Evaluate each factor and assign it a numeric value to estimate the landscape coefficient.

Landscape Coefficient Formula:

$$K_L = K_s \times K_d \times K_{mc}$$

Where:

K_L = Landscape coefficient
K_s = Species factor
K_d = Density factor
K_{mc} = Microclimate factor

Table 6-1: Species factor (K_s)

Vegetation	High	Medium	Low
Turf Grass	0.8	0.65	0.5
Trees	0.8	0.5	0.3
Shrubs	0.7	0.5	0.3
Ground Cover	0.8	0.5	0.3

Species Factor (K_s) is a value given to differentiate plant species to account for their varying evapotranspiration rates. For practical purposes, a category of high, medium, or low will define all turf grass and ornamental plants. High water use grass will require about 70 percent to 80 percent of reference ET, medium water use grass about 65 percent, and low water use grass less than 50 percent. High water use plants will require about 70 percent to 80 percent of reference ET, medium water use plants about 50 percent, and low water use plants less than 30 percent. Native plants that are established may require no supplemental irrigation. Values for species factors are sometimes available through local sources. When available, this data tends to be more accurate.

Table 6-2: Density factor (K_d)

Vegetation	High	Average	Low
Turf Grass	1.0	1.0	1.0
Trees	1.3	1.0	0.5
Shrubs	1.1	1.0	0.5
Ground Cover	1.1	1.0	0.5

Density Factor (K_d) is a value given to a planting area to account for the vegetation density. Turf grass will always have a density factor of one. Newly planted and sparsely planted landscapes often have less leaf surface area than mature, dense landscapes and typically would use less water. Sparsely planted landscapes typically use less water and a dense planting will he higher.

Table 6-3: Microclimate factor (K_{mc})

Vegetation	High	Moderate	Low
Turf Grass	1.2	1.0	0.8
Trees	1.4	1.0	0.5
Shrubs	1.3	1.0	0.5
Ground Cover	1.2	1.0	0.5

Microclimate Factor (K_{mc}) is a value given to a planting area to account for environmental conditions. A high microclimate condition is one in which wind, heat-absorbing surfaces, or heat-reflecting surfaces affect the landscape. A low microclimate condition is one in which shade or protection from wind affect the landscape. An average microclimate condition is one in which any of these factors do not influence the site.

For example, if the species factor for a low water use shrub is 0.3, the density factor is average at 1.0, and the microclimate factor is high at 1.3, the landscape coefficient is calculated:

$$0.39 = 0.3 \times 1.0 \times 1.3$$

E. Plant Water Requirement (PWR)

The Plant Water Requirement (PWR) is modified ET to approximate the water use of the plants being irrigated. The Plant Water Requirement (PWR) is typically less than the reference ET. Use the following equation to calculate the Plant Water Requirement (PWR) for turf grass and ornamentals for a particular period (e.g., days, week, and month) in inches.

Plant Water Requirement Formula:

$$PWR = ET_r \times K_L$$

Where:

PWR = Plant water requirement (inches)
ET_r = Reference evapotranspiration (inches)
K_L = Landscape coefficient

For example, if the reference ET is 5.68 inches per month for July and the landscape coefficient is 0.39, the plant water requirement is calculated:

$$2.22 \text{ inches} = 5.68 \times 0.39$$

6.3.2 (II.) Irrigation Water Requirement

F. Precipitation Rate (PR)

The irrigation system application rate or precipitation rate should be known so that irrigation schedules can be developed. The Precipitation Rate (PR) is typically the average or a gross precipitation rate and does not account for weaknesses in distribution uniformity.

There are several ways to estimate application rates for irrigation zones:

- Manufacturer catalog data
- Precipitation rate formulas
- Field measurements of actual sprinkler performance using catch cans

What is Precipitation Rate?

Precipitation rate is a measure of the rate at which water accumulates in an irrigation area per unit of time and is measured in inches of water per hour (in./hr.).

Sprinkler systems can easily apply water at rates greater than the typical soil's ability to absorb water, which leads to runoff and reduced efficiency.

Manufacturer Catalog Data provides sprinkler performance information. Precipitation rates are provided as a guide assuming irrigation equipment is installed at a specific spacing. Actual field conditions may vary, which will affect the precipitation rate.

The Standard Formula calculates precipitation rates for sprinklers spaced in square, rectangular, or triangular patterns. Use the flow (gpm) of a full circle sprinkler times the conversion constant of 96.3, then divide by the area within the spacing (distance between the heads times the spacing between the rows).

Standard Precipitation Rate Formula:

$$PR = \frac{96.3 \times Q}{S_r \times S_h}$$

Where:

PR = Precipitation rate (inches per hour)
96.3 = Conversion factor
Q = Gpm of a full circle sprinkler
S_r = Row spacing (feet)
S_h = Head spacing (feet)

For example, if the flow of a full circle sprinkler is 4.0 gallons per minute, the row spacing is 15 feet, and the head spacing is 14 feet, the precipitation rate is calculated:

1.83 inches per hour = (96.3 x 4) / (15 x 14)

The Irregular Shaped Area Formula calculates precipitation rates for sprinklers placed at different spacing throughout an irregular shaped area. Use the gpm of all of the sprinklers times the conversion constant of 96.3, and then divide by the area within the square footage of the total area.

Irregular Shaped Area Precipitation Rate Formula:

$$PR = \frac{96.3 \times Q}{A}$$

Where:

PR = Precipitation rate (inches per hour)
96.3 = Conversion factor
Q = Gpm of all sprinklers
A = Station area (square feet)

For example, if the total flow of the zone is 16 gallons per minute and the area being watered is 840 square feet, the precipitation rate is calculated:

1.83 inches per hour = (96.3 x 16) / 840

The General Drip Formula calculates application rates (emitter discharge rate) for emitter systems with consistent spacing between emitters and rows for plantings and turf grass. The formula uses a modified version of the standard precipitation rate formula, supplying water in inches per hour. Use the gph of the emitter times the conversion constant of 231.1, and then divide by the area within the spacing (distance between the emitters times the spacing between the rows).

General Drip Formula:

$$AR = \frac{231.1 \times gph}{S_s \times S_r}$$

Where:

AR = Application rate (inches per hour)
231.1 = Conversion factor
gph = Gph of emitter
S_s = Emitter spacing (inches)
S_r = Row spacing (inches)

For example, if the emitter flow rate is 1 gallon per hour and the emitter and row spacing are 18 inches, the application rate is calculated:

0.7 inches per hour = (231.1 x 1) / (18 x 18)

Table 6-4 shows the precipitation rates for common point source drip spacing schemes. For other applications, calculate the Precipitation Rate (PR) using the formula.

Table 6-4: Emitter discharge rates

			Emitter Flow Rate		
Plant Size (dia.)	Typical Plant	Spacing	0.5 Gph	1.0 Gph	2.0 Gph
1 – 2 ft.	Ground cover	12 in.	0.80 in./hr.	1.60 in./hr.	3.21 in./hr.
3 – 4 ft.	Small shrub	24 in.	0.20 in./hr.	0.40 in./hr.	0.80 in./hr.
5 – 6 ft.	Medium shrub	36 in.	0.09 in./hr.	0.18 in./hr.	0.36 in./hr.
7 – 8 ft.	Large shrub	42 in.	0.07 in./hr.	0.13 in./hr.	0.26 in./hr.
9 – 14 ft.	Small tree	42 in.	0.07 in./hr.	0.13 in./hr.	0.26 in./hr.
15 – 20 ft.	Medium tree	48 in.	0.05 in./hr.	0.10 in./hr.	0.20 in./hr.
21 + ft.	Large tree	48 in.	0.05 in./hr.	0.10 in./hr.	0.20 in./hr.

Field measurements are a more accurate approach. A landscape irrigation audit consists of a series of field procedures for collecting and compiling irrigation system data; then using this data to evaluate system performance characteristics, such as distribution uniformity and precipitation rates. With this information, the landscape irrigation auditor develops detailed irrigation schedules for each station throughout the year.

G. Total Run Time per Period

When the Plant Water Requirement (PWR) and the Precipitation Rate (PR) are known, the run time per period can be calculated. Each individual zone will be unique due to the variables such as plant type, sprinkler selection, soil types, etc. The recommendation is to develop irrigation schedules for each month to accommodate changes in weather. Use the following equation to calculate the total run time per period (e.g., days, week, and month) in minutes.

Total Run Time Formula:

$$\text{Total run time} = \frac{\text{PWR}}{\text{PR}} \times 60$$

Where:

PWR = Plant water requirement (inches)
PR = Precipitation Rate (inches per hour)
60 = Conversion - hours to minutes

For example, if the plant water requirement is 2.22 inches and the precipitation rate is 0.7 inches per hour, the run time is calculated:

190 minutes = (2.22 / 0.7) x 60

6.3.3 (III.) Scheduling Requirements

H. Soil Type

Soil texture is the size and shape of individual soil particles such as sand, silt, or clay. Soil texture class describes the relative amounts of sand, silt or clay in that particular soil (e.g., sandy loam, loamy clay, clay loam, etc.) The percentage of each of these three particles is what determines the actual soil type.

Soil structure is the arrangement of soil particles. Soil particle refers to any unit that is part of the soil makeup including primary elements (sand, silt, or clay) or secondary aggregated particles.

A simple way to determine the soil type is to take a sample from a representative part of the site and place the moistened soil sample in your hand and squeeze. Table 6-5 lists the general characteristics of the three main soil types.

Table 6-5: Determining the soil type

Soil type	Characteristics
Course (Sand)	Soil particles are loose. Squeezed in the hand when dry, it falls apart when pressure is released. Squeezed when moist, it will form a cast, but will crumble easily when touched.
Medium (Loam)	Has a moderate amount of fine grains of sand and very little clay. When dry, it can be readily broken. Squeezed when wet, it will from a cast that can be easily handled.
Fine (Clay)	When dry, may form hard lumps or clods. When wet, the soil is quite plastic and flexible. When squeezed between the thumb and forefinger the soil will form a ribbon that will not crack.

The Jar Test Method is another method for determining soil types.

Supplies needed:

- 1 quart “Mason” jar with straight sides and a tight lid
- 2 cups of a representative sample of soil
- Water
- Ruler

What to do:

- Put the soil into the jar
- Fill the jar with water
- Shake until the soil particles are suspended in the water

What to expect:

- The sand will settle in the bottom of the jar in about one minute
- The silt layer will settle on top of the sand in two to three hours
- The clay layer will settle on the silt in about twenty-four hours
- Some clay particles and organic matter may not settle at all

After approximately twenty-four hours, measure each layer (sand, silt, and clay) and determine the percent for each layer. Use the chart below to determine the soil type. Note: only two of the three types of soil particles are required to determine soil type.

For example, a soil with 40 percent sand, 40 percent silt, and 20 percent clay is classified as medium loam.

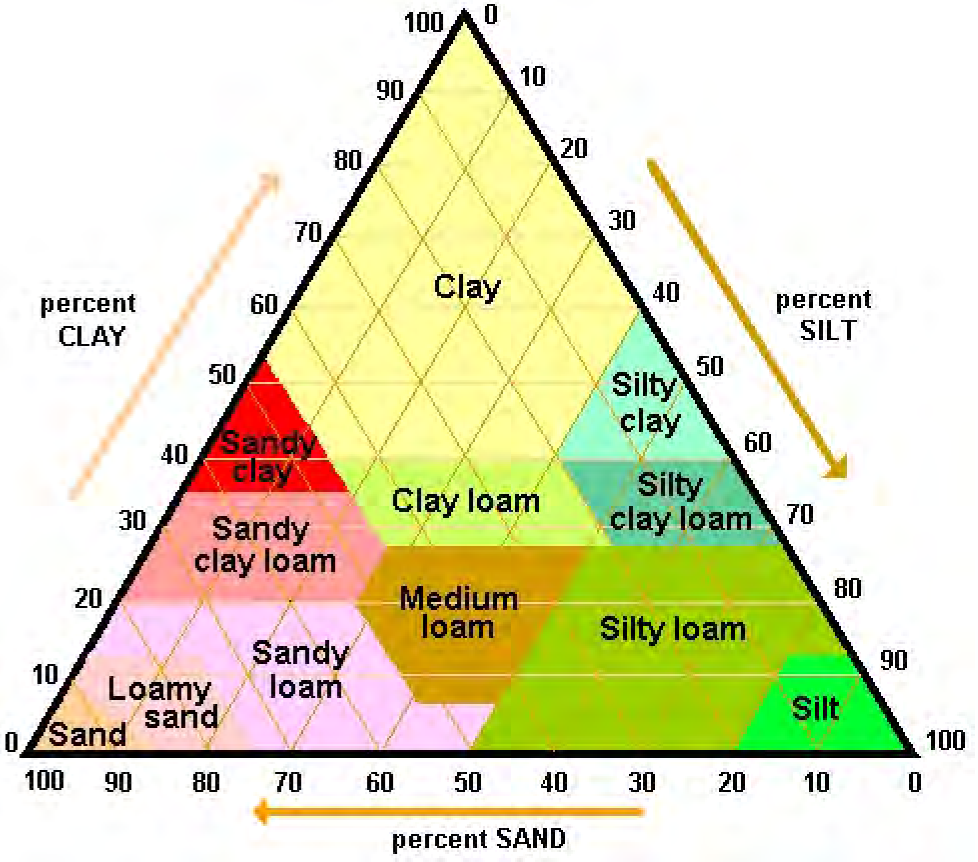


Figure 6-1: Soil Triangle

Table 6-7: Soil properties

Soil texture class	AW in./in.	MAD %
Clay	0.17	30
Silty Clay	0.17	40
Clay Loam	0.18	40
Loam	0.17	50
Sandy Loam	0.12	50
Loamy Sand	0.08	50
Sand	0.06	50

I. Managed Allowable Depletion (MAD)

Managed allowable depletion (MAD) is the maximum percent of plant available water that the irrigation manager allows to be removed from the soil before irrigation occurs. Table 6-7 shows acceptable values for MAD.

J. Available Water (AW)

Soil properties determine how much water the soil can hold and how much of that water will be available to the plants. Available Water (AW) is the measure of the stored water by soil texture class. The AW is measured in inch per inch or inch per foot. Refer to Table 6-7 for AW measured in inches of water per inch of soil per soil type.

K. Active Root Zone Depth (RZ)

An essential design parameter is the consideration of plant root depths and water loss due to percolation below the root zone. The soil depth from which a plant extracts most of its water needs is the active root zone depth and is expressed in inches.

Figure 6-2 shows that the top half of the root zone is the most active, which absorbs up to 70 percent of the plant’s water. Typically, the design process for irrigation systems target water delivery to the upper 50 to 75 percent of the root zone.

For example, shrubs with an 18-inch root depth receive 70 percent of their water in the top nine inches and 90 percent in the top 12 inches.

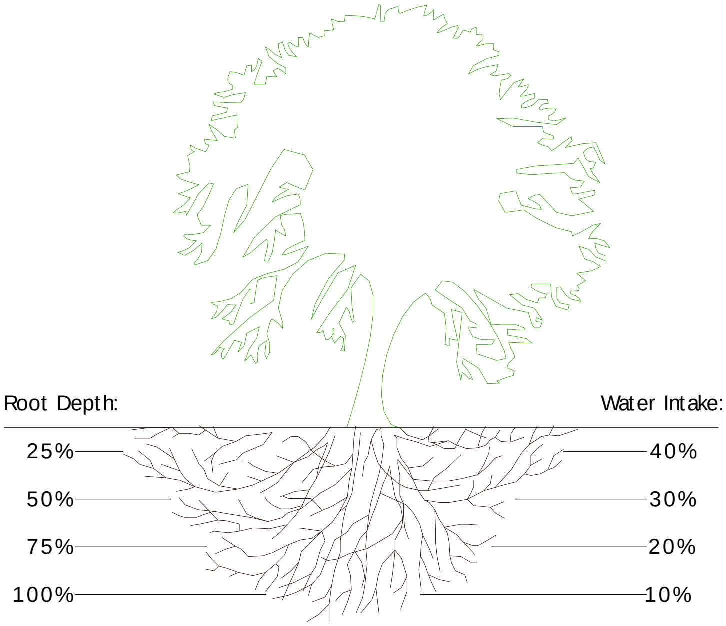


Figure 6-2: Soil moisture extraction by plant root zone

A “Rule of Thumb” for Active Root Zone depths (RZ):

- 6” Turf
- 6” Ground cover
- 12” Shrubs
- 18” Trees

L. Plant Available Water (PAW)

Plant Available Water (PAW) is the quantity of water stored within a plant’s root zone between the conditions of field capacity (after drainage) and the permanent wilting point (when the plant can no longer extract significant amounts of water and dies). Plant Available Water (PAW) is expressed in inches and based on the available water holding capacity of the soil and the active root zone depth. Calculate the PAW by multiplying the Available Water (AW) by the Active Root Zone Depth (RZ).

Plant Available Water Formula:

$$PAW = AW \times RZ$$

Where:

PAW = Plant available water (inches)
AW = Available water (inch of water per inch of soil)
RZ = Active Root zone depth (inch)

For example, if the available water is .08 inches and the active root zone is 12 inches, the plant available water is calculated:

$$0.96 \text{ inches} = .08 \times 12$$

M. Allowable Depletion (AD)

Allowable depletion (AD) is the allowed water to be depleted from the soil before an irrigation event is scheduled. The Allowable depletion (AD) is determined by a percentage Managed Allowable Depletion (MAD) of Plant Available Water (PAW). Use the following equation to calculate the amount of water that the plants can use between irrigations.

Allowable Depletion Formula:

$$AD = PAW \times MAD$$

Where:

AD = Allowable depletion (inch)
PAW = Plant available water (inch)
MAD = Managed allowable depletion (decimal)

For example, if the plant available water is 0.96 inches and the MAD is 50 percent, the allowable depletion is calculated:

0.48 inches = 0.96 x 0.5

N. Irrigation Days per Period

The two key elements of an irrigation schedule are how often to water and how long. There are two different ways to look at irrigation frequency. The first is irrigation days per period, which means how many times to water per week or month. The days available for watering should be identified. Certain days may not be available due to maintenance schedules, watering restrictions, or some other condition. The second is the frequency of water days method based on Allowable Depletion (AD). Use the following equation to calculate the number of days to irrigate per period (e.g., days, week, and month).

Irrigation Days per Period Formula:

$$\text{Irrigation days per period} = \frac{\text{PWR}}{\text{AD}}$$

Where:

PWR = Plant water requirement (inch)
AD = Allowable depletion (inch)

For example, if the plant water requirement is 2.22 inches and the allowable depletion is 0.48 inches, the irrigation days per period is calculated:

4.625 (round up to 5) days = 2.22 / 0.48

Always round up to the next full day. In addition, the number of days may need to be adjusted to fit the controller’s capabilities. A typical irrigation schedule might include once, twice, three times per week, etc. Therefore, a monthly schedule of five days will not meet this requirement and need to be adjusted to eight times, which is twice per week.

O. Irrigation Frequency

The irrigation frequency demand-based method is the best and most efficient method of watering if the controller has the capabilities. Use the following equation to calculate how often to water (e.g., every other day, every third day, etc.)

Irrigation Frequency Formula:

$$\text{Irrigation frequency} = \frac{\text{Reference period (days)}}{\text{Irrigation days}}$$

For example, if the reference period is 31 days and the irrigation days are 5, the irrigation frequency is calculated:

6.2 (round down to Every 6th) day = 31 / 5

P. Run Time per Day

The other key element is the station run time. A good irrigation schedule replaces the water depleted from the root zone based on the allowable depletion without over watering. The run time is calculated using the run time per period and factoring in the irrigation days, either irrigation days per period or irrigation frequency. Use the following equation to calculate the run time per day.

Run Time per Day Formula:

$$\text{Run time per day} = \frac{\text{Run time per period}}{\text{Irrigation days}}$$

For example, if the run time per period is 190 minutes and the irrigation days per period are 5, or 8 the run time per day is calculated:

38 minutes = 190 / 5   24 minutes = 190 / 8

This zone's irrigation schedule for the month of July would be every 6th day for 38 minutes, or twice per week for 24 minutes.

6.4. Schedule Adjustment

A. Fine tune the run times of individual stations with consideration to differences in microclimate, precipitation rate, or uniformity.
B. Adjust schedules to meet any changes in the weather; these changes can be from week-to-week, month-to-month, or they can be seasonal changes.
C. Trim back after the schedules are in place:

- When trimming reaches the point that stress is noticeable in some areas of the site, inspect the system near the weak area.
- Often the weakness can be corrected with minor adjustments to the nearby sprinklers.
- If the station is simply not receiving enough water, then that station should be allocated more time and not be trimmed back any further.

6.5. Effective Rainfall

Rainfall influences the amount of irrigation water needed. Effective rainfall is the fraction of the total rainfall that is actually stored in the root zone. When calculating irrigation schedules, the designer cannot predict the effective rainfall or know when it will rain, therefore determine irrigation schedules without consideration for rainfall.

A. The irrigation manager should postpone irrigation during a rain event and wait until the soil has dried down to a reasonable level.

Information for the sample graphs below was taken from Toro Company Rainfall-Evapotranspiration Data.

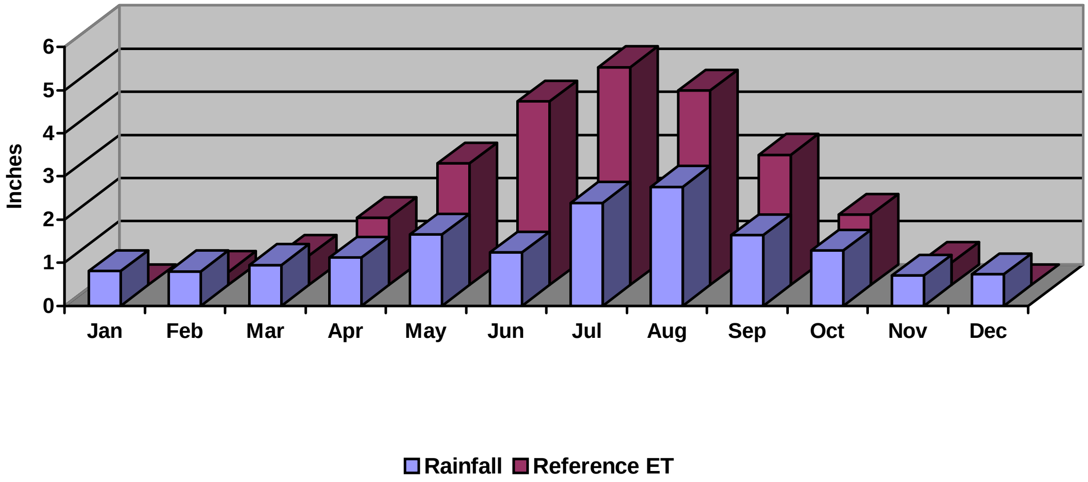


Figure 6-3: Reference ET and average rainfall in Santa Fe

6.6. Base Schedule Worksheet for Irrigation Schedules

Project: ______________________________ Date: ____________

Location: ____

Controller: ______________________ Station Number: ______ Reference Period: ____________

Item	Source		Value	Unit or Function
I. Plant Water Requirement				
A. Plant Material	Audit or planting plan			Classification
B. Reference Period	Judgment			Days
C. Reference Evapotranspiration (ET_r)	Various sources			Inches of water
D. Landscape Coefficient (K_L)	K_s ____ x K_d ____ x K_{mc} ____ =			Plant specific multiplier
E. Plant Water Requirement (PWR)	ET_r x K_L	C x D		Inches
II. Irrigation Water Requirement				
F. Precipitation Rate (PR)	Audit or calculation			Inches per hour
G. Total Run Time per Period	(PWR / PR) x 60	(E / F) x 60		Minutes
III. Scheduling Requirements				
H. Soil Type	Audit or estimate			Classification
I. Management Allowed Depletion (MAD)	Table 6-7			Multiplier
J. Available Water (AW)	Table 6-7			Inches per inch of soil
K. Active Root Zone Depth (RZ)	Audit or estimate			Inches
L. Plant Available Water (PAW)	AW x RZ	J x K		Inches
M. Allowable Depletion (AD)	PAW x MAD	L x I		Inches
N. Irrigation Days per Period	PWR / AD	E / M		Days in a period
O. Irrigation Frequency	Ref. period / irr. days	B / N		Days frequency
P. Run Time per Day	Total time / irr. days	G / N		Minutes

VII. Contracts & the Contractor

Balancing Public Health, Safety & Welfare with Business & Economic Development

New Mexico
Regulation & Licensing Department

Licensed Contractor

The Construction Industries Division authorizes a contractor holding the MS6 classification to:

- ✓ Install, alter, repair, or service sprinkler systems, which are connected to a potable water supply
- ✓ Excavate and backfill as necessary for proper installation of the system
- ✓ Install or repair plug-in type electrical control panels and apparatus
- ✓ Install control wiring of 24 volts or less

7.1. Irrigation Contractor

Irrigation contractors are specialty contractors, whose principal contracting business is the execution of contracts and subcontracts to install, repair, and maintain irrigation systems in an acceptable way, meeting all specifications and requirements.

A qualified contractor:

- Has experience with the type and scale of work required and has equipment and personnel adequate to perform the work satisfactorily.
- Is able to perform necessary cutting and joining of all types and classifications of pipe, understands limitations of each piping system, and has knowledge of required fittings and components of the water delivery system including backflow prevention components.
- Understands basic hydraulics as applied to pumps, irrigation piping, sprinkler heads, water hammer, and backflow prevention principles.
- Has knowledge of the various types of control devices used in irrigation systems including mechanically, hydraulically, and electrically controlled valves and irrigation controllers.
- Has basic electrical knowledge needed for installation of electric motors and associated electronic control systems.
- Has knowledge of required licensing laws and codes in New Mexico.
- Has a current MS6 license with the New Mexico Construction Industries Division to bid on a project or do construction, alteration, demolition, or installation.

A. A Licensed Contractor licensed by the Construction Industries Division must perform all work.

B. A journeyman's license is required for individuals working under a licensed contractor.

C. A journeyman holding the JS classification cannot have more than three apprentice workers under him or her.

D. A licensed JS journeyman must be on the job site at all times during construction; a telephone or radio on the job site does not qualify as a substitute.

7.2. Contractor License Verification

The function of the Construction Industries Division is to license contractors and provide for the protection of life and property by adopting and enforcing building codes and standards thereby promoting the general welfare of the people of New Mexico.

To verify the validity of a contractor's license, visit www.rld.state.nm.us/cid on the Internet and use licensee search to determine if the contractor holds a current license and that the license is for the scope of work proposed, or contact the Construction Industries Division office:

Construction Industry Division
Regulation and Licensing Department
2550 Cerrillos Road
Santa Fe, NM 87505
Phone: (505) 476-4700 – Fax: (505) 476-4685
Email: rldcid@state.nm.us

Contractors' Licensing Services, Inc. (CLSI) is handling all the licensing needs on behalf of the state of New Mexico Construction Industries Division. For more information regarding how to apply for a contractor's license in New Mexico or to search for an existing contractor, visit www.contractorsnm.com on the Internet or contact CLSI:

Contractors' Licensing Services Inc.
3211 Coors Blvd SW Ste. A-3
Albuquerque NM, 87121
Phone: (505) 452-8311 – Fax: (505) 476-4685
Email: email@contractorsnm.com

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NEW MEXICO
REGULATION & LICENSING DEPARTMENT

The Construction Industries Division is responsible for:

- ✓ Examinations and the issuance of licenses for contractors, and certificates of competence for journeymen
- ✓ The conduct of unlicensed contractor investigations
- ✓ Code compliance and other complaints related to violations of the Construction Industries Licensing Act

7.3. Certification Verification

The IA Certification Board of Governors has established certification programs to achieve national recognition of irrigation specialists (e.g., irrigation designers, contractors, and landscape irrigation auditors).

For information about the IA or any of its educational and certification programs, members and irrigation specialists visit www.irrigation.org on the Internet. To verify certification status, search under "Certification" and select "Certified Professionals," or contact:

The Irrigation Association
6540 Arlington Boulevard
Falls Church, VA 22042-6638
Phone: (703) 536-7080 - Fax: (703) 536-7019

THE IRRIGATION ASSOCIATION®

Certification

Certification for Irrigation Designers and Contractors indicate that the successful applicant has:

- ✓ A minimum of three years of irrigation-related experience and/or education
- ✓ Successfully passed a series of written examinations covering both general irrigation subjects and specialty areas
- ✓ Agreed to follow a specific "Code of Ethics" established by the Certification Board of Governors
- ✓ Yearly educational activity required to maintain active status and to keep current with the industry

7.4. Insurance

Insurance policies are required to protect the City, contractor, and property.

The City requires a certificate of insurance before signing a contract including:

- A Workers' Compensation Insurance policy required by the Workers' Compensation Law of the State of New Mexico for all employers in the construction trades, regardless of the number of employees.
- A Comprehensive General Liability Insurance policy maintained by the contractor in that it will protect the contractor, owner, City, and the architect in case of unforeseen disasters such as flooding, landslides, or other calamities caused by the contractor's work under the contract; as a rule, liability policies should have limits of between $300,000 and $500,000 for residential work and at least $1,000,000 for commercial work.
- A Comprehensive Automobile Liability Insurance policy maintained by the contractor in that it will include owned, hired, and non-owned vehicles and name the owner as additional insured, which provides another element of liability protection in case one of the contractor's vehicles is involved in an accident on City or private property.
- All subcontractors with one or more employees must provide a worker's compensation insurance policy and general liability insurance policy.

7.5. Authorized Representative

For City contracted projects, the City will designate an authorized representative to work with the contractor to ensure the irrigation system installation follows specifications. For the range of these documents, the term "Engineer" refers to the authorized representative.

The engineer will have full authority to:

- Approve work performed by the contractor and make field changes that are necessary.
- Approve progress payments as each phase is completed.
- Act as an inspector on the job and have all authorities vested in an inspector as specified in these documents.
- Stop work whenever such stoppage may be necessary to insure proper execution of the contract and will have authority to reject all work and materials, which do not conform to the contract.

A. The contractor will make no effort to impede free movement of the engineer.
B. If the contractor disagrees with any decision of the engineer, the contractor may file a written complaint with the City and the City will notify the contractor in writing of their decision to support or override the original decision of the engineer.

7.6. Written Bids

The City will obtain and evaluate written bids of proposed work for all City contracted projects and make sure all contractors are bidding on the same exact scope of work including the exact materials required.

A. It is the responsibility of all parties concerned to carefully examine the plans and specifications relating to the proposed work for completeness, accuracy, and clarity; any conflict, errors, or clarification requests will be immediately brought to the attention of the designer and/or engineer for written interpretation or instructions.
B. Submit bid proposals to the City before the start of construction.

Basic items to include in a bid:

- Describe every aspect of the job in detail; have a dollar amount attached to it, warranty terms, and a scaled plan.
- Break down the bid into subsections with quantities, sizes, and brands specified.
- Include preparatory and finish work.
- Include amounts and brands of irrigation equipment.
- Include copies of licenses, insurance policies, and a list of references
- Bids must follow design specifications.

Basic items to include in a bid proposal:

- A list of materials to include all items the contractor will provide for the complete installation of the irrigation system.
- All items on the list should include a description of the type of product, manufacturer’s model number, and size.

Contracts

A contract is a guarantee of professional work and a statement specifying mutually agreed upon standards. A written contract protects the owner and contractor.

Awarding a contract to the lowest bidder can spell disaster. The low bidder may have mistakenly left something out of the bid or takes shortcuts, uses cheaper materials, may not be licensed and insured, or may walk off the job to work on another project, etc.

A rule of thumb is to throw out the high and low bids and then look at the remaining bids.

- Submit specification sheets of copies thereof with the bid proposal for items on the list of materials.

7.7. Contracts

All agreements, no matter what the amount, should be in writing and state clearly exactly what work needs to be accomplished. Contracts are not just for the City; all irrigation system installations should not be executed without a contract.

Basic items to include in a contract:

- A list of permits needed and who will obtain them, which should be the licensed contractor.
- A project starting date, an estimated completion date, and a cancellation penalty.
- The total price and a payment schedule: do not pay up front, consider partial payments upon completion of portions of the work and balance due.
- A list detailing what the contractor will and will not do.
- Warranties and guarantees of workmanship, length of warranty, and what is and is not covered.
- Validation of any required license and certificates of insurance.
- Who will do the work, the contractor or a subcontractor.
- The name, street address, and telephone number of the contractor(s).
- A statement that the contractor will do any necessary cleanup and removal of debris after the job is completed.
- Workday restrictions, special requests, etc.

Any changes the City, owner, and contractor agree to make in work or materials should be in writing. Include in this written "Change Order" any additions or reductions in the total job price and mutually agreed upon in advance of performance.

A. No claim for increased compensation for additions, changes, or alterations should be considered unless written authorization is granted; otherwise, any additional materials and/or labor due to additions, alterations, and changes necessary to meet existing conditions will be furnished under the contract.
B. Selection of a contractor should not be entirely dependent upon price.

7.8. Quality Assurance

A. The designer specifies irrigation system components within the capabilities and limitations stated by the manufacturer, by these guidelines, and by any applicable local or other codes; the contractor should install the irrigation system within these standards.
B. The contractor assumes full responsibility for proper installation of the system.
C. The contractor should follow all regulations, ordinances, and codes governing the type of work specified.
D. All materials and equipment should be warranted in writing for a minimum period of one year against defects in materials and workmanship from their respective manufacturers.
E. All installation work should be warranted for a minimum period of one year against defective workmanship and handling by the installer.
F. Warranties will become effective on the day the system, or any portion thereof, is put into operation.
G. The design will be warranted by the designer to perform as indicated when installed according to the specifications, plans, and factory installation procedures; and when properly operated and maintained by the owner.

VIII Installation

8.1. Introduction

The purpose of this section is to establish minimum standards for the installation of irrigation systems that ensures the system is efficient and uniformly distributes the water. A properly designed irrigation system with optimum pressure, flow, and spacing has the potential to achieve a high uniformity. Thus, a poor installation with an unqualified contractor can spell disaster.

The scope of work addressed by these guidelines consists of the furnishing of all materials, irrigation equipment, and labor necessary for the complete irrigation system installation in accordance within the guidelines.

It is critical that all materials and equipment be installed in a neat and competent manner according to the manufacturer's published recommendations and specifications, as shown on the detail drawings, plans, and as specified herein.

8.2. Testing and Inspections

For City contracted projects, the City will designate an authorized representative (engineer) to perform the inspections as described in these documents.

A. The local jurisdiction has precedence over inspections as applicable and as stated in these documents.
B. The inspections as described in these documents will be the minimum required inspections during the course of construction.
C. Additional inspections may be conducted at any time at the discretion of the City.

The engineer will execute periodic inspections throughout the duration of the installation. It is recommended that owners of commercial and residential installations conduct inspections. These inspections will insure that the installation complies with the design intent, specifications, and these guidelines:

- No water supply system or portion thereof will be covered or concealed until it first has been tested, inspected, and approved.
- Install all piping in the system to meet minimum depth requirements as described in these documents.
- All control wire in the system should meet specifications and wire splice connections should comply with wet location applications.
- Install all control valves in the system to meet depth requirements and install enclosures to the proper grade.
- Adjust pressure-regulating valves to the proper pressure settings.

- All controllers in the system should function properly and be in conformance to applicable codes.
- Keep an inspection log at the job site that includes signatures, times, and dates along with a description of inspections performed.
- Submit a copy of the log to the City upon completion of the landscaping.

8.3. Pre-Installation

A. Confirm static pressure and water supply capacity at the site as stated on the irrigation design before starting the sprinkler system installation.
B. Inspect the site for existing conditions that will affect the irrigation system design or installation, and develop a plan to minimize disturbance of existing structures and landscape.
C. Stake out the location of each run of pipe and all sprinkler heads and valves before trenching.
D. Do not exceed the sprinkler head spacing shown on the plans and place the sprinklers in the exact locations and configuration as shown on the plans.
E. Verify area dimensions while staking sprinkler head locations.
F. Stake sprinkler head locations and measure from permanent objects, buildings, etc., or survey bench markers.
G. As the staking progresses, all additions, changes, or equipment locations should be noted on the copy of the "working plans" from which the "as-built" drawings will be made.
H. The sprinkler layout and spacing of the staked irrigation system design in the field should meet with the accuracy and approval of the engineer.
I. The engineer will approve each run of the system before start of actual installation; conflicts between irrigation system layout and proposed plant material, drainage systems, light standards, etc., will be resolved in the field by the engineer at the time of field staking.
J. Do not execute deviations from the plans and specifications without written approval from the City.
K. Locate and mark all underground utilities before trenching.

It is the responsibility of the landscape irrigation contractor to prepare for the installation of the irrigation system.

The Contractor:

- ✓ Will be responsible for correct procedures in loading, unloading, staging, transporting, and handling all materials to be used in the system.
- ✓ Will do layout, staking, excavation, boring, trenching, grading, and backfilling.
- ✓ Will install all piping and water delivery components, irrigation controls, and electrical systems.
- ✓ Is obligated to follow all regulations, ordinances, and codes.

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NMOC
Professional Resources for Damage Prevention

New Mexico One Call:

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Obtain location of existing utilities two working days in advance of any excavation by contacting New Mexico One Call:

Santa Fe: 1-800-321-2537
Statewide: 1-800-321-ALERT
Albuquerque: 260-1990
By Fax: (505) 260-1248 or (800) 727-8809
By Web: www.nmonecall.org

Or 811 will connect you directly to your local one call center

8.4. Sprinkler Permits for Private Property

A. The installation of all irrigation systems requires a sprinkler permit including residential systems.
B. The contractor should be responsible for obtaining and paying for all necessary permits required for the installation or construction of any work included under contract, which are required by the City following SFCC Chapter 14 and current Uniform Plumbing Code.
C. Call for plumbing inspection at the property as part of the permit requirement. Arrange for and be present at any such inspections. Any additional work or furnishing of materials required due to inspection by the City will be at no cost to the Owner.
D. The City of Santa Fe will inspect the irrigation system for approved backflow prevention and proper installation height of backflow preventer above the highest outlet.

For information, contact:

Land Use Department
Inspections and Enforcement Division
200 Lincoln Avenue
Santa Fe, New Mexico 87504
Phone: (505) 955-6646

8.5. Excavation and Trenching

A. Trench and excavate pipelines true to line.
B. The trench bottom should be uniform, free of debris, and of sufficient width to properly place pipe and support it over its entire length.
C. Excavate trenches to be wide enough so that there will be a four inch minimum horizontal separation between pipes in the same trench.
D. Depth of bury for trenches should be sufficient to provide the specified pipe cover as described in these specifications.
E. Backfill and carefully tamp over excavating to provide a smooth and firm bearing surface for laying pipe.

Depth of bury for City of Santa Fe parks, municipalities, medians, and streetscapes:

- Install all constant pressure mainline where there is a minimum 36 inches of cover.
- Install all non-constant pressure mainline located downstream of the master valve where there is a minimum 24 inches of cover.
- Install all lateral lines where there is a minimum 18 inches of cover.

Depth of bury for the City of Santa Fe industrial, commercial, multi-family, and residential:

- Install all constant pressure mainline where there is a minimum 24 inches of cover.
- Install all non-constant pressure mainline located downstream of the master valve where there is a minimum 18 inches of cover.
- Install all lateral lines where there is a minimum 12 inches of cover.

8.6. Record Drawings

Record drawings are not just for the City. All irrigation system installations should be documented with an “as-built” record drawing. Maintain at least one set of "working prints" for annotating all installation changes, corrected daily to show all changes in the location of sprinkler heads, controllers, backflow preventers, valves, drains, meters, points of connection, wire splice points, pipe, and wire routing and other changes that may have been made from the original drawings and specifications as provided.

A. Show all gate valves, manual drains, wire splices, automatic and manual valve locations, controllers, power supply, and mainline piping with actual measurements to reference points so they may be easily located in the field.
B. Carefully record and keep up to date these "working prints" daily throughout the progress of the project, whereupon they will be returned to the designer for preparation of the final "as built" plans, which will provide a permanent record of this work.

8.7. Backflow Prevention Assemblies

8.7.1. Atmospheric Vacuum Breaker (AVB)

A. Install AVB in a location where it is accessible for periodic inspection or repair.
B. Flush the mainline of foreign material before installation of AVB.
C. Install AVB assembly at least six inches above the highest piping or outlet downstream.
D. Do not install any shut-offs on outlet side of device.
E. Install AVB so that the Air Inlet operates in the vertical position.
F. When threading the device in line, place wrench only on hex ends; keep pipe dope off interior surfaces of valve.

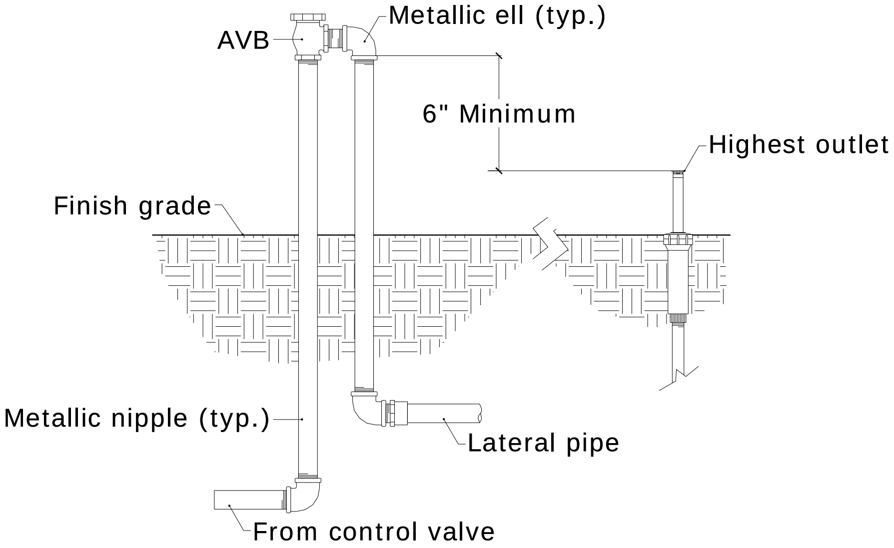

Figure 8-1: AVB assembly

8.7.2. Pressure Vacuum Breaker (PVB)

A. Install PVB assembly in a location where it is accessible for periodic testing or repair.
B. Install PVB assembly with side clearances of 12 inches on one side and 24 inches on the other.
C. Flush the mainline of foreign material before installation of PVB.
D. Install PVB assembly at least 12 inches above the highest piping or outlet downstream.
E. Install unions a minimum of four inches above grade on each leg of backflow preventer.
F. Install PVB so that the Air Inlet operates in the vertical position.
G. Install PVB where some spillage is not objectionable, as instantaneous siphon conditions and pressure surges will cause "spitting".
H. When threading the device in line, place wrench only on ball valve hex ends; keep pipe dope off interior surfaces of valve.
I. Install PVB with freeze protection.
J. The installation of a master valve may be on either side of the PVB.
K. Test the backflow prevention assembly by a certified backflow assembly tester at the time of installation.

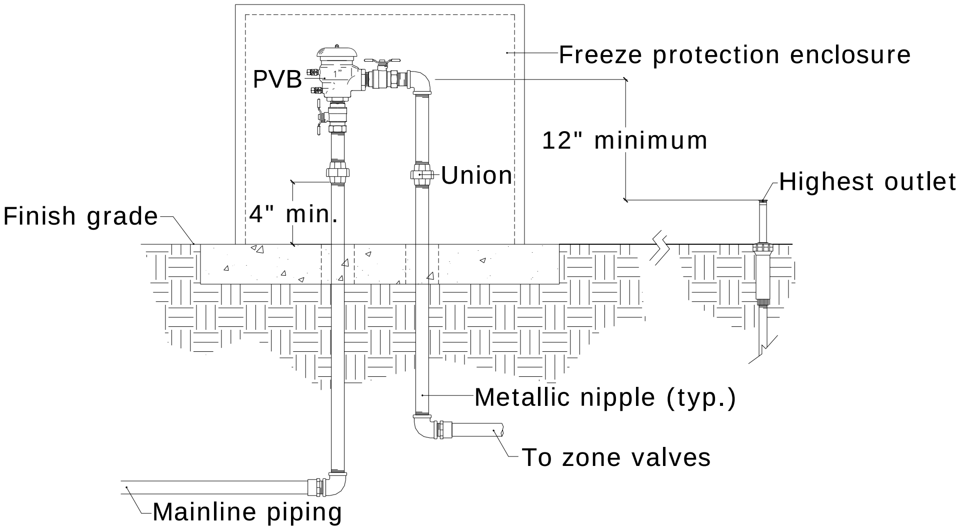

Figure 8-2: PVB assembly

8.7.3. Reduced Pressure Assembly (RP)

A. Install RP in a horizontal position with a minimum clearance of 12 inches and a maximum of 30 inches between the relief valve discharge port and floor or grade, and a minimum of 12 inches horizontal clearance around unit for access and ease of testing and maintenance of relief valve.
B. Install unions a minimum of four inches above grade on each leg of backflow preventer.
C. Install RP assembly in a location where water discharged from the relief port will not be objectionable or cause damage to property and/or equipment.
D. Flush the mainline of foreign material before installation of RP.
E. Install RP with freeze protection.
F. Install a master valve on the downstream side of the RP.
G. Test the backflow prevention assembly by a certified backflow assembly tester at the time of installation.

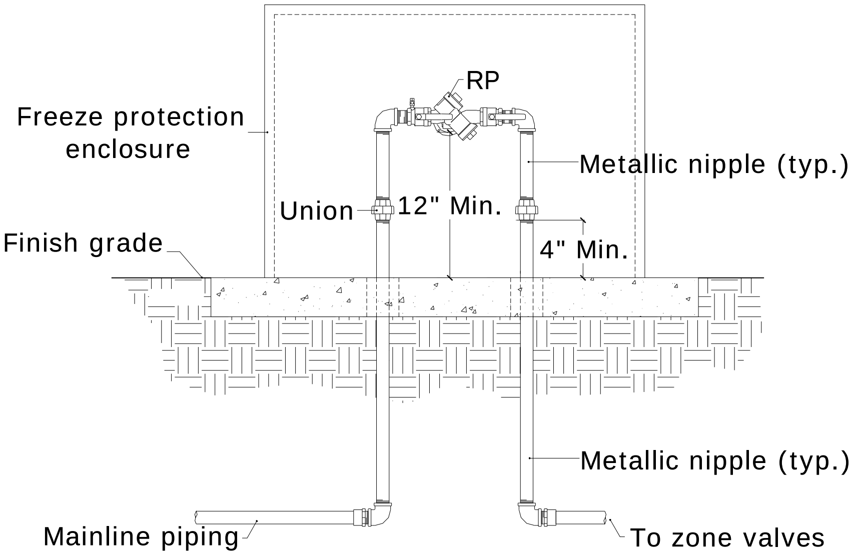

Figure 8-3: RP assembly

8.8. Backflow Prevention Freeze Protection (PVB, RP)

Protect backflow prevention assemblies for the winter in areas where freezing temperatures may occur. Proper draining procedures, insulation from freezing using heat tape, and heated protective enclosures are all methods of freeze protection.

Enclosure Installation:

- Pour a full concrete pad a minimum of four inches thick around valve, allowing a minimum one-inch radial space between valve riser and pad.
- Slab should be at least four inches greater than enclosure in length and width.
- Mount enclosure assembly on the concrete pad according to the manufacturer's instructions and any existing contract drawings.
- Ensure enclosure installation is plumb, level, and square.

Draining:

- Follow manufacturer's recommendations for proper draining procedures and include a copy of the procedures in the operations and maintenance manual.

8.9. Backflow Prevention Assembly Testing (PVB, RP)

Test devices, which are designed to be field-tested, before final inspection of the initial installation and once each year thereafter using field test procedures conforming to ANSI/ASSE 5010 Series Professional Qualifications Standards or equivalent. Testable devices are those backflow prevention devices having test cocks (e.g., pressure vacuum breakers and reduced pressure backflow preventers).

A. Repair backflow where tests indicate that the device is not functioning properly, in accordance with the manufacturer’s instructions and retest.
B. Certified individuals approved by an agency acceptable to the Administrative Authority must perform testing and repair of devices.
C. The local code enforcement officer will inspect the backflow prevention assemblies to verify that the make, model, and size conform to specifications and the installation and function is in conformance with applicable code.

Backflow Tester Training Schools:

- Albuquerque TVI, 525 Buena Vista SE, Albuquerque, New Mexico 87106 (505) 272-7989
- Viking II, 3300 Princeton #29 NE, Albuquerque, New Mexico 87107 (505) 883-3159

8.10. Valves

8.10.1. Drain Valves

A. Install automatic drain at a 90° angle from pipe; do not install facing down where debris can clog the drain and cause failure.
B. Install drain valves downstream from approved backflow preventer.
C. Provide a minimum of one cubic foot pea gravel for proper drainage.
D. Indicate locations of drain valves on "as-built" record drawing.

8.10.2. Quick Coupler Valves

A. Install quick coupler valves downstream of approved backflow preventer.
B. Install quick coupler valve flush with grade or in valve box as per specifications.
C. Provide each quick coupler valve with its own key.

8.10.3. Hose Bibs/Hydrants

A. Install hose bibs/hydrants downstream of approved backflow preventer.
B. Install the backflow preventer at the recommended height above the outlet of the highest hose bib/hydrant.

8.10.4. Isolation Valves

A. Install a manual shut-off valve at every valve box location; place shut-off valves before each automatic valve in the valve box or one shut-off valve to control all automatic valves in a valve box.
B. Install shut-off valve with enough clearance for proper operation.
C. Install a manual shut-off valve at point of connection; the valve depth should be the same depth of bury as mainline.

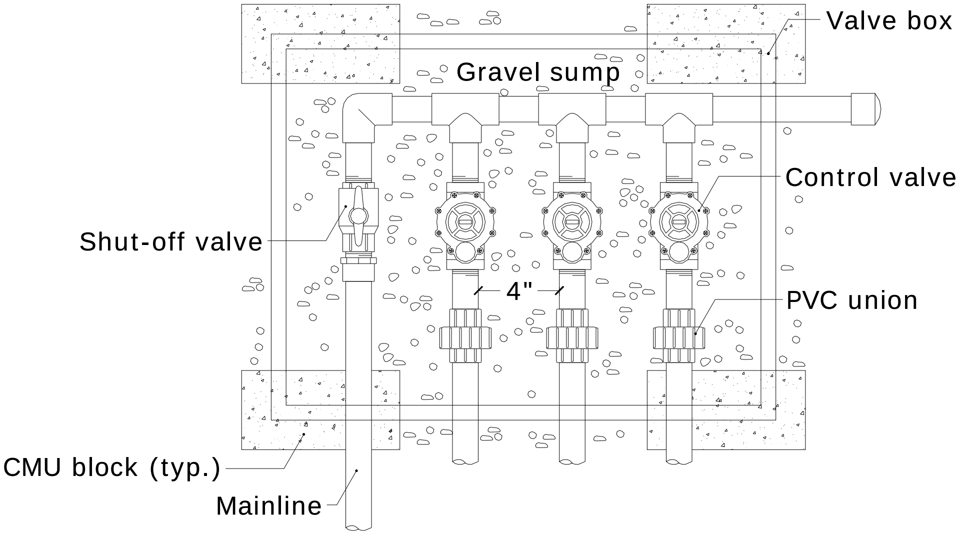

Figure 8-4: Isolation valve with valve manifold

8.11. Automatic Control Valves

A. Flush the mainline thoroughly before installing control valve assemblies.
B. Install all control valves below grade.
C. Install control valves where depth of bury is no more than six inches above the mainline piping.
D. Install all control valves with a minimum of 18 inches of cover.
E. Install a schedule 80 PVC union after each valve.

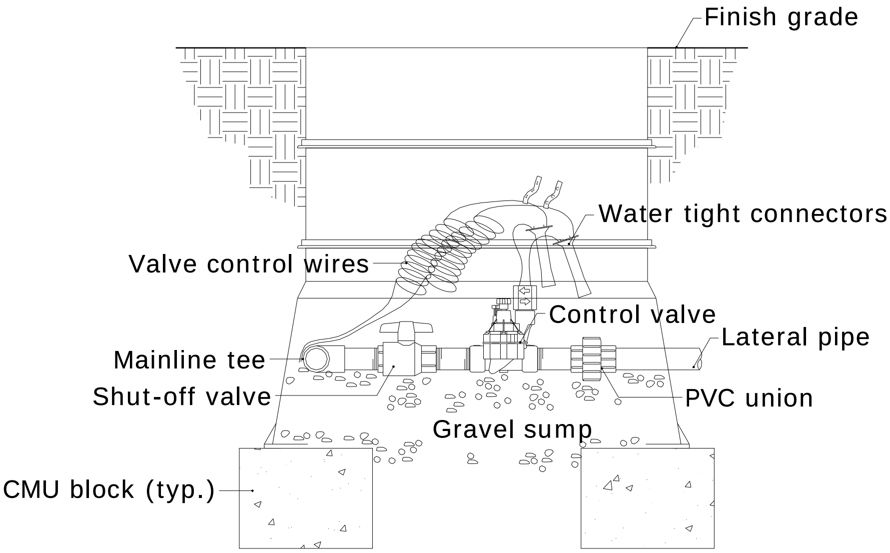

Figure 8-5: Automatic control valve assembly

8.11.1. Drip Control Valves

A. Install drip filter downstream of zone valve.
B. Install drip filter with filter element pointing down.
C. Install pressure regulator downstream of zone valve and filter.

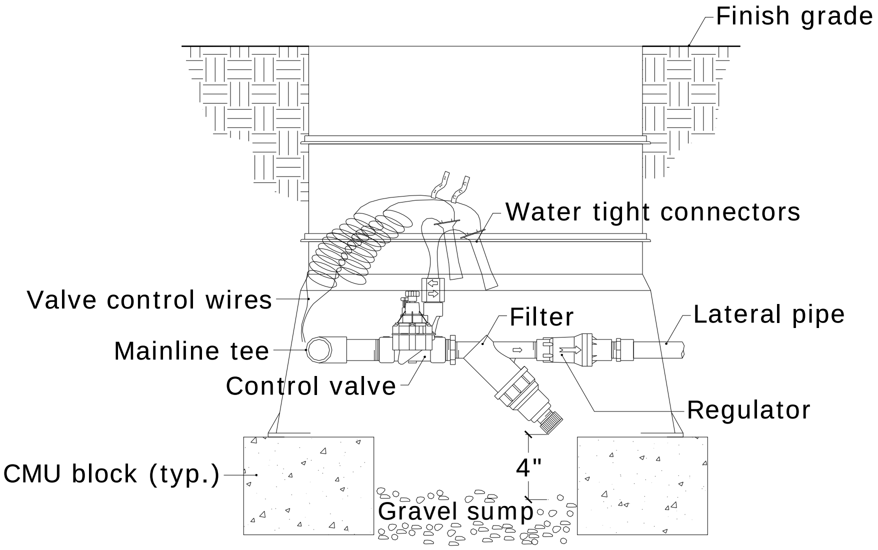

Figure 8-6: Drip valve assembly

8.12. Valve Boxes

A. Allow enough clearance for proper operation and maintenance.
B. Install valve boxes flush with finished grade in turf areas.
C. Install valve boxes a minimum of two inches above finished grade in non-turf areas to allow for mulch.
D. Install a pea gravel sump a minimum of six inches in depth and the same width and length of the valve box.
E. Do not lay valve box directly on pipe. Allow for a clearance of one inch around pipe.
F. Tape the space between pipe and valve box using a good quality duct tape and/or insulation to prevent the entrance of dirt into the valve box.

Install four solid CMU blocks, one at each corner of valve box:

- Small boxes up to 30 inches at the base use 4" x 6" x 8" blocks
- Medium boxes over 30 inches at the base use 4" x 6" x 16" blocks

8.13. 24-Volt Control Wire

A. Install all aboveground wire runs and wire entries into buildings in electrical conduit using proper junction boxes at all changes in direction.
B. Whenever possible, install the 24-volt control valve wiring in the same trench as the sprinkler system mainline piping.
C. When trenches used for piping are not appropriate for routing of wire, provide a trench 18 inches deep for 24-volt wires and identify locations with dimensions on the "as-built" record drawings.
D. Lay the wires loose in the trench and provide for expansion at all bends to allow for contraction of the wire.
E. Run wiring beneath and besides mainline piping.
F. Tape multiple control wires together in 10-foot increments.
G. Tie a 24-inch loop in all wiring at changes of direction of 30° or greater; untie after all connections have been made.
H. Lay wire-marking tape in the trench six inches above wire.

8.13.1. Extra Wire

A. Install a minimum of two extra control valve wires of a different color to each valve box.
B. Clearly mark wire in valve box and at controller.

8.13.2. Wire Splices

A. Approved field splices will be located in a valve box; show the location of these wire splice boxes on the "as-built" record drawings.
B. Waterproof valve wire splices with 3M 3570 Scotchlok, DBY, or approved equal watertight connectors.
C. Provide a minimum 24-inch coil in the wires placed in the wire splice and valve boxes, so the wire splices extend no less than 24 inches above ground level.
D. Identify the control wires with 3M-wire marker tape or approved equal at each valve, controller, and splices; show the numbering sequence of the valves on the "as-built" record drawings.

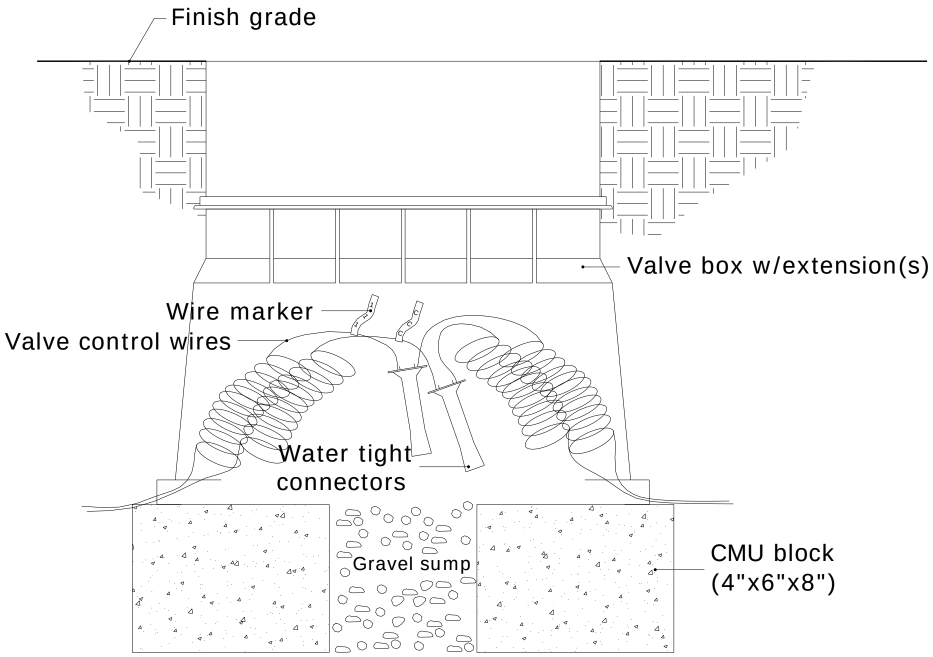

Figure 8-7: Wire splice with coil in valve box

8.13.3. Wire Sleeve Pipe

A. Use class 200 PVC pipe sleeves two pipe sizes larger than the diameter of the wire bundle (minimum of 1 ¼ inch).
B. Extend sleeve six to eight inches beyond edge of hard surface.
C. Always place wire in its own sleeve.
D. Tape ends of the pipe sleeves closed using a good quality duct tape to prevent the entrance of dirt into the sleeve.

8.14. Cements, Cleaners/Primers and Joint Compounds

Selection:

- Choose the proper solvent cements and primers for the type of piping and weather conditions.
- According to the American Society for Testing and Materials (ASTM), the label on a primer must identify its function and the designation "F-656"; this avoids confusion with plastic piping cleaner, which intends only to clean the surface of the pipe.
- Most primers are colored blue or purple to aid you in verifying their use in a completed joint.

Applicator:

- To prevent dry joints when solvent welding, use an applicator at least one-half the pipe diameter.

Threads:

- Use a non-hardening thread-sealing compound.
- Use a sealing compound that is compatible to plastics; many brands of pipe sealant contain oils, solvents, or carriers that can damage plastic.
- Use a sealing compound that does not lubricate the joint to the point that over-tightening is encouraged.

Gasket Pipe:

- Lubricate "O" ring gasket and pipe spigot ends with the lubricant recommended or supplied by the manufacturer.

Solvent Welding Procedures:

- Assembly materials needed: Miter box & saw, clean rags, primer, and knife, the right cement for the kind and size of PVC you are installing, and the right size applicator for the size of pipe.
- Cut the pipe square.
- Remove burrs, inside and out.
- Remove dirt and moisture with rag.
- Apply cleaner if applicable.
- Check dry fit; the pipe must enter at least one-third of the way into the socket without forcing it. If fit is too tight file or sand the pipe to the proper fit within the socket area.
- Apply primer.
- Apply cement while primer is still wet; flow cement on pipe with the proper applicator, then a thin coat in the fitting, and then pipe again. Use a brush at least one-half the diameter of the pipe.
- Work quickly, while applying cement; do not puddle the cement inside the fitting nor let cement run down inside the pipe.
- Assemble the pipe and fitting immediately; be sure to bottom the socket while both surfaces are still wet.
- Hold for about a minute; get help on larger sizes, or use mechanical helpers.
- Wipe off excess cement.
- Wait before disturbing, 30 minutes to six hours, depending on the temperature.
- Place pipe in trench carefully.
- Snake pipe in trench from side to side.
- Shade pipe with backfill, leaving joints exposed for inspection.
- Set period will depend on, type of cement, size of pipe, temperature and humidity, and dry joint tightness; for most cases 24 to 48 hours is a safe period for the pipe system to stand vented to atmosphere before testing.

8.15. PVC Pipe and Fittings

8.15.1. Threaded Plastic Fittings

A. Use a thread sealant (not a thread lubricant) and assemble the joint to finger tight plus one turn, two turns at the most.
B. When mating to a threaded metal piping system, the recommendation is to join a plastic male thread to a metal female thread.

8.15.2. Pipe Identification

A. Use PVC pipe that is continuously marked with identification of the manufacturer, nominal size, schedule, and pressure rating.
B. Supply pipe in 20-foot lengths and free of defects.

8.15.3. Assembly:

A. Install plastic pipe and fittings in accordance with the manufacturer's published recommendations and procedures.
B. Before installation, clean the interior of the pipe of all direct and foreign matter and keep in a clean condition during and after laying of the pipe.
C. When installing more than one pipe in the same trench, do not install one pipe above or below another.
D. Do not install mainline and lateral pipe in the same trench.
E. Do not place pipe in curving trenches that causes bending and stress on pipe and fittings.

8.15.4. Compression Couplings

A. Do not use compression, slip fix, and/or flo span couplings on sprinkler system installation.

8.15.5. Saddle Taps

A. Do not use saddle taps on sprinkler system installation.

8.15.6. Thrust Blocks

A. Construct thrust blocks at all direction changes, size changes, valves, and terminations, or at any other points of the system that will result in an unbalanced thrust line for equipment 2 ½ inches and larger.
B. Pour concrete between the space of the pipe and against undisturbed earth to the height of the outside diameter of the pipe and in accordance with the plans or standard details.

8.15.7. Flushing

A. After sprinkler piping, risers, valves, thrust blocks, etc., have been installed and after cement has had proper time to set, open the control valve to flush out the system with a full head of water.

8.16. Leakage Testing

A. Upon completion of a particular section of the irrigation system, and after sufficient time has elapsed for the curing of solvent weld joints, partial backfilling can begin, leaving all joints, risers, and connections exposed for visual inspection during the leakage test.
B. After completion and acceptance for the test by the engineer for a particular section of the irrigation system, the backfill operation can be completed.
C. Test all pressure piping hydrostatically at not less than 150 percent of designed operating pressure for a minimum one-hour, to the satisfaction of the engineer and a record kept of the conditions, leaks, repairs, and the date(s) of such tests.
D. Bleed air out of the system before testing.

Mainline:

- As specified, test the mainline for a minimum one-hour period with a maximum permissible pressure drop of two pounds after temperature has stabilized.
- First, flush the system thoroughly and fill the line slowly with water to remove air.
- Use a metering pump; elevate the water pressure to 150 percent of designed operating pressure, holding there for a minimum one-hour.
- While under pressure, inspect all joints for leaks.
- Repair all leaks and retest the pipeline until it passes the test.

Laterals:

- As specified, test all laterals for a minimum one-hour period at static psi.
- First, flush the system thoroughly before capping risers and fill the line slowly with water to remove air.
- While under pressure, inspect all joints for leaks.
- Repair all leaks and retest the system until the system passes the test.
- At the conclusion of the pressure test, install the heads and complete the backfill operation.

8.17. Sprinklers

A. Thoroughly flush all lateral piping before installation of sprinklers.
B. Install sprinkler heads to grade unless otherwise specified.
C. Install sprinkler heads in the vertical position on flat landscaped areas.
D. In areas where installing sprinklers on slopes, keep the sprinklers positioned perpendicular to the slope surface; the sprinkler should never be more than 10° away from normal.
E. Do not install above ground riser-mounted sprinklers/bubblers in areas subject to vehicular or pedestrian traffic.
F. Adjust all sprinklers to avoid any discharge on hardscapes and structures.
G. Install top of bubbler level with top of mulch or maximum one inch above.

8.18. Automatic Controllers

- Mount the controller and wire according to the manufacturer's recommended procedures and as specified.
- The engineer should approve the location of all controllers before the actual installation of said controllers.
- Connect all electric control valves in the numerical sequences as shown on the plans.
- Install the controller in a locking controller enclosure as specified on the plans.
- Connect the controller to a dedicated electrical breaker.
- A licensed Electrician must supply 120-volt power to the controller location. A separate, un-switched circuit with its own fuse or circuit breaker is recommended.
- Install all 120-volt wiring in accordance with local electrical codes.

Wall Mount:

- Install controller at eye level with a minimum of 52 inches and maximum of 64 inches from grade level to the top of controller.

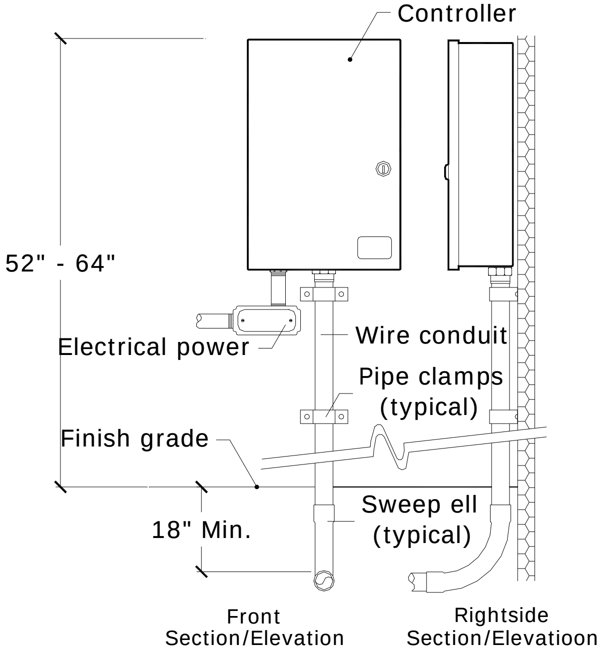

Figure 8-8: Typical wall mount controller installation

Pedestal Mount:

- Install controller on a concrete foundation sloped away from controller for drainage and a minimum of four inches thick.

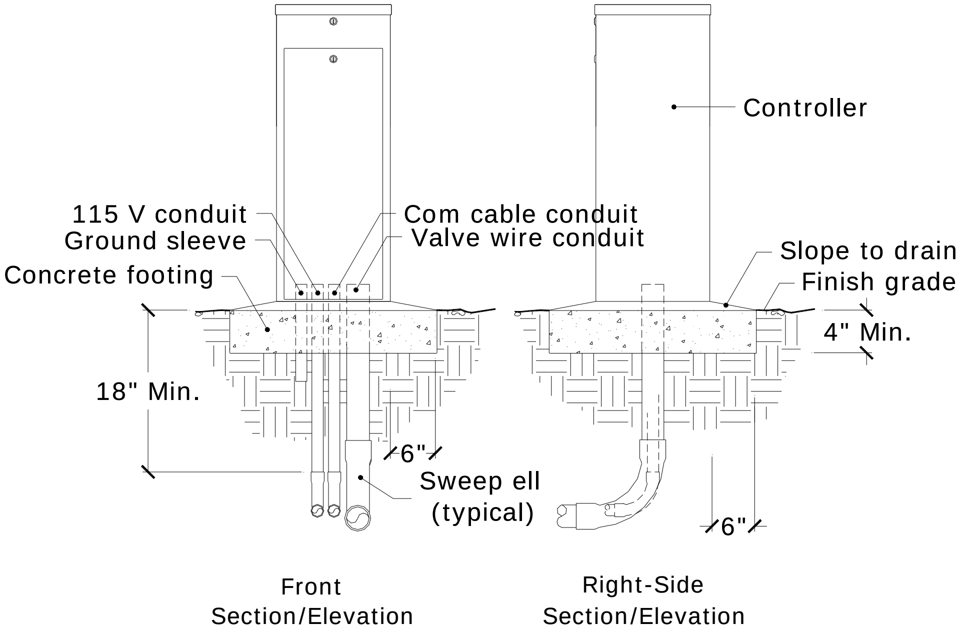

Figure 8-9: Typical pedestal mount controller installation

8.19. 110-Volt Wire

A. Install all 110-volt wiring above ground in gray schedule 40, PVC electrical conduit, flexible metallic conduit, or electrical metallic conduit.
B. Install all 110-volt wiring below ground in conduit per electrical code.

8.20. Backfilling

A. All underground work for City contracted projects must be inspected and approved by the engineer supervising the installation for correctness and completeness before backfilling.
B. All backfill material will be subject to approval by the engineer; backfill materials should be free from rubbish, rock, large stones, brush, sod, frozen material, or other unsuitable substances that may damage pipe during the backfilling operations.

For all installations:

C. Native excavated material may be used to backfill the trench.
D. Start filling the trench to not displace, deform, or damage the pipe. Compact the initial fill firmly around and above the pipe.
E. Place backfill in horizontal layers not exceeding six inches in depth and thoroughly tamp and compact to original density or better so that no settling will result.
F. Fill the pipeline with water before you begin. Before soaking, the initial backfill should be of sufficient depth to insure complete coverage of the pipe after consolidation; add enough water to the trench to thoroughly saturate the initial backfill without excessive pooling, and allow the wetted fill to dry before beginning the final backfill.

8.21. Sprinkler Coverage Inspection

For City contracted projects, a CLIA or the engineer will execute the sprinkler coverage inspection to verify the irrigation system is working properly.

Upon completion of the irrigation system, the inspection of the sprinkler coverage will verify:

- Correct adjustment of all sprinklers for no over-spray onto buildings and hardscapes
- All sprinklers operate at their design radius of throw
- Spray patterns overlap as designed
- The connection of all sprinklers to the appropriate zone
- All nozzle sizes and types called for in the system design or appropriate to the situation have been used

8.22. Pressure Distribution Testing

For City contracted projects, a CLIA or the engineer will execute the pressure test to verify the irrigation system is working properly.

A. Test the design operating pressure of the system as stated on the plan; confirm that the pressure at any point in the system does not differentiate more than 10 percent of the design operating pressure at that point.
B. Confirm that there is not more than 10 percent pressure variation between the first and last head.
C. The minimum number of zones to be tested includes at least the largest zone, smallest zone, and the zones closest and farthest from the source in terms of mainline distance.

D. Test each zone by measuring pressure at a minimum of two points; measure one pressure at the sprinkler closest to the zone control valve and measure the second at the sprinkler farthest from the zone control valve.

8.23. Application Uniformity Testing

For City contracted projects, conduct a landscape irrigation audit for all new development with spray irrigated landscaped areas totaling 1000 square feet or more in size. Select an auditor that is certified (CLIA) and independent of the property owner and of all contractors associated with the property.

A. Conduct the audit in accordance with the current edition of the Landscape Irritation Auditor's Handbook.
B. The irrigation system should meet the minimum requirement of uniformity before acceptance.
  - All fixed spray systems should meet 60 percent distribution uniformity.
  - All rotary systems should meet 75 percent distribution uniformity.
C. Submit a copy of the audit report with a twelve-month irrigation-watering schedule to the City upon completion.

8.24. Site Restoration

A. Restore all existing landscape, pavement, and grade of areas affected by work to the original condition or to the satisfaction of the engineer or owner.
B. Properly compact the pipeline trenches to the densities required by the plans and specifications.

IX. Final Acceptances

9.1. Introduction

The purpose of this section is to establish minimum standards for the contractor that ensures all materials, equipment, and documentation is provided according to specifications, as shown on the plans and as specified herein. The scope of work by these guidelines includes:

- Warranty requirements
- Operations and maintenance manual
- As-built record drawing
- Operating instructions
- Maintenance schedules
- Watering schedules
- Extra equipment

9.2. System Maintenance and Warranty

9.2.1. Warranty

The contractor:

- Guarantees the installation workmanship for a minimum period of one year from date of completion.
- Makes all necessary, reasonable efforts to handle any guarantee claims within five working days of notification of the claim.
- Promptly furnishes and installs, without cost to the City or owner, all parts or materials, which prove defective in material or workmanship.
- At no expense to the City repairs and brings to original condition all damage due to irrigation system line breaks caused by defective material or workmanship.

9.2.2. Trench Settlement

A. For a minimum period of one year from final acceptance of the system, the contractor will repair any settlement of the trenches, resulting in a smooth, level area, by one of the following methods:

- Bring to grade by top dressing (raking topsoil into the grass).
- Bring to grade with topsoil and seed.
- Remove existing sod, fill depression with top soil and replace with new sod to match existing sod.

9.3. Operations and Maintenance Manual

Upon completion of project, where all work is to the satisfaction of the City or owner, present the following items in the form of an operations and maintenance manual:

- As-built record drawing
- Operating instructions
- Maintenance schedules
- Watering schedules
- Certificates

9.3.1. “As-Built” record Drawing

A. Provide a complete “as-built” record drawing of the irrigation system that is acceptable to the City or owner.
B. Provide a reproducible record drawing prepared by a qualified drafts-person showing the entire complete irrigation system.
C. Plans must show all changes in the design and indicate the actual installation and location of all equipment, sizes, and materials.
D. Provide and install in each of the controllers on the project a legible reduction, laminated in plastic; “as-built” record drawing of the area of the irrigation system that each controller operates.

Include the following specific items:

- Mainline and lateral pipe
- Backflow prevention equipment
- Point of connection, master valve, control valves, and pressure regulators
- Gate valves, ball valves, and quick coupler valves
- Manual and automatic drain valves
- Hose bibs and hydrants
- Sprinkler, bubblers, drip emitters, filters, controller, and wire route(s)
- Water source and pump information
- Detail sheets
- Date
- Designer’s name, address, telephone number, and certification or license number
- Installer’s name, address, telephone number, contractor’s license numbe,r and certification

9.3.2. Operating Instructions

A. Provide the manufacturer’s recommended operating instructions and owner’s manuals for all products incorporated into the irrigation system.
B. Include a list of materials, catalog sheets, and parts breakdown brochures of the actual products used.

9.3.3. Maintenance Schedules

A. Provide recommended maintenance schedules for the system.
B. Include in the list a timetable of when each routine is to be completed and how to accomplish each of the tasks.

Include the following specific items:

- Controller battery type and replacement
- Drip filter cleaning
- Flushing drip system and checking for clogged emitters
- Winterizing procedures
- Sprinkler adjustments and repairs

9.3.4. Watering Schedules

A. Provide irrigation schedules as specified in these documents.

9.3.5. Certificates

A. Provide all required testing and inspection certifications with final application for payment.

9.4. Extra Equipment

A. Provide two of each, extra equipment, tools, and special wrenches if required for the maintenance of the irrigation system.

Include the following but not limit:

- Sprinkler heads and bubblers
- Extra nozzles of each type indicated on the drawings
- Special sprinkler head wrenches
- Water meter keys
- Gate valve keys
- Valve box keys
- Quick coupler keys
- Controller keys

9.5. Final Inspection and Acceptance

A. After receiving the operations and maintenance manual and extra equipment, the City will give a written acceptance of the total project to the contractor.
B. After testing and acceptance of the system, the contractor along with the engineer will instruct the owner in the operation and maintenance of the system.
C. The recommendation is to inspect the irrigation system before the end of the warranty period to insure the system is working properly.

A.

New Mexico Evapotranspiration and Rainfall Data*

ET will vary from region to region and site to site due to microclimatic conditions. To determine irrigation schedules, reference ET needs to be adjusted for known plant water requirements and site conditions.

The figures represent inches of moisture. Rainfall (RF*) is based on 30-year averages from 1930 to 1961. ET figures are potential evapotranspiration calculated from a modified Blaney-Criddle formula. The difference between RF and ET is designated as DIFF.

KEY

ET = inches of potential evapotranspiration
RF = inches of rainfall
DIFF = RF – ET

New Mexico

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Central Valley (Albuquerque)													
RF	0.41	0.44	0.41	0.45	0.61	0.72	1.46	1.61	1.20	0.81	0.32	0.47	8.91
ET	0.38	0.64	1.44	2.76	4.58	6.37	7.17	6.43	4.42	2.52	0.93	0.46	38.10
DIFF	.03	<0.20>	<1.03>	<2.31>	<3.97>	<5.65>	<5.71>	<4.82>	<3.22>	<1.71>	<0.61>	.01	<29.19>
Central Highlands (Mountainair)													
RF	0.90	0.84	0.93	0.79	1.10	1.25	2.94	2.95	1.86	1.20	0.61	0.92	16.29
ET	0.26	0.41	0.98	1.94	3.33	4.85	5.48	4.81	3.39	1.91	0.71	0.35	28.42
DIFF	0.64	0.43	<.05>	<1.15>	<2.23>	<3.60>	<2.54>	<1.86>	<1.53>	<0.71>	<0.10>	0.57	<12.13>

*Information in this appendix was taken from Toro Company, *Rainfall-Evapotranspiration Data*.

Evapotranspiration and Rainfall Data (continued)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Southeastern Plains (Carlsbad)													
RF	0.47	0.39	0.49	0.66	1.64	1.33	2.13	2.02	1.67	1.34	0.36	0.50	13.30
ET	0.52	0.78	1.68	3.10	4.95	6.79	7.33	6.66	4.69	2.84	1.17	0.66	41.17
DIFF	.05	<0.39>	<1.19>	<2.44>	<3.31>	<5.46>	<5.20>	<4.64>	<2.72>	<1.50>	<0.81>	0.16	<27.87>
Southern Desert (Las Cruces)													
RF	0.63	0.61	0.44	0.31	0.30	0.56	1.77	1.95	1.42	0.90	0.38	0.64	9.91
ET	0.56	0.83	1.78	3.11	4.94	6.91	7.66	6.80	4.88	2.97	1.24	0.68	42.36
DIFF	.07	<0.22>	<1.34>	<2.80>	<4.64>	<6.35>	<5.89>	<4.85>	<3.46>	<2.07>	<0.86>	.04	<32.45>
Southwestern Mountains (Grants)													
RF	0.73	0.67	0.66	0.54	0.50	0.75	2.27	2.71	1.61	0.98	0.46	0.71	12.59
ET	0.26	0.41	0.98	1.87	3.23	4.85	5.67	4.94	3.41	1.92	0.71	0.35	28.60
DIFF	0.47	0.26	<0.32>	<1.33>	<2.73>	<4.10>	<3.40>	<2.23>	<1.80>	<0.94>	<0.25>	0.36	<16.01>
Northeastern Plains (Clovis)													
RF	0.41	0.37	0.55	0.99	2.29	1.80	2.70	2.53	1.69	1.25	0.41	0.48	15.47
ET	0.35	0.55	1.27	2.53	4.31	6.23	7.00	6.30	4.26	2.42	0.91	0.45	36.58
DIFF	.06	<0.18>	<0.72>	<1.54>	<2.02>	<4.43>	<4.30>	<3.77>	<2.57>	<1.17>	<0.50>	.03	<21.11>
Northwestern Plateau (Gallup)													
RF	0.76	0.81	0.79	0.64	0.64	0.47	1.42	1.78	1.13	1.01	0.60	0.79	10.84
ET	0.00	0.33	0.86	1.87	3.37	4.95	6.15	5.37	3.56	1.91	0.60	0.00	28.97
DIFF	0.76	0.48	<.07>	<1.23>	<2.73>	<4.48>	<4.73>	<3.59>	<2.43>	<0.90>	0.00	0.79	<18.13>
Northern Mountains (Santa Fe)													
RF	0.81	0.80	0.95	1.12	1.65	1.24	2.39	2.76	1.64	1.28	0.70	0.73	16.07
ET	0.00	0.30	0.68	1.56	2.82	4.26	5.05	4.51	3.02	1.63	0.52	0.00	24.35
DIFF	0.81	0.50	0.27	<0.44>	<1.17>	<3.02>	<2.66>	<1.75>	<1.38>	<0.35>	0.18	0.73	<8.28>

*Information in this appendix was taken from Toro Company, *Rainfall-Evapotranspiration Data*.

B.

Measurements and Formulas

Length:

1 inch = 2.54 centimeters
1 inch = 0.254 meters
1 foot = 0.3048 meters
1 foot = 12 inches
1 yard = 0.9144 meters
1 yard = 3 feet

Area:

1 square foot = 144 square inches
1 square yard = 9 square feet
1 acre = 43,560 square feet
1 square mile = 640 acres

Volume:

1 gallon = 231 cubic inches
1 cubic foot = 7.48 gallons
1 cubic yard = 27 cubic feet
1 unit (Ccf) = 748 gallons
1 inch = 0.623 gallons
1 acre inch = 27,154 gallons
1 acre foot = 12 acre inch
1 acre foot = 325,850 gallons
1 acre foot = 43,560 cubic feet

Weight:

1 gallon = 8.34 pounds
1 cubic foot = 62.36 pounds

Pressure / Tension:

1 psi = 2.31 feet of head
1 foot of head = 0.433 psi
1 bar = 14.48 psi
1 bar = 100 kPa
1 bar = 100 centibar (cb)
1 bar = 0.987 atmosphere

Basic Geometry:

Triangle: $A = (\text{base} \times \text{height}) / 2$

Trapezoid: $A = \{(\text{base}_1 + \text{base}_2) \times \text{height}\} / 2$

Circle: $A = \prod r^2$

General: $V = \text{depth} \times \text{area}$

General: $\text{rate} = \text{amount} / \text{time}$

C.

Abbreviations

A	area
AD	allowable depletion
AE	application efficiency
AR	application rate
$\mathbf{A_s}$	emitter wetted area
AVB	atmospheric vacuum breaker
Avg.LQ	average of lower 25% sample
AW	available water
AWG	American wire gauge
BMP	Best Management Practice
C	roughness factor
CCF	unit of water
CDA	catch device throat area
cfs	cubic feet per second
CIC	Certified Irrigation Contractor
CID	Certified Irrigation Designer
CIT	Center for Irrigation Technology
CLIA	Certified Landscape Irrigation Auditor
CLSI	Contractors' Licensing Services Inc.
$\mathbf{Cv_{avg.}}$	Average catch volume
D	diameter

DU	distribution uniformity
DU_{LQ}	low quarter distribution uniformity
E	efficiency
E_{wm}	management efficiency
ET	evapotranspiration
ET_O	reference evapotranspiration
ET_r	reference evapotranspiration
EU	emission uniformity
FC	field capacity
F_f	friction factor
fps	feet per second
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
H_f	friction loss
IA	Irrigation Association
ID	inside diameter of a pipe
in.	inches
in./day	inches per day
in./hr.	inches per hour
IPS	iron pipe size
IWR	irrigation water requirement
K_c	crop coefficient
K_{cf}	water allotment conversion factor
K_d	density factor

K_L	landscape coefficient
K_{mc}	microclimate factor
K_s	species factor
K_{wa}	water allotment adjustment factor
L	length
MAD	managed allowable depletion
ml	millileters
n	number of emitters
OD	outside diameter of a pipe
PAW	plant available water
PC	pressure compensating
PCD	pressure compensating device
PE	polyethylene pipe
POC	point of connection
PR	precipitation rate
psi	pounds per square inch
PVB	pressure vacuum breaker
PVC	polyvinyl-chloride pipe
PWP	permanent wilting point
PWR	plant water requirement
Q	flow rate
R	radius
RP	reduced pressure backflow device
RZ	root zone
S	spacing

sch.	schedule of pipe
SDR	standard dimension ratio of pipe
SPACE	Sprinkler Profile & Coverage Evaluation
sq. ft.	square feet
sq. in.	square inch
S_r	row spacing
S_h	head spacing
TDH	total dynamic head
TDS	total dissolved solids
TR	testing run time
V	velocity
WA	water allotment
WR	water requirement

D.

Glossary of Irrigation Terminology

administrative authority - The individual official, board, department, or agency established and authorized by a state, county, city, or other political subdivision created by law to administer and enforce the provisions of the plumbing code as adopted or amended. (Uniform Plumbing Code, 1997)

airgap - A backflow technique utilizing a physical separation or air gap between two piping systems or hydraulic devices. The unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet conveying potable water to the flood level rim of any tank, vat, or fixture. (Uniform Plumbing Code, 1997)

air vent - A component to relieve trapped air from pipelines, allows air to escape during pipeline filling and prevents vacuum locks while the pipeline empties.

allowable depletion [AD] {in} - The amount of total plant available water (PAW) that is to be depleted from the active plant root zone before irrigation is applied. (Water Mgt Committee, 2001)

american wire gauge [AWG] – A numbering system used to designate the size of wire conductors. (IA Principles of Irrigation, 2002)

anti-siphon valve - A device to prevent contaminated water from an irrigation system, from entering into the domestic water supply.

application efficiency {%} – The amount of water stored in the root zone that is available for the plants to use divided by the average amount of water applied during irrigation. Climate, management, equipment, system design, installation, and maintenance influence the efficiency. (IA Scheduling, 1998)

application rate [AR] {in/hr} – A rate at which an irrigation system applies water to a specific area, over a given time period.

approved backflow preventer – A device installed to protect the potable water supply from contamination by irrigation water as approved by Uniform Plumbing Code 1997 Edition.

arc - The arc of a sprinkler head is the angle of coverage in degrees from one side of throw to the other. A 360° arc denotes a full circle sprinkler head. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

as-built plan - A revised record drawing of the entire completed irrigation system. The plans indicate actual installation and location of all equipment, sizes, materials, and routing of pipe and control lines, along with all other pertinent information.

atmospheric vacuum breaker [AVB] - An anti-siphon device that uses a float and seal to direct water flow. Water draining back from irrigation lines is directed to atmosphere to protect the domestic water supply. This vacuum breaker cannot have continuous pressure on the supply side.

automatic control valve – A component in an irrigation system that regulates the on/off of water from the main line to the laterals. An automatic controller activates this irrigation valve by way of hydraulic or electrical control lines.

automatic irrigation system - An irrigation system that operates in agreement with a preset schedule programmed into the automatic controller.

available pressure - Pressure at any given point when an irrigation system is in operation when all friction losses are subtracted from the static pressure.

available water [AW] {in/in} – The portion of water in a soil that can be readily absorbed by plant roots. The amount of water in the soil released between field capacity and the permanent wilting point. (ASAE, 1998)

backflow - Reverse flow of water from an irrigation system into the potable water source by backpressure or back siphonage. (LVVWD Guidelines, 1993) Water that drains back, or is sucked back, from irrigation lines.

backflow connection – Any arrangement whereby backflow can occur. (Uniform Plumbing Code, 1997)

backflow prevention device - A safety device, required by law, to prevent contaminated water from the irrigation lines from entering into the domestic water system under a backflow situation.

back pressure - An increase of pressure in the downstream piping system above the supply pressure at the point of consideration, which would cause, or tend to cause, a reversal of the normal direction of flow. (ASAE, 1998)

back-siphonage - The flowing back of used, contaminated, or polluted water from irrigation lines into a water supply pipe due to a negative pressure in such pipe. (Uniform Plumbing Code, 1997)

base plant - The predominant plant in a given planting scheme. (IA Landscape Drip, 2000)

base plant scheduling - A method of scheduling that allows for the watering of different plant types, having different watering needs, but the location of said plants is on the same zone.

Best Management Practice [BMP] - A voluntary irrigation practice that is designed to reduce water consumption and protect water quality. The irrigation best management practice is economical, practical, and sustainable and will maintain a healthy, functional landscape without exceeding the water requirements of the landscape. (Water Mgt Committee, 2001)

bid proposal - A written price proposal submitted to the irrigation system purchaser that includes all items the contractor will provide for the complete installation of the irrigation system.

brackish water - Water polluted or contaminated by organic matter, salts or acids, or a combination thereof.

bubbler - A type of sprinkler head that delivers a relatively large volume of water. Bubblers are typically used to irrigate trees and shrubs.

building supply – The pipe carrying potable water from the water meter or other source of water supply to a building or other point of use or distribution on the lot. (Uniform Plumbing Code, 1997)

capacity {gpm} – The actual pump delivery at a specific head.

catch-can test – A measurement of precipitation and uniformity from a sprinkler system, taken by placing graduated containers at evenly spaced intervals throughout an irrigated area.

Certified Backflow Assembly Tester – A person who has shown competence to test and maintain backflow assemblies to the satisfaction of the Administrative Authority having jurisdiction. (Uniform Plumbing Code, 1997)

Certified Irrigation Contractor [CIC] - An irrigation professional, who has met a set of minimum standards specified by The Irrigation Association, whose principle business is the execution of contracts and subcontracts to install, repair, and maintain irrigation systems. The CIC must conduct business in such a manner that projects meet the specifications and requirements of the contract. (Water Mgt Committee, 2001)

Certified Irrigation Designer [CID] - An irrigation professional, who has met a set of minimum standards specified by The Irrigation Association, and who engages in the preparation of professional irrigation designs. The CID evaluates site conditions and determines net irrigation requirements based on the needs of the project. The designer is then responsible for the selection of the most effective irrigation equipment and design methods. The objective of a CID is to establish specifications and design drawings for the construction of an irrigation project. (Water Mgt Committee, 2001)

Certified Landscape Irrigation Auditor [CLIA] - An irrigation professional, who has met a set of minimum standards specified by The Irrigation Association, and is involved in the analysis of landscape irrigation water use. Auditors collect site date, make maintenance recommendations and perform water audits. Through their analytical work at the site, these irrigation professionals develop monthly irrigation base schedules. Prior to certification examination, auditors are required to take an Irrigation Association approved preparatory course. (Water Mgt Committee, 2001)

check valve – A component that prevents drainage of water from the low points of an irrigation zone after irrigation, or only permits water to flow in one direction. Check valves rely on weight or spring tension to remain closed against reverse flows.

class (of pipe) - A method of grouping pipe according to the working pressure at which it can be used. Class 200 pipe can be used where pressures do not exceed 200 psi.

clay soil - A soil that is usually hard and forms very hard lumps or clods when dry and sticky when wet. A moist sample will form a ribbon that will not crack when squeezed between the thumb and forefinger. Clay is a medium fine textured soil.

coefficient of uniformity [CU] - Compares the average deviation in each catch can to the mean. The closer to 100 percent the better the uniformity. Developed for agriculture and does not indicate where dry and wet spots occur. (IA Principles of Irrigation, 2002)

component - A part of the irrigation system such as: sprinkler heads, valves, pipe, controllers, etc.

consumptive use - The amount of water used by a plant. Demand depends primarily on plant type, stage of growth, and weather factors.

contamination - An impairment of the quality of the potable water that creates an actual hazard to the public health through poisoning or through the spread of disease by sewage, industrial fluids or waste. Contamination is defined as High Hazard. (Uniform Plumbing Code, 1997)

contractor - Any person who engages in the design, fabrication, and installation of an irrigation system on a contractual basis for monetary compensation.

control line - The line that carries a signal from the controller to the automatic control valve, to open and close the valve. A control line can be hydraulic or electrical.

controller - The timing mechanism and it's mounting box that signals the automatic valves by way of hydraulic or electric control lines in an irrigation system to open and close on a pre-set program.

coverage - A term that refers to the application of water to an area. Coverage can be in relation to the throw of a sprinkler head against the spacing of it. Coverage also can be the overall job the sprinkler head or system is doing in irrigating the turf.

crop coefficient [K_c] – A factor or coefficient used to modify reference evapotranspiration to reflect the water use of a particular plant or group of plants particularly with reference to the plant species. (IA Principles of Irrigation, 2002)

cross-connection - Any connection or arrangement, physical or otherwise, between a potable water supply system and any plumbing fixture or any tank, receptacle, equipment, or device, through which it may be possible for non-potable, used, unclean, polluted, and contaminated water, or other substances, to enter into any part of such potable water system under any condition. (Uniform Plumbing Code, 1997)

cycle - Refers to one complete scheduled application of water by a controller through all programmed stations, defined by a start time and its duration. Multiple cycles can be scheduled, separated by time intervals, to allow infiltration of applied water.

cycling - A procedure that applies a series of light applications, rather than a single longer application, to apply the same quantity of water.

dedicated metering - Separate metering for landscape irrigation only.

deep percolation - Drainage of water below the bottom of the plant root zone. The water is not available for the plant to use and results in wasted water.

deficit irrigation practice – An irrigation water management strategy where the plant root zone is not filled to field capacity or the plant water requirement is not fully met. (Water Mgt Committee, 2001)

density factor [K_d] – A factor or coefficient used to modify reference evapotranspiration to reflect the water use of a particular plant or group of plants with reference to the density of the plant material. K_d ranges from 0.5 for a sparse planting to 1.3 for very dense plantings and averages 1.0. K_d for turf is typically 1.0. (IA Landscape, 2000)

densogram - A graphical representation of the overlap pattern of sprinklers. The darker areas represent heavier application rates and the lighter areas represent lighter application rates.

designer - Any person responsible for specifying which irrigation system components to use and how to use said components.

design capacity {gpm} - The maximum amount of water available for use in an irrigation system.

design operating pressure {psi} - The pressure that an irrigation system is designed to operate. The design pressure is determined by subtracting estimated friction losses from the static water pressure.

diameter (of a sprinkler) - The distance of coverage of a full circle sprinkler head from end to end.

direct burial wire - Plastic coated single strand copper wire for use as control lines for electric valves. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

distribution - The manner in which a sprinkler applies water to the turf.

distribution curve - A curve showing the rate of water application by a sprinkler head at various points along the radius.

distribution profile – The water delivered from a single sprinkler head is spread over an increasingly larger area as the distance form the sprinkler head increases. The result is less water applied to the area farthest away from the sprinkler head. The profile of a typical sprinkler pattern resembles a triangle.

distribution uniformity [DU] {%} - A measure of the efficiency of overhead irrigation calculated by analyzing the results of catch-can tests. DU represents the average of the driest 25 percent of the application rate in the sprinkler pattern divided by the average application rate of the entire pattern. DU is the evenness with which water is distributed over an irrigated area. The closer to 100 percent the better the uniformity. Easy to calculate and does not indicate where dry and wet spots occur.

domestic water supply - Water that is satisfactory for drinking, culinary and domestic purposes or potable water. Water that meets the requirements of the health authority having jurisdiction. The domestic water supply requires protection to prevent contamination from irrigation systems.

double check valve [DC] – A backflow prevention device that consists of two spring loaded check valves connected in line. The double check is considered a low hazard device because both check valves can become fouled without any visible signs and is not acceptable backflow prevention for irrigation systems.

drip emitter - See **emitter**.

drain valve - A component that drains water from an irrigation line. It can be a manual drain valve in pressurized lines or an automatic drain valve in non-pressurized lines.

drip irrigation - The slow, accurate application of water to plant root zones with a system of pipe and emitters usually operated under reduced pressure. Drip irrigation products are normally rated in gallons per hour (gph).

dual programming - The capacity of an irrigation controller to schedule the frequency and duration of irrigation cycles to meet varying water requirements of plants served by a system. A dual program controller will have the capability of two separate programs such as one for drip and another for sprinklers.

dynamic pressure {psi} - The pressure reading that exists in a pipeline system with water flowing. (Toro Subsurface Irrigation Design, 1998)

effective rainfall {in} - The amount of total rain that is actually stored in the root zone. Some rainwater does not reach the soil profile because it is held in mulch or turf thatch or because it runs off. Some water may percolate below the root zone and be lost depending upon the intensity and duration of the rain event and the water content of the soil prior to the rain event. (IA Scheduling, 1999)

effective rooting depth – The soil depth from which a full grown plant extracts most of the water needed for transpiration. (Hess, 1999)

efficiency [E] {%} - A value representing the amount of water beneficially applied, divided by the total water applied. Efficiency includes both the limitation of the irrigation systems distribution uniformity, and the possible errors of irrigation scheduling.

electric valve - A component in an irrigation system that regulates the on/off of water from the main line to the laterals. An automatic controller activates this irrigation valve by way of electrical control lines (direct burial ground wire) between the controller and valve.

elevation gain {psi} - An increase in water pressure when water is used downhill from its source. The gain is 0.433 pounds per square inch for each foot of elevation.

elevation loss {psi} - A decrease in water pressure when water is used uphill from its source. The loss is 0.433 pounds per square inch for each foot of elevation.

emitter - A low volume emission device that delivers water to plants at a calculated flow rate, measured in gallons per hour. Emitters directly apply water to an individual plant root zone.

emission uniformity [EU] {%} - A factor that denotes how consistent the emission devices are at applying water. Factors that affect EU are psi, temperature, emitter type, and quality & consistency in manufacturing.

emitter wetted area [A_s] - The area that is wet from an emitter after irrigation.

engineer - Refers to the person designated by the City as an authorized representative to work with the contractor to ensure the irrigation system follows specifications.

evaporation - The water lost to the atmosphere from the soil.

evapotranspiration [ET] {in/time period} - The amount of water lost to the atmosphere by the combination of evaporation and transpiration of the plants growing in the soil.

field capacity [FC] {in/ft} - A measure of the water held by the soil against the influence of gravity. A soil is usually at field capacity when allowed to drain freely after saturation from rainfall or irrigation.

filter (drip) - A component added in a control zone to screen dirt and debris from the water to prevent clogging of the emission devices.

fixed spray head – See **spray head**

flow {gpm} - The movement of water through the irrigation piping system. (Toro Subsurface Irrigation Design, 1998)

flow sensor – A device that measures the rate of liquid flow or the total accumulated flow. (Water Mgt Committee, 2001)

feet per second [fps] - The measurement of the velocity of water in the piping system.

flush manifold - The end line or pipe in a subsurface grid that connects to all the driplines. A flush valve and/or cap are installed in the manifold to flush debris and sediment from the grid during each irrigation cycle. (Toro Subsurface Irrigation Design, 1998)

freeze sensor - A device wired to a controller that will override a scheduled watering program when the outdoor temperature drops to a near freezing level.

frequency – See **irrigation frequency**

friction factor [F_f] {psi} - A method of sizing pipe that allows the designer to predetermine the amount of pressure variation in the piping.

friction loss [H_f] {psi} - The loss of pressure (force) incurred when water is moving through the components and piping of an irrigation system. Losses depend on the pipe roughness, length and diameter, orifice sizes in components, mechanical restrictions, and volume of water being moved.

gallons per hour [gph] - A measure of the flow of water through an irrigation system. Gph is typically the standard flow measurement of water in a low volume irrigation system.

gallons per minute [gpm] - A standard measure of the flow of water through an irrigation system. Gpm is typically the standard flow measurement of water in irrigation design.

gate valve - A component used to manually shut off the water supply to a certain area.

gauge (wire) – A wire sizing standard. The larger the gauge number, the smaller the wire.

graywater - Household wastewater generated on site, such as rinse water, washing machine discharge, or bath water none of which includes materials that could pose a health hazard. (Water Mgt Committee, 2001)

hardscape – Impervious surfaces within the landscape, such as concrete walkways or brick paving. (Water Mgt Committee, 2001)

head (of a pump) - A measure of pressure in terms of an equivalent height of water column, which would create that pressure (feet of head).

head (of a sprinkler) - A component that distributes water to a specific area. Other terms used for head are sprinkler or sprinkler head.

head to head - The placing of sprinkler heads so that the distance between heads matches the radius of them and that the pattern of precipitation from one head completely overlaps the area between it and an adjacent head. Head to head coverage refers to 100 percent coverage.

hydraulics – Principles that are a part of the design and function of an irrigation system that includes fluid in motion under pressure.

hydrozone - A portion of a landscape area having plants with similar water needs that will be irrigated on the same schedule, using the same irrigation method.

infiltration rate (intake rate) {in/hr} - The dynamic rate at which irrigation water applied to the soil surface can move into the soil profile. The rate typically declines rapidly after an initial period of surface hydration. This value depends largely on the texture of the soil and whether the soil is overly compacted. (Water Mgt Committee, 2001)

in-line emitter tubing - A polyethylene tube, typically one-half inch, with emitters pre-installed at the factory.

installed cost - The total cost of an irrigation system completely installed, including materials, labor, overhead, and profit.

intake rate (of soil) {in/hr} – The rate that water infiltrates a bare soil at a specific time during the water application period. (IA Principles of Irrigation, 2002)

irrigation - The intentional application of water for purposes of sustained plant growth. (Water Mgt Committee, 2001)

The Irrigation Association [IA] - A non-profit trade organization representing the irrigation industry at the national and international level formed to improve the products and practices used to manage water resources. Its primary purpose is to provide members with comprehensive programs and services to help them keep pace with the rapidly changing technology of the industry. The IA is dedicated to serving the needs of its members and to helping shape the future of irrigation. The IA establishes and conducts authoritative educational programs to broaden and focus public awareness of issues related to water management, to provide professional certification of practitioners of irrigation-related disciplines and to ensure the accessibility of research information pertinent to industry practices and products. (Water Mgt Committee, 2001)

irrigation audit - See **landscape irrigation audit**

irrigation contractor - Any person who is in the business of installing, repairing, or maintaining landscape irrigation systems. See also Certified Irrigation Contractor. (Water Mgt Committee, 2001)

irrigation design - Drawings and associated documents detailing irrigation system layout, component installation, and maintenance requirements. (Water Mgt Committee, 2001)

irrigation designer - See **designer**.

irrigation efficiency – A measure of the amount of water stored in the root zone that is available for the plants to use, divided by the average amount of water applied during irrigation. Climate, management, equipment, system design, installation, and maintenance influence the efficiency.

irrigation frequency - The number of irrigation events per day, week, or other period. The number of full irrigation applications per unit of time.

irrigation interval - The number of full days between irrigation applications. (Water Mgt Committee, 2001)

irrigation requirement – See **irrigation water requirement**

irrigation run time - See **run time**.

irrigation schedule - The watering program that indicates the operating times, frequency, and intervals for each irrigation system zone.

irrigation system – A set of components that may include the water source, water distribution network, control components, and other general irrigation equipment. (Rain Bird, 1997)

irrigation water requirement [IWR] {in} - The amount of water the irrigation system will need to apply with consideration to uniformity.

landscape architect – See **designer**

landscape coefficient [K_l] – A factor or coefficient used to modify reference evapotranspiration to reflect the water use of a particular plant or group of plants that includes species factor, density factor, and microclimate factor (e.g., KL = K_s x K_d x K_{mc}). (IA Landscape, 2000)

landscape contractor – Any person who is in the business of constructing, installing, and/or maintaining turf, trees or ornamental plant material, and associated hardscaping in an urban environment. (Water Mgt Committee, 2001)

landscape irrigation audit – A procedure to collect and present information concerning the uniformity of application, precipitation rate, and general condition of an irrigation system and its components. (Water Mgt Committee, 2001)

landscape irrigation auditor – See **Certified Landscape Irrigation Auditor**

landscape professional – Any person engaged in landscaping as a source of livelihood.

lateral - The pipe in an irrigation system located downstream from the remote control valve that delivers water to the sprinklers or emitters. This pipe does not have constant pressure in the line.

line source - This method of irrigation applies to dense hydrozones where in-line emitter tubing waters an area or bed of plants.

loam soil - A soil containing less than 40 percent clay and more than 20 percent sand. Loam usually has a mixture of sand, silt and clay. When squeezed, a moist sample will form a cast and not easily crumble when handled. Squeezed when dry, it will form a cast that will bear careful handling. A loam soil is a medium textured soil having a mixture of the different grades of sand, silt, and clay in such proportion that the characteristics of not one predominate.

low head drainage - Drainage of water from irrigation lines at the low elevations after irrigation.

mainline - The pipe in an irrigation system that delivers water to the remote control valves. This pipe is generally under constant pressure and located upstream from the remote control valves.

managed allowable depletion [MAD] {%} - The portion or percent of soil moisture that an irrigator will allow to be depleted from the active plant root zone before irrigation is applied without stress to the plant; selection of a low allowable depletion requires more frequent irrigation of smaller amounts. A higher allowable depletion will require less irrigation of larger amounts.

management efficiency [E_{wm}] {%} - Quantifies how well the irrigation water is being managed and applying just the amount of supplemental irrigation water needed by the plants to keep them healthy, but not excessively irrigated. (Water Mgt Committee, 2001)

manifold - A group of control valves located together in the same area.

master valve - A normally closed valve installed at the supply point of the main that opens when the automatic system is activated.

matched precipitation rate - Equal water-delivery rate of sprinkler heads with varying arc patterns within an irrigation zone. The flow rate of a quarter circle sprinkler is equal to one half that of a half circle sprinkler, and the flow rate of a half circle sprinkler is equal to one half that of a full circle sprinkler.

microclimate - A subdivision of a landscape characterized by environmental conditions that may differ from the typical site condition to a degree that ET_r will be affected, either higher or lower that the expected ET_r for the site. Examples of conditions that might create a separate microclimate include reflected heat, breezeways, and shading. (Water Mgt Committee, 2001)

microclimate factor [K_{mc}] – A factor or coefficient used to modify reference evapotranspiration to reflect the microclimate of an area. K_{mc} ranges from 0.5 to 1.4 and averages 1.0. For typical lawn conditions, K_{mc} = 1.0 and for plantings in medium strips within a large parking lot or in an environment having nearby reflective glass, K_{mc} = 1.2 to 1.4. (IA Landscape, 2000)

micro irrigation - The slow, accurate application of water to plant root zones with a system of pipe and emitters usually operated under reduced pressure. Micro irrigation products are normally rated in gallons per hour (gph).

micro spray - A low volume emission device that operates at lower flow rates than a conventional spray head. Micro sprays are used to water an entire hydrozone rather than individual plant root zones.

moisture sensor – A device that monitors or measures soil water content or tension. (Water Mgt Committee, 2001)

multiple cycles - Refers to several scheduled short applications of water by a controller separated by time intervals, rather than one long application to extract maximum efficiency from a sprinkler system.

multiple start times - An irrigation controller's capacity to accept programming of more than one irrigation cycle for a zone in a given day.

non-volatile memory - A feature in irrigation controllers that will retain the programmed information in electronic memory during a power failure without the need for a battery. (Hunter, 2003)

nozzle - The discharge orifice of the sprinkler head. (LVVWD Guidelines for Landscape Irrigation Systems, 1993) A nozzle is typically an interchangeable part on the top of a sprinkler head that determines the spray pattern and distance of throw.

operating cost - The cost of operating an irrigation system that includes the cost of water, pumping, repairs, maintenance, and labor. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

operating pressure - The pressure at which an irrigation system or sprinkler head operates when all friction losses are subtracted from the static pressure, usually indicated at the base of a sprinkler head.

overlap - The amount or percentage of the coverage that one sprinkler pattern overlaps another in an installed pattern.

over spray - The application of water via sprinkler irrigation to areas other than the intended area.

over water - The application of more water than needed for proper growth. (LVVWD Guidelines for Landscape Irrigation Systems, 1993) Wasted water due to run-off or deep percolation is the result of over watering. Keeping the soil saturated can prevent the plant from receiving oxygen.

percent switch - A feature of an irrigation controller that allows a change in the duration of all programmed irrigation by a percentage.

permanent wilting point [PWP] {in/in} - The soil moisture content at which the plant wilts and remains in a wilted state and will not recover, ceasing normal growth and transpiration.

pitot tube - A small ell shaped tube that can be attached to a pressure gauge or other measuring device to measure the velocity head of water discharging from a nozzle.

plant available water [PAW] {in} - The quantity of water stored within the root zone between the conditions of field capacity and the permanent wilting point.

plant factor - A decimal fraction that represents a portion of reference evapotranspiration and a standard for a plant's water requirement.

plant water requirement [PWR] {in} - The amount of water used by a plant as computed by $PWR = ET_r \times K_L$, where ET_r is the reference evapotranspiration and K_L is the plant-specific landscape coefficient. The evapotranspiration rate by the plant for a particular period in inches. (Water Mgt Committee, 2001)

point of connection [POC] - The location where a tap is made into the water supply for connection of an irrigation system.

point source - This method of irrigation applies to sparsely spaced hydrozones where drip emitters water individual plants.

polyethylene tubing [PE] - Black, flexible distribution component typically used in low volume irrigation systems to bring water to emission devices.

potable water - Water that is satisfactory for drinking, culinary, and domestic purposes and meets the requirements of the health authority having jurisdiction. (Uniform Plumbing Code, 1997)

pounds per square inch [psi] - The standard unit of measure for water pressure.

precipitation rate [PR] {in/hr} - The average rate at which an irrigation system applies water in an area per unit of time.

pressure - The force of water that exists in a piping system, measured in pounds per square inch (psi).

pressure compensating device [PCD] - A device that when added to a sprinkler nozzle eliminates fogging and provides precise flow rates.

pressure loss - The reduction of water pressure under flow conditions, caused primarily by friction of water against the inner walls of pipe and components or elevation changes.

pressure rating (pipe) - The estimated maximum internal pressure that the water in the pipe can exert continuously where failure of the pipe will not occur. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

pressure regulator - A component added to an irrigation system to reduce the downstream pressure. Pressure regulators are available pre-set or adjustable.

pressure relief valve - A component that provides surge protection for irrigation systems. The valve will open and discharge to atmosphere when the pressure in a pipeline exceeds a preset point to relieve the high-pressure condition.

pressure vacuum breaker [PVB] - A backflow prevention device than incorporates the use of a spring loaded seat for positive sealing to protect domestic water from possibly contaminated irrigation water. This Vacuum breaker can have constant pressure on the inlet and outlet sides.

program - A program is information the user enters into the controller's memory that determines when the system will water. A program contains what days to water, what time to start watering, and how long each zone will water.

pump - A mechanical device that converts mechanical forms of energy into hydraulic energy.

pump curve - A graphic representation of a pump's performance including efficiency, total dynamic head, flow rate, etc. over its entire operating range.

PVC pipe – An abbreviation for poly vinyl chloride plastic pipe, a semi-rigid plastic pipe commonly used in irrigation systems. This pipe uses solvent weld fittings.

radius (of a sprinkler) - The distance of throw from the base of the sprinkler head to the furthest reach of the pattern.

rain delay – A feature of an irrigation controller to allow the irrigation manager to temporarily override a scheduled watering program during a rain event for a pre-determined number of days.

rain sensor - A device wired to a controller that will override a scheduled watering program in the event of a specified amount of rainfall.

rain switch – See **rain sensor**

reclaimed water - Domestic wastewater that has been treated to a quality suitable for a beneficial use from a treatment plant. (Toro Subsurface Irrigation Design, 1998) Water for purposes other than as a potable supply (e.g. turf irrigation).

record drawing - A revised drawing of the entire completed irrigation system. The plans indicate actual installation and location of all equipment, sizes, materials, and routing of pipe and control lines, along with all other pertinent information.

reduced pressure assembly [RP, RPA, RPZ] - A backflow prevention device than incorporates the use of two spring loaded check valves and a hydraulically dependent differential relief valve. The RP can have constant pressure and back pressure. It is the only type of mechanical device that is generally accepted for hazardous backflow conditions.

reference evapotranspiration [ET_o] – The rate of evapotranspiration from well-watered cool season grass kept four to six inches tall.

reference evapotranspiration [ET_r] – The rate of evapotranspiration from a well-watered agricultural crop such as alfalfa kept 18 to 20 inches tall.

remote control valve - A component in an irrigation system that regulates the on/off of water from the main line to the laterals. An automatic controller activates this irrigation valve by way of hydraulic or electrical control lines.

restrained pipe joints - Pipe joints held together by glue or mechanical devices that resist internal pressure forces without the aid of thrust blocks. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

retrofit - The replacement and upgrading of components within an existing irrigation system.

riser (of a sprinkler) - A threaded nipple that attaches the sprinkler head to the lateral pipe.

root zone [RZ] {in} - The depth of the soil profile occupied by the roots of the plant. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

rotors - Gear driven sprinklers that spray a solid stream of water and rotate slowly in a circular pattern.

runoff - Water that is not absorbed by the soil or landscape to which it is applied. Runoff occurs when water is applied at too great a rate or when water is applied for too long a time.

runtime {minutes, hours} - The duration of an irrigation event for a given zone or station.

sandy soil - When squeezed, a moist sample will form a cast, but will crumble easily when touched and easily fall apart. Squeezed in the hand when dry, it will fall apart when pressure is released. Sand is a course-textured soil.

saturation – A soil is at saturation when 100 percent of the pore space is filled with water and all oxygen is displaced.

schedule (of pipe) - A term that designates a standard series of wall thickness for all sizes in which a pipe is made. One-inch schedule 40 PVC will have the same wall thickness as two-inch schedule 40 PVC.

scheduling - The procedure of establishing and implementing the time and amount of irrigation water to apply. (IA Principles of Irrigation, 2002)

scheduling coefficient [SC] – A theoretical window that is 1 percent or 5 percent of the total area between sprinklers. This window is slid over the entire area looking for the driest area. The precipitation rate in the driest area is divided into the average precipitation rate for the whole area. The closer to one the better the uniformity. Less than 1.5 indicates a good nozzle/spacing combination. Easy to understand, difficult to calculate and does not indicate over-watering. (IA Principles of Irrigation, 2002)

service line - The pipe supplying water from the city water main to the water meter. (Toro Subsurface Irrigation Design, 1998)

single leg profile - One row of cans to provide a precipitation rate profile of the throw of an individual sprinkler head. (IA Principles of Irrigation, 2002)

sleeve (pipe) - A pipe used to enclose, protect, and facilitate the installation of other pipes, wires, or tubing; usually used under pavement, sidewalks, or planters.

slope - A vertical rise in the grade. A 4:1 slope equals a four-foot horizontal distance per one foot of vertical change. Percent for the slope equals vertical rise in feet per 100 feet of horizontal distance, thus a 4:1 slope equals a 25 percent slope.

soil moisture sensor - A device installed in the root zone to measure soil moisture, wired to a controller. Two sensors can be used to start and stop irrigations or one sensor can be used to override a scheduled watering program of an individual zone valve or section of zone valves when there is sufficient moisture.

soil probe - A soil-coring tool that allows an intact soil core to be removed from the soil profile for examination. (Water Mgt Committee, 2001)

soil type - Horticulturists classify soil by the three particles that compose soil; sand, silt, and clay. The percentage of each of these particles is what determines the actual soil type. The size of the soil particles is the basis for these three classifications, clay being the smallest, silt is larger, and sand the largest.

spacing - The distance between sprinkler heads, emitters, or drip lines.

spaghetti tubing - A distribution component typically used in low volume irrigation systems to bring water from the polyethylene tubing directly to plant root zones.

species factor [K_s] - A factor or coefficient used to adjust reference evapotranspiration to reflect plant species. Generally, values for K_s range from 0.2 to 0.9 and average 0.5. K_s is 0.6 for warm-season turf and 0.8 for cool-season turf. (IA Landscape, 2000)

spray head - A sprinkler head that delivers water in a fixed pattern. Precipitation rates are high relative to the area covered by the spray pattern.

sprinkler - A component that distributes water to a specific area. Other terms for sprinkler are head or sprinkler head.

square spacing - A method used in irrigation design to locate the position of sprinkler heads. The use of square spacing is for areas defined by a border that so not allow overthrow from the sprinkler heads.

standard dimension ratio [SDR] - The ratio of pipe diameter to wall thickness. SDR PVC will have uniform pressure ratings for all pipe sizes.

static water pressure {psi} - The pressure of water that exists in a piping system when there is no water flowing.

station - A position on a controller that controls a zone valve or area of the sprinkler system.

subsurface grid - A group of parallel, inline driplines that are connected to supply manifolds and flush manifolds. (Toro Subsurface Irrigation Design, 1998)

supplemental irrigation - The application of water to a landscape in addition to natural precipitation.

supply (water source) - The origin of the water used in the irrigation system.

surge - The build-up of water pressure in a piping system due to certain characteristics of the pipe, valves, and flows. (Toro Subsurface Irrigation Design, 1998)

swing joint - A flexible connection between the lateral pipe and the sprinkler head that allows the head to move when force is applied. Easily adjusts sprinkler head to final grade. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

system efficiency {%} - A factor that denotes how efficient the irrigation system is at applying water. When water from the system discharges, only a certain percentage will reach the plant root zone and be available for plant consumption. The percentage of water that reaches the plant and is available equates to the system efficiency. (IA Landscape Drip, 2000)

thrust blocks - Blocks of concrete formed between unrestrained fittings and undisturbed soil.

thrust restraint - The securing of fittings and joints from movement due to the unbalanced action of internal water pressure. (LVVWD Guidelines for Landscape Irrigation Systems, 1993)

total dynamic head [TDH] - A function of the system. TDH is pressure that is generally expressed in feet, and its value is the summation of the total discharge head minus the total suction head or plus the total suction lift.

trajectory - The measurement (in degrees) of the angle of the water projecting out from the sprinkler's nozzle. A trajectory of zero degrees would indicate a flat projection of water out from the nozzle. (Hunter, 2003)

transpiration - The water plants use to transport dissolved chemicals and minerals to control the physical shape and direction of growth and that evaporates from leaves as a means of controlling leaf temperature.

triangular spacing - A method used in irrigation design to locate the position of sprinkler heads. The use of triangular spacing is primarily for large open areas where overthrow is not a problem.

uniformity - The evenness of the precipitation over a given area. (IA Contractor, 1999)

unrestrained pipe joints - Gasket or O-ring joints that are not capable of counter balancing the force created by the internal hydraulic pressure of the system.

valve - A component that controls the flow of water to the irrigation system.

velocity [V] {fps} - The speed at which water flows through the piping system. (Toro Subsurface Irrigation Design, 1998)

wastewater - Water containing waste including graywater, blackwater, or water contaminated by waste contact, including process-generated and contaminated rainfall runoff. (Toro Subsurface Irrigation Design, 1998)

water allotment [WA] {ccf or gallons} – A volume of water allocated to the entire landscape area. This allotment is established by the water purveyor for the purpose of ensuring adequate supply of water resources. (Water Mgt Committee, 2001)

water audit - Landscape irrigation audits produce detailed information about actual irrigation system performance in the field. This information is used to prepare detailed irrigation schedules for each station throughout the year.

water demand - The total amount of flow (gpm) required by a group of sprinkler heads or zone valve at any given time.

water hammer - The surging of pressure that occurs when a control valve is suddenly closed. In extreme conditions, this surging will cause the pipes to vibrate or create a pounding noise. Water hammer is most commonly caused by fast closing valves or high velocity water flow.

water main - The city water pipe located in the street or right-of-way. (Toro Subsurface Irrigation Design, 1998)

water meter - A device used to measure the flow of water. (IA Principles of Irrigation, 2002)

water pressure {psi} - The force of water that exists in a piping system.

water source - The city main line normally supplies water for residential and commercial landscape irrigation use and in some cases a pump. The available flow rate is determined through the size of the water meter and the size of the service line.

watering window - The amount of time available to water in any one period. This may be several hours a day for given days of the week. (IA Landscape Drip, 2000)

watering schedule - The watering program that indicates the operating times, frequency, and intervals for each irrigation system zone.

wetting pattern - The area of the ground that is wet just after an irrigation. (IA Landscape Drip, 2000)

wind sensor - A device connected to a controller that will override a scheduled watering program during periods of high wind.

wire - In an automatic sprinkler system, low voltage direct burial wire is used to connect the automatic control valves to the controller. The larger the gauge numbers for the wire, the thinner the wire.

working pressure (pipe) {psi} - The internal water pressure that a pipe can withstand without damage.

zone - An area or grouping of irrigation components, including sprinklers or emitters and pipes, controlled and operated simultaneously by one remote control valve.

E.

Technical Data

Friction Loss Charts

Velocity of flow values are computed from the equation:

$$V = (0.408 \times Q)/d^2$$

Where:

V = Velocity in feet per second
0.408 = Conversion factor
Q = Flow (gpm)
d = Inside pipe diameter (inches)

Friction pressure loss values are computed from the equation:

$$H_f = 0.090194 \times (100/C)^{1.852} \times (Q^{1.852}/d^{4.866})$$

Where:

H_f = Pressure loss (psi)
C = Roughness factor
Q = Flow (gpm)
d = Inside pipe diameter (inches)

The value of the C factor is a measure of the roughness of the inside of the pipe. The lower the number, the rougher the inside of the pipe and the greater the pressure loss.

The shaded area on the chart designates those flow rates that exceed 5 fps. It is recommended that caution be used with flow rates above 5 fps in main lines where water hammer will be a concern.

Size – indicates the "nominal" pipe size. Nominal means "in name only," and none of the actual pipe dimensions are exactly that size.

Standard Pipe Dimensions (Inches)

Class 125 PVC SDR 32.5

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.840	0.750	.045	125
¾”	1.050	0.954	.048	125
1”	1.315	1.211	.052	125
1 ¼”	1.660	1.548	.056	125
1 ½”	1.900	1.784	.058	125
2”	2.375	2.229	.073	125
2 ½”	2.875	2.699	.088	125
3”	3.500	3.284	0.108	125
4”	4.500	4.224	0.138	125
6”	6.625	6.217	0.204	125
8”	8.625	8.095	0.265	125

Class 160 PVC SDR 26

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
1”	1.315	1.195	.060	160
1 ¼”	1.660	1.532	.064	160
1 ½”	1.900	1.754	.073	160
2”	2.375	2.193	.091	160
2 ½”	2.875	2.655	0.110	160
3”	3.500	3.230	0.135	160
4”	4.500	4.154	0.173	160
6”	6.625	6.115	0.255	160
8”	8.625	7.961	0.332	160

Standard Pipe Dimensions (Inches)

Class 200 PVC SDR 21

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.840	0.716	.062	200
¾”	1.050	0.930	.060	200
1”	1.315	1.189	.063	200
1 ¼”	1.660	1.502	.079	200
1 ½”	1.900	1.720	.090	200
2”	2.375	2.149	0.113	200
2 ½”	2.875	2.601	0.137	200
3”	3.500	3.166	0.167	200
4”	4.500	4.072	0.214	200
6”	6.625	5.993	0.316	200
8”	8.625	7.805	0.410	200

Class 315 PVC SDR 13.5

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.840	0.716	.062	315
¾”	1.050	0.894	.078	315
1”	1.315	1.121	.097	315
1 ¼”	1.660	1.414	0.123	315
1 ½”	1.900	1.618	0.141	315
2”	2.375	2.023	0.176	315
2 ½”	2.875	2.449	0.213	315
3”	3.500	2.982	0.259	315
4”	4.500	3.834	0.333	315
6”	6.625	5.643	0.491	315

Standard Pipe Dimensions (Inches)

Schedule 40 PVC

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.840	0.622	0.109	600
¾”	1.050	0.824	0.113	480
1”	1.315	1.049	0.133	450
1 ¼”	1.660	1.380	0.140	370
1 ½”	1.900	1.610	0.145	330
2”	2.375	2.067	0.154	300
2 ½”	2.875	2.469	0.203	280
3”	3.500	3.068	0.216	260
4”	4.500	4.026	0.237	220
6”	6.625	6.031	0.280	180
8”	8.625	7.981	0.322	160

Schedule 80 PVC

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.840	0.546	0.147	850
¾”	1.050	0.742	0.154	690
1”	1.315	0.957	0.179	630
1 ¼”	1.660	1.278	0.191	520
1 ½”	1.900	1.500	0.200	470
2”	2.375	1.939	0.218	420
2 ½”	2.875	2.323	0.276	400
3”	3.500	2.900	0.300	370
4”	4.500	3.826	0.337	320
6”	6.625	5.761	0.432	280
8”	8.625	7.625	0.500	250

Standard Pipe Dimensions (Inches)

Polyethylene Pipe SDR 15

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.742	0.622	.060	80
¾”	0.944	0.824	.060	80
1”	1.189	1.049	.070	80
1 ¼”	1.564	1.380	.092	80
1 ½”	1.824	1.610	0.107	80
2”	2.343	2.067	0.138	80
2 ½”	2.799	2.469	0.165	80

Polyethylene Pipe SDR 11.5

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.742	0.622	.060	100
¾”	0.968	0.824	.072	100
1”	1.231	1.049	.091	100
1 ¼”	1.620	1.380	0.120	100
1 ½”	1.890	1.610	0.140	100
2”	2.427	2.067	0.180	100
2 ½”	2.899	2.469	0.215	100

Polyethylene Pipe SDR 9

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.760	0.622	.069	125
¾”	1.008	0.824	.092	125
1”	1.283	1.049	0.117	125
1 ¼”	1.686	1.380	0.153	125
1 ½”	1.968	1.610	0.179	125
2”	2.527	2.067	0.230	125

Standard Pipe Dimensions (Inches)

Type "M" Copper Tube

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.625	0.569	.028	
¾”	0.875	0.811	.032	
1”	1.125	1.055	.035	
1 ¼”	1.375	1.291	.042	
1 ½”	1.625	1.527	.049	
2”	2.125	2.009	.058	
2 ½”	2.625	2.495	.065	
3”	3.125	2.981	.072	
4”	4.125	3.953	.095	

Type "L" Copper Tube

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.625	0.545	.040	
¾”	0.875	0.785	.045	
1”	1.125	1.025	.050	
1 ¼”	1.375	1.265	.055	
1 ½”	1.625	1.505	.060	
2”	2.125	1.985	.070	
2 ½”	2.625	2.465	.080	
3”	3.125	2.945	.090	
4”	4.125	3.905	0.110	

Standard Pipe Dimensions (Inches)

Type "K" Copper Tube

Pipe Size	OD Inches	ID Inches	Wall Thickness	Maximum Working Pressure
½”	0.625	0.527	.049	
¾”	0.875	0.745	.065	
1”	1.125	0.995	.065	
1 ¼”	1.375	1.245	.065	
1 ½”	1.625	1.481	.072	
2”	2.125	1.959	.083	
2 ½”	2.625	2.435	.095	
3”	3.125	2.907	0.109	
4”	4.125	3.857	0.134	

Class 160 PVC Plastic Pipe

SDR 26 (1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	1"		1¼"		1½"		2"		Size
ID	1.195		1.532		1.754		2.193		ID
OD	1.315		1.660		1.900		2.375		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	.02	0.29	.01	0.17	.00	0.13			1
2	.07	0.57	.02	0.35	.01	0.27	.00	0.17	2
3	0.16	0.86	.05	0.52	.02	0.40	.01	0.25	3
4	0.26	1.14	.08	0.70	.04	0.53	.01	0.34	4
5	0.40	1.43	0.12	0.87	.06	0.66	.02	0.42	5
6	0.56	1.71	0.17	1.04	.09	0.80	.03	0.51	6
7	0.75	2.00	0.22	1.22	0.12	0.93	.04	0.59	7
8	0.96	2.29	0.29	1.39	0.15	1.06	.05	0.68	8
9	1.19	2.57	0.36	1.56	0.18	1.19	.06	0.76	9
10	1.45	2.86	0.43	1.74	0.22	1.33	.08	0.85	10
11	1.72	3.14	0.51	1.91	0.27	1.46	.09	0.93	11
12	2.03	3.43	0.60	2.09	0.31	1.59	0.11	1.02	12
13	2.35	3.71	0.70	2.26	0.36	1.72	0.12	1.10	13
14	2.70	4.00	0.80	2.43	0.42	1.86	0.14	1.19	14
15	3.06	4.29	0.91	2.61	0.47	1.99	0.16	1.27	15
16	3.45	4.57	1.03	2.78	0.53	2.12	0.18	1.36	16
17	3.86	4.86	1.15	2.96	0.60	2.25	0.20	1.44	17
18	4.29	5.14	1.28	3.13	0.66	2.39	0.22	1.53	18
19	4.75	5.43	1.42	3.30	0.73	2.52	0.25	1.61	19
20	5.22	5.71	1.56	3.48	0.81	2.65	0.27	1.70	20
25	7.89	7.14	2.36	4.35	1.22	3.32	0.41	2.12	25
30	11.06	8.57	3.30	5.22	1.71	3.98	0.58	2.55	30
35	14.71	10.00	4.39	6.08	2.27	4.64	0.77	2.97	35
40	18.84	11.43	5.62	6.95	2.91	5.30	0.98	3.39	40
50	28.48	14.29	8.50	8.69	4.40	6.63	1.48	4.24	50
60			11.92	10.43	6.17	7.96	2.08	5.09	60
70			15.86	12.17	8.21	9.28	2.77	5.94	70
80			20.30	13.91	10.51	10.61	3.54	6.79	80
90					13.07	11.94	4.41	7.64	90
100					15.89	13.26	5.36	8.48	100
110					18.96	14.59	6.39	9.33	110
120							7.51	10.18	120
130							8.71	11.03	130
140							9.99	11.88	140
150							11.35	12.73	150
160							12.80	13.57	160
170							14.32	14.42	170
180									180
190									190
200									200
210									210
220									220
230									230
240									240
250									250

Class 160 PVC Plastic Pipe

SDR 26 (1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2½"		3"		4"		6"		Size
ID	2.655		3.230		4.154		6.115		ID
OD	2.875		3.500		4.500		6.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	.06	0.87	.02	0.59	.01	0.35			15
20	0.11	1.16	.04	0.78	.01	0.47			20
25	0.16	1.45	.06	0.98	.02	0.59			25
30	0.23	1.74	.09	1.17	.03	0.71	.00	0.33	30
35	0.30	2.03	0.12	1.37	.03	0.83	.01	0.38	35
40	0.39	2.32	0.15	1.56	.04	0.95	.01	0.44	40
50	0.59	2.89	0.23	1.96	.07	1.18	.01	0.55	50
60	0.82	3.47	0.32	2.35	.09	1.42	.01	0.65	60
70	1.09	4.05	0.42	2.74	0.12	1.66	.02	0.76	70
80	1.40	4.63	0.54	3.13	0.16	1.89	.02	0.87	80
90	1.74	5.21	0.67	3.52	0.20	2.13	.03	0.98	90
100	2.11	5.79	0.81	3.91	0.24	2.36	.04	1.09	100
110	2.52	6.37	0.97	4.30	0.29	2.60	.04	1.20	110
120	2.96	6.95	1.14	4.69	0.34	2.84	.05	1.31	120
130	3.44	7.52	1.32	5.08	0.39	3.07	.06	1.42	130
140	3.94	8.10	1.52	5.47	0.45	3.31	.07	1.53	140
150	4.48	8.68	1.73	5.87	0.51	3.55	.08	1.64	150
160	5.05	9.26	1.94	6.26	0.57	3.78	.09	1.75	160
170	5.65	9.84	2.18	6.65	0.64	4.02	0.10	1.85	170
180	6.28	10.42	2.42	7.04	0.71	4.26	0.11	1.96	180
190	6.94	11.00	2.67	7.43	0.79	4.49	0.12	2.07	190
200	7.63	11.58	2.94	7.82	0.86	4.73	0.13	2.18	200
210	8.35	12.15	3.22	8.21	0.95	4.97	0.14	2.29	210
220	9.10	12.73	3.51	8.60	1.03	5.20	0.16	2.40	220
230	9.88	13.31	3.81	8.99	1.12	5.44	0.17	2.51	230
240	10.70	13.89	4.12	9.39	1.21	5.67	0.18	2.62	240
250	11.54	14.47	4.44	9.78	1.31	5.91	0.20	2.73	250
260			4.78	10.17	1.40	6.15	0.21	2.84	260
270			5.12	10.56	1.51	6.38	0.23	2.95	270
280			5.48	10.95	1.61	6.62	0.25	3.06	280
290			5.85	11.34	1.72	6.86	0.26	3.16	290
300			6.23	11.73	1.83	7.09	0.28	3.27	300
320			7.02	12.51	2.06	7.57	0.31	3.49	320
340			7.85	13.30	2.31	8.04	0.35	3.71	340
360			8.73	14.08	2.57	8.51	0.39	3.93	360
380			9.65	14.86	2.84	8.98	0.43	4.15	380
400					3.12	9.46	0.48	4.36	400
425					3.49	10.05	0.53	4.64	425
450					3.88	10.64	0.59	4.91	450
475					4.29	11.23	0.65	5.18	475
500					4.72	11.82	0.72	5.46	500
525					5.16	12.41	0.79	5.73	525
550					5.63	13.00	0.86	6.00	550
575					6.11	13.60	0.93	6.27	575
600					6.61	14.19	1.01	6.55	600

Class 200 PVC Plastic Pipe

SDR 21 (1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.716		0.930		1.189		1.502		1.720		ID
OD	0.840		1.050		1.315		1.660		1.900		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.25	0.80	.07	0.47	.02	0.29	.01	0.18	.00	0.14	1
2	0.89	1.59	0.25	0.94	.08	0.58	.02	0.36	.01	0.28	2
3	1.88	2.39	0.53	1.42	0.16	0.87	.05	0.54	.03	0.41	3
4	3.20	3.18	0.90	1.89	0.27	1.15	.09	0.72	.05	0.55	4
5	4.84	3.98	1.36	2.36	0.41	1.44	0.13	0.90	.07	0.69	5
6	6.79	4.78	1.90	2.83	0.58	1.73	0.18	1.09	0.10	0.83	6
7	9.03	5.57	2.53	3.30	0.77	2.02	0.25	1.27	0.13	0.97	7
8	11.56	6.37	3.24	3.77	0.98	2.31	0.31	1.45	0.16	1.10	8
9	14.38	7.16	4.03	4.25	1.22	2.60	0.39	1.63	0.20	1.24	9
10	17.48	7.96	4.90	4.72	1.48	2.89	0.48	1.81	0.25	1.38	10
11	20.85	8.75	5.84	5.19	1.77	3.17	0.57	1.99	0.29	1.52	11
12	24.50	9.55	6.86	5.66	2.08	3.46	0.67	2.17	0.34	1.65	12
13	28.42	10.35	7.96	6.13	2.41	3.75	0.77	2.35	0.40	1.79	13
14	32.60	11.14	9.13	6.60	2.76	4.04	0.89	2.53	0.46	1.93	14
15	37.04	11.94	10.38	7.08	3.14	4.33	1.01	2.71	0.52	2.07	15
16	41.74	12.73	11.69	7.55	3.54	4.62	1.13	2.89	0.59	2.21	16
17	46.70	13.53	13.08	8.02	3.96	4.91	1.27	3.07	0.66	2.34	17
18	51.92	14.33	15.54	8.49	4.40	5.19	1.41	3.26	0.73	2.48	18
19			16.08	8.96	4.86	5.48	1.56	3.44	0.81	2.62	19
20			17.68	9.43	5.35	5.77	1.72	3.62	0.89	2.76	20
25			26.72	11.79	8.09	7.22	2.59	4.52	1.34	3.45	25
30			37.46	14.15	11.33	8.66	3.63	5.44	1.88	4.14	30
35					15.08	10.10	4.84	6.33	2.50	4.83	35
40					19.31	11.54	6.19	7.23	3.20	5.52	40
50					29.19	14.48	9.36	9.04	4.84	6.90	50
60							13.12	10.85	6.79	8.27	60
70							17.46	12.66	9.03	9.65	70
80							22.36	14.47	11.56	11.03	80
90									14.38	12.41	90
100									17.48	13.79	100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Class 200 PVC Plastic Pipe

SDR 21 (1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		6"		Size
ID	2.149		2.601		3.166		4.072		5.993		ID
OD	2.375		2.875		3.500		4.500		6.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	psi Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.18	1.33	.07	0.90	.03	0.61	.01	0.37			15
20	0.30	1.77	0.12	1.21	.05	0.81	.01	0.49			20
25	0.45	2.21	0.18	1.51	.07	1.02	.02	0.62			25
30	0.64	2.65	0.25	1.81	0.10	1.22	.03	0.74	.00	0.34	30
35	0.85	3.09	0.33	2.11	0.13	1.42	.04	0.86	.01	0.40	35
40	1.08	3.53	0.43	2.41	0.16	1.63	.05	0.98	.01	0.45	40
50	1.64	4.42	0.65	3.02	0.25	2.04	.07	1.23	.01	0.57	50
60	2.30	5.30	0.91	3.62	0.35	2.44	0.10	1.48	.02	0.68	60
70	3.05	6.18	1.21	4.22	0.46	2.85	0.14	1.72	.02	0.80	70
80	3.91	7.07	1.55	4.82	0.59	3.26	0.17	1.97	.03	0.91	80
90	4.87	7.95	1.92	5.43	0.74	3.66	0.22	2.21	.03	1.02	90
100	5.91	8.83	2.34	6.03	0.90	4.07	0.26	2.46	.04	1.14	100
110	7.06	9.72	2.79	6.63	1.07	4.48	0.31	2.71	.05	1.25	110
120	8.29	10.60	3.27	7.24	1.26	4.88	0.37	2.95	.06	1.36	120
130	9.61	11.48	3.80	7.84	1.46	5.29	0.43	3.20	.07	1.48	130
140	11.03	12.37	4.36	8.44	1.67	5.70	0.49	3.44	.08	1.59	140
150	12.53	13.25	4.95	9.05	1.90	6.11	0.56	3.69	.09	1.70	150
160	14.12	14.14	5.58	9.65	2.14	6.51	0.63	3.94	0.10	1.82	160
170			6.24	10.25	2.40	6.92	0.70	4.18	0.11	1.93	170
180			6.94	10.86	2.67	7.33	0.78	4.43	0.12	2.04	180
190			7.67	11.46	2.95	7.73	0.87	4.68	0.13	2.16	190
200			8.43	12.06	3.24	8.14	0.95	4.92	0.15	2.27	200
210			9.23	12.66	3.55	8.55	1.04	5.17	0.16	2.39	210
220			10.06	13.27	3.87	8.95	1.14	5.41	0.17	2.50	220
230			10.92	13.87	4.20	9.36	1.23	5.66	0.19	2.61	230
240			11.82	14.47	4.54	9.77	1.33	5.91	0.20	2.73	240
250					4.90	10.18	1.44	6.15	0.22	2.84	250
260					5.27	10.58	1.55	6.40	0.24	2.95	260
270					5.65	10.99	1.66	6.64	0.25	3.07	270
280					6.04	11.40	1.78	6.89	0.27	3.18	280
290					6.45	11.80	1.89	7.14	0.29	3.29	290
300					6.87	12.21	2.02	7.38	0.31	3.41	300
320					7.74	13.03	2.27	7.87	0.35	3.64	320
340					8.66	13.84	2.54	8.37	0.39	3.86	340
360					9.62	14.65	2.83	8.86	0.43	4.09	360
380							3.13	9.35	0.48	4.32	380
400							3.44	9.84	0.52	4.54	400
425							3.85	10.46	0.59	4.83	425
450							4.28	11.07	0.65	5.11	450
475							4.73	11.69	0.72	5.40	475
500							5.20	12.30	0.79	5.68	500
525							5.69	12.92	0.87	5.96	525
550							6.20	13.53	0.95	6.25	550
575							6.73	14.15	1.03	6.53	575
600							7.28	14.76	1.11	6.82	600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Class 315 PVC Plastic Pipe

SDR 13.5 (1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.716		0.894		1.121		1.414		1.618		ID
OD	0.840		1.050		1.315		1.660		1.900		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.25	0.80	.08	0.51	.03	0.32	.01	0.20	.00	0.16	1
2	0.89	1.59	0.30	1.02	0.10	0.65	.03	0.41	.02	0.31	2
3	1.88	2.39	0.64	1.53	0.21	0.97	.07	0.61	.04	0.47	3
4	3.20	3.18	1.09	2.04	0.36	1.30	0.12	0.82	.06	0.62	4
5	4.84	3.98	1.64	2.55	0.55	1.62	0.18	1.02	.09	0.78	5
6	6.79	4.78	2.30	3.06	0.77	1.95	0.25	1.22	0.13	0.94	6
7	9.03	5.57	3.07	3.57	1.02	2.27	0.33	1.43	0.17	1.09	7
8	11.56	6.37	3.93	4.08	1.31	2.60	0.42	1.63	0.22	1.25	8
9	14.38	7.16	4.88	4.59	1.62	2.92	0.52	1.84	0.27	1.40	9
10	17.48	7.96	5.93	5.10	1.97	3.25	0.64	2.04	0.33	1.56	10
11	20.85	8.75	7.08	5.62	2.35	3.57	0.76	2.24	0.39	1.71	11
12	24.50	9.55	8.32	6.13	2.77	3.90	0.89	2.45	0.46	1.87	12
13	28.42	10.35	9.65	6.64	3.21	4.22	1.04	2.65	0.54	2.03	13
14	32.60	11.14	11.07	7.15	3.68	4.55	1.19	2.86	0.62	2.18	14
15	37.04	11.94	12.57	7.66	4.18	4.87	1.35	3.06	0.70	2.34	15
16	41.74	12.73	14.17	8.17	4.71	5.19	1.52	3.26	0.79	2.49	16
17	46.70	13.53	15.85	8.68	5.27	5.52	1.70	3.47	0.88	2.65	17
18	51.92	14.33	17.62	9.19	5.86	5.84	1.89	3.67	0.98	2.81	18
19			19.48	9.70	6.48	6.17	2.09	3.88	1.09	2.96	19
20			21.42	10.21	7.12	6.49	2.30	4.08	1.19	3.12	20
25			32.38	12.76	10.77	8.12	3.48	5.10	1.81	3.90	25
30					15.09	9.74	4.88	6.12	2.53	4.68	30
35					20.08	11.36	6.49	7.14	3.37	5.45	35
40					25.71	12.99	8.31	8.16	4.31	6.23	40
50							12.56	10.20	6.52	7.79	50
60							17.60	12.24	9.14	9.35	60
70							23.42	14.28	12.16	10.91	70
80									15.57	12.47	80
90									19.36	14.03	90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Class 315 PVC Plastic Pipe

SDR 13.5 (1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		6"		Size
ID	2.023		2.449		2.982		3.834		5.643		ID
OD	2.375		2.875		3.500		4.500		6.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.24	1.50	.09	1.02	.04	0.69	.01	0.42			15
20	0.40	1.99	0.16	1.36	.06	0.92	.02	0.56			20
25	0.61	2.49	0.24	1.70	.09	1.15	.03	0.69	.00	0.32	25
30	0.85	2.99	0.34	2.04	0.13	1.38	.04	0.83	.01	0.38	30
35	1.14	3.49	0.45	2.38	0.17	1.61	.05	0.97	.01	0.45	35
40	1.45	3.99	0.57	2.72	0.22	1.84	.06	1.11	.01	0.51	40
50	2.20	4.98	0.87	3.40	0.33	2.29	0.10	1.39	.01	0.64	50
60	3.08	5.98	1.22	4.08	0.47	2.75	0.14	1.67	.02	0.77	60
70	4.10	6.98	1.62	4.76	0.62	3.21	0.18	1.94	.03	0.90	70
80	5.25	7.98	2.07	5.44	0.79	3.67	0.23	2.22	.04	1.03	80
90	6.53	8.97	2.58	6.12	0.99	4.13	0.29	2.50	.04	1.15	90
100	7.94	9.97	3.13	6.80	1.20	4.59	0.35	2.78	.05	1.28	100
110	9.47	10.97	3.74	7.48	1.43	5.05	0.42	3.05	.06	1.41	110
120	11.12	11.96	4.39	8.16	1.68	5.51	0.50	3.33	.08	1.54	120
130	12.90	12.96	5.09	8.84	1.95	5.96	0.57	3.61	.09	1.67	130
140	14.80	13.96	5.84	9.52	2.24	6.42	0.66	3.89	0.10	1.79	140
150	16.81	14.95	6.64	10.20	2.55	6.88	0.75	4.16	0.11	1.92	150
160			7.48	10.88	2.87	7.34	0.84	4.44	0.13	2.05	160
170			8.37	11.56	3.21	7.80	0.94	4.72	0.14	2.18	170
180			9.30	12.24	3.57	8.26	1.05	5.00	0.16	2.31	180
190			10.28	12.93	3.94	8.72	1.16	5.27	0.18	2.43	190
200			11.30	13.61	4.34	9.18	1.28	5.55	0.19	2.56	200
210			12.37	14.29	4.75	9.64	1.40	5.83	0.21	2.69	210
220			13.49	14.97	5.17	10.09	1.52	6.11	0.23	2.82	220
230					5.62	10.55	1.65	6.38	0.25	2.95	230
240					6.08	11.01	1.79	6.66	0.27	3.08	240
250					6.56	11.47	1.93	6.94	0.29	3.20	250
260					7.05	11.93	2.08	7.22	0.32	3.33	260
270					7.56	12.39	2.23	7.49	0.34	3.46	270
280					8.09	12.85	2.38	7.77	0.36	3.59	280
290					8.63	13.31	2.54	8.05	0.39	3.72	290
300					9.19	13.76	2.70	8.33	0.41	3.84	300
320					10.35	14.68	3.05	8.88	0.46	4.10	320
340							3.41	9.44	0.52	4.36	340
360							3.79	9.99	0.58	4.61	360
380							4.19	10.55	0.64	4.87	380
400							4.61	11.10	0.70	5.13	400
425							5.16	11.80	0.79	5.45	425
450							5.73	12.49	0.87	5.77	450
475							6.33	13.18	0.97	6.09	475
500							6.97	13.88	1.06	6.41	500
525							7.62	14.57	1.16	6.73	525
550									1.27	7.05	550
575									1.38	7.37	575
600									1.49	7.69	600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Schedule 40 PVC Plastic Pipe

(1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.622		0.824		1.049		1.380		1.610		ID
OD	0.840		1.050		1.315		1.660		1.900		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.49	1.05	0.12	0.60	.04	0.37	.01	0.21	.00	0.16	1
2	1.76	2.11	0.45	1.20	0.14	0.74	.04	0.43	.02	0.31	2
3	3.73	3.16	0.95	1.80	0.29	1.11	.08	0.64	.04	0.47	3
4	6.35	4.22	1.62	2.40	0.50	1.48	0.13	0.86	.06	0.63	4
5	9.60	5.27	2.44	3.00	0.76	1.85	0.20	1.07	.09	0.79	5
6	13.46	6.33	3.43	3.61	1.06	2.22	0.28	1.29	0.13	0.94	6
7	17.91	7.38	4.56	4.21	1.41	2.60	0.37	1.50	0.18	1.10	7
8	22.93	8.44	5.84	4.81	1.80	2.97	0.47	1.71	0.22	1.26	8
9	28.52	9.49	7.26	5.41	2.24	3.34	0.59	1.93	0.28	1.42	9
10	34.67	10.55	8.82	6.01	2.73	3.71	0.72	2.14	0.34	1.57	10
11	41.36	11.60	10.53	6.61	3.25	4.08	0.86	2.36	0.40	1.73	11
12	48.60	12.65	12.37	7.21	3.82	4.45	1.01	2.57	0.48	1.89	12
13	56.36	13.71	14.34	7.81	4.43	4.82	1.17	2.79	0.55	2.05	13
14	64.65	14.76	16.45	8.41	5.08	5.19	1.34	3.00	0.63	2.20	14
15			18.70	9.01	5.78	5.56	1.52	3.21	0.72	2.36	15
16			21.07	9.61	6.51	5.93	1.71	3.43	0.81	2.52	16
17			23.57	10.22	7.28	6.30	1.92	3.64	0.91	2.68	17
18			26.21	10.82	8.10	6.67	2.13	3.86	1.01	2.83	18
19			28.97	11.42	8.95	7.04	2.36	4.07	1.11	2.99	19
20			31.85	12.02	9.84	7.42	2.59	4.28	1.22	3.15	20
25					14.87	9.27	3.92	5.36	1.85	3.94	25
30					20.85	11.12	5.49	6.43	2.59	4.72	30
35					27.74	12.98	7.30	7.50	3.45	5.51	35
40					35.52	14.83	9.35	8.57	4.42	6.30	40
50							14.14	10.71	6.68	7.87	50
60							19.82	12.85	9.36	9.44	60
70									12.45	11.02	70
80									15.95	12.59	80
90									19.83	14.17	90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Schedule 40 PVC Plastic Pipe

(1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		6"		Size
ID	2.067		2.469		3.068		4.026		6.065		ID
OD	2.375		2.875		3.500		4.500		6.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.21	1.43	.09	1.00	.03	0.65	.01	0.38			15
20	0.36	1.91	0.15	1.34	.05	0.87	.01	0.50			20
25	0.55	2.39	0.23	1.67	.08	1.08	.02	0.63			25
30	0.77	2.86	0.32	2.01	0.11	1.30	.03	0.76	.00	0.33	30
35	1.02	3.34	0.43	2.34	0.15	1.52	.04	0.88	.01	0.39	35
40	1.31	3.82	0.55	2.68	0.19	1.73	.05	1.01	.01	0.44	40
50	1.98	4.77	0.83	3.35	0.29	2.17	.08	1.26	.01	0.55	50
60	2.77	5.73	1.17	4.02	0.41	2.60	0.11	1.51	.01	0.67	60
70	3.69	6.68	1.55	4.69	0.54	3.03	0.14	1.76	.02	0.78	70
80	4.73	7.64	1.99	5.35	0.69	3.47	0.18	2.01	.03	0.89	80
90	5.88	8.59	2.48	6.02	0.86	3.90	0.23	2.27	.03	1.00	90
100	7.15	9.55	3.01	6.69	1.05	4.33	0.28	2.52	.04	1.11	100
110	8.53	10.50	3.59	7.36	1.25	4.77	0.33	2.77	.05	1.22	110
120	10.02	11.46	4.22	8.03	1.47	5.20	0.39	3.02	.05	1.33	120
130	11.62	12.41	4.89	8.70	1.70	5.63	0.45	3.27	.06	1.44	130
140	13.33	13.37	5.61	9.37	1.95	6.07	0.52	3.52	.07	1.55	140
150	15.14	14.32	6.38	10.04	2.22	6.50	0.59	3.78	.08	1.66	150
160			7.19	10.71	2.50	6.94	0.67	4.03	.09	1.77	160
170			8.04	11.38	2.79	7.37	0.74	4.28	0.10	1.89	170
180			8.94	12.05	3.11	7.80	0.83	4.53	0.11	2.00	180
190			9.88	12.72	3.43	8.24	0.92	4.78	0.12	2.11	190
200			10.87	13.39	3.78	8.67	1.01	5.03	0.14	2.22	200
210			11.89	14.06	4.13	9.10	1.10	5.29	0.15	2.33	210
220			12.96	14.72	4.50	9.54	1.20	5.54	0.16	2.44	220
230					4.89	9.97	1.30	5.79	0.18	2.55	230
240					5.29	10.40	1.41	6.04	0.19	2.66	240
250					5.71	10.84	1.52	6.29	0.21	2.77	250
260					6.14	11.27	1.64	6.54	0.22	2.88	260
270					6.58	11.70	1.75	6.80	0.24	2.99	270
280					7.04	12.14	1.88	7.05	0.26	3.11	280
290					7.51	12.57	2.00	7.30	0.27	3.22	290
300					8.00	13.00	2.13	7.55	0.29	3.33	300
320					9.02	13.87	2.40	8.05	0.33	3.55	320
340					10.09	14.74	2.69	8.56	0.37	3.77	340
360							2.99	9.06	0.41	3.99	360
380							3.30	9.57	0.45	4.21	380
400							3.63	10.07	0.49	4.44	400
425							4.06	10.70	0.55	4.71	425
450							4.52	11.33	0.62	4.99	450
475							4.99	11.96	0.68	5.27	475
500							5.49	12.59	0.75	5.55	500
525							6.01	13.22	0.82	5.82	525
550							6.55	13.84	0.89	6.10	550
575							7.11	14.47	0.97	6.38	575
600									1.05	6.66	600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Schedule 80 PVC Plastic Pipe

(1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.546		0.742		0.957		1.278		1.500		ID
OD	0.840		1.050		1.315		1.660		1.900		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.92	1.37	0.21	0.74	.06	0.45	.01	0.25	.01	0.18	1
2	3.32	2.74	0.75	1.48	0.22	0.89	.05	0.50	.02	0.36	2
3	7.03	4.11	1.58	2.22	0.46	1.34	0.11	0.75	.05	0.54	3
4	11.98	5.47	2.69	2.96	0.78	1.78	0.19	1.00	.09	0.73	4
5	18.11	6.84	4.07	3.71	1.18	2.23	0.29	1.25	0.13	0.91	5
6	25.38	8.21	5.71	4.45	1.65	2.67	0.40	1.50	0.19	1.09	6
7	33.77	9.58	7.59	5.19	2.20	3.12	0.54	1.75	0.25	1.27	7
8	43.24	10.95	9.72	5.93	2.82	3.56	0.69	2.00	0.32	1.45	8
9	53.78	12.32	12.09	6.67	3.51	4.01	0.86	2.25	0.39	1.63	9
10	65.37	13.69	14.69	7.41	4.26	4.45	1.04	2.50	0.48	1.81	10
11			17.53	8.15	5.08	4.90	1.24	2.75	0.57	1.99	11
12			20.60	8.89	5.97	5.35	1.46	3.00	0.67	2.18	12
13			23.89	9.63	6.93	5.79	1.70	3.25	0.78	2.36	13
14			27.40	10.37	7.94	6.24	1.94	3.50	0.89	2.54	14
15			31.14	11.12	9.03	6.68	2.21	3.75	1.01	2.72	15
16			35.09	11.86	10.17	7.13	2.49	4.00	1.14	2.90	16
17			39.26	12.60	11.38	7.57	2.79	4.25	1.28	3.08	17
18			43.64	13.34	12.65	8.02	3.10	4.50	1.42	3.26	18
19			48.24	14.08	13.99	8.46	3.42	4.75	1.57	3.45	19
20			53.05	14.82	15.38	8.91	3.76	5.00	1.73	3.63	20
25					23.25	11.14	5.69	6.25	2.61	4.53	25
30					32.59	13.36	7.98	7.49	3.66	5.44	30
35							10.61	8.74	4.87	6.35	35
40							13.59	9.99	6.23	7.25	40
50							20.54	12.49	9.42	9.07	50
60							28.79	14.99	13.21	10.88	60
70									17.57	12.69	70
80									22.50	14.51	80
90											90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Schedule 80 PVC Plastic Pipe

(1120, 1220) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		6"		Size
ID	1.939		2.323		2.900		3.826		5.761		ID
OD	2.375		2.875		3.500		4.500		5.563		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.29	1.63	0.12	1.13	.04	0.73	.01	0.42			15
20	0.50	2.17	0.21	1.51	.07	0.97	.02	0.56			20
25	0.75	2.71	0.31	1.89	0.11	1.21	.03	0.70	.00	0.31	25
30	1.05	3.26	0.44	2.27	0.15	1.46	.04	0.84	.01	0.37	30
35	1.40	3.80	0.58	2.65	0.20	1.70	.05	0.98	.01	0.43	35
40	1.79	4.34	0.74	3.02	0.25	1.94	.07	1.11	.01	0.49	40
50	2.70	5.43	1.12	3.78	0.38	2.43	0.10	1.39	.01	0.61	50
60	3.79	6.51	1.57	4.54	0.53	2.91	0.14	1.67	.02	0.74	60
70	5.04	7.60	2.09	5.29	0.71	3.40	0.18	1.95	.03	0.86	70
80	6.45	8.68	2.68	6.05	0.91	3.88	0.24	2.23	.03	0.98	80
90	8.03	9.77	3.33	6.80	1.13	4.37	0.29	2.51	.04	1.11	90
100	9.75	10.85	4.05	7.56	1.38	4.85	0.36	2.79	.05	1.23	100
110	11.64	11.94	4.83	8.32	1.64	5.34	0.43	3.07	.06	1.35	110
120	13.67	13.02	5.68	9.07	1.93	5.82	0.50	3.34	.07	1.48	120
130	15.86	14.11	6.58	9.83	2.24	6.31	0.58	3.62	.08	1.60	130
140			7.55	10.58	2.57	6.79	0.67	3.90	.09	1.72	140
150			8.58	11.34	2.92	7.28	0.76	4.18	0.10	1.84	150
160			9.67	12.10	3.29	7.76	0.85	4.46	0.12	1.97	160
170			10.82	12.85	3.68	8.25	0.95	4.74	0.13	2.09	170
180			12.03	13.61	4.09	8.73	1.06	5.02	0.14	2.21	180
190			13.29	14.37	4.52	9.22	1.17	5.30	0.16	2.34	190
200					4.97	9.70	1.29	5.57	0.18	2.46	200
210					5.44	10.19	1.41	5.85	0.19	2.58	210
220					5.92	10.67	1.54	6.13	0.21	2.70	220
230					6.43	11.16	1.67	6.41	0.23	2.83	230
240					6.96	11.64	1.81	6.69	0.25	2.95	240
250					7.51	12.13	1.95	6.97	0.27	3.07	250
260					8.07	12.61	2.10	7.25	0.29	3.20	260
270					8.66	13.10	2.25	7.53	0.31	3.32	270
280					9.26	13.58	2.40	7.80	0.33	3.44	280
290					9.88	14.07	2.57	8.08	0.35	3.57	290
300					10.52	14.55	2.73	8.36	0.37	3.69	300
320							3.08	8.92	0.42	3.93	320
340							3.45	9.48	0.47	4.18	340
360							3.83	10.03	0.52	4.43	360
380							4.23	10.59	0.58	4.67	380
400							4.66	11.15	0.64	4.92	400
425							5.21	11.85	0.71	5.22	425
450							5.79	12.54	0.79	5.53	450
475							6.40	13.24	0.87	5.84	475
500							7.04	13.94	0.96	6.15	500
525							7.70	14.63	1.05	6.45	525
550									1.15	6.76	550
575									1.24	7.07	575
600									1.35	7.38	600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Polyethylene Pipe (PE)

SDR 9, 11.5, 15 (2306, 3206, 3306) C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.622		0.824		1.049		1.380		1.610		ID
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.49	1.05	0.12	0.60	.04	0.37	.01	0.21	.00	0.16	1
2	1.76	2.11	0.45	1.20	0.14	0.74	.04	0.43	.02	0.31	2
3	3.73	3.16	0.95	1.80	0.29	1.11	.08	0.64	.04	0.47	3
4	6.35	4.22	1.62	2.40	0.50	1.48	0.13	0.86	.06	0.63	4
5	9.60	5.27	2.44	3.00	0.76	1.85	0.20	1.07	.09	0.79	5
6	13.46	6.33	3.43	3.61	1.06	2.22	0.28	1.29	0.13	0.94	6
7	17.91	7.38	4.56	4.21	1.41	2.60	0.37	1.50	0.18	1.10	7
8	22.93	8.44	5.84	4.81	1.80	2.97	0.47	1.71	0.22	1.26	8
9	28.52	9.49	7.26	5.41	2.24	3.34	0.59	1.93	0.28	1.42	9
10	34.67	10.55	8.82	6.01	2.73	3.71	0.72	2.14	0.34	1.57	10
11	41.36	11.60	10.53	6.61	3.25	4.08	0.86	2.36	0.40	1.73	11
12	48.60	12.65	12.37	7.21	3.82	4.45	1.01	2.57	0.48	1.89	12
13	56.36	13.71	14.34	7.81	4.43	4.82	1.17	2.79	0.55	2.05	13
14	64.65	14.76	16.45	8.41	5.08	5.19	1.34	3.00	0.63	2.20	14
15			18.70	9.01	5.78	5.56	1.52	3.21	0.72	2.36	15
16			21.07	9.61	6.51	5.93	1.71	3.43	0.81	2.52	16
17			23.57	10.22	7.28	6.30	1.92	3.64	0.91	2.68	17
18			26.21	10.82	8.10	6.67	2.13	3.86	1.01	2.83	18
19			28.97	11.42	8.95	7.04	2.36	4.07	1.11	2.99	19
20			31.85	12.02	9.84	7.42	2.59	4.28	1.22	3.15	20
25			48.15	15.02	14.87	9.27	3.92	5.36	1.85	3.94	25
30					20.85	11.12	5.49	6.43	2.59	4.72	30
35					27.74	12.98	7.30	7.50	3.45	5.51	35
40					35.52	14.83	9.35	8.57	4.42	6.30	40
50							14.14	10.71	6.68	7.87	50
60							19.82	12.85	9.36	9.44	60
70							26.36	15.00	12.45	11.02	70
80									15.95	12.59	80
90									19.83	14.17	90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Polyethylene Pipe (PE)

SDR 9, 11.5, 15 (2306, 3206, 3306) C = 140
Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		6"		Size
ID	2.067		2.469		3.069		4.026		6.065		ID
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.21	1.43	.09	1.00	.03	0.65	.01	0.38	.00	0.17	15
20	0.36	1.91	0.15	1.34	.05	0.87	.01	0.50	.00	0.22	20
25	0.55	2.39	0.23	1.67	.08	1.08	.02	0.63	.00	0.28	25
30	0.77	2.86	0.32	2.01	0.11	1.30	.03	0.76	.00	0.33	30
35	1.02	3.34	0.43	2.34	0.15	1.52	.04	0.88	.01	0.39	35
40	1.31	3.82	0.55	2.68	0.19	1.73	.05	1.01	.01	0.44	40
50	1.98	4.77	0.83	3.35	0.29	2.17	.08	1.26	.01	0.55	50
60	2.77	5.73	1.17	4.02	0.41	2.60	0.11	1.51	.01	0.67	60
70	3.69	6.68	1.55	4.69	0.54	3.03	0.14	1.76	.02	0.78	70
80	4.73	7.64	1.99	5.35	0.69	3.47	0.18	2.01	.03	0.89	80
90	5.88	8.59	2.48	6.02	0.86	3.90	0.23	2.27	.03	1.00	90
100	7.15	9.55	3.01	6.69	1.05	4.33	0.28	2.52	.04	1.11	100
110	8.53	10.50	3.59	7.36	1.25	4.77	0.33	2.77	.05	1.22	110
120	10.02	11.46	4.22	8.03	1.47	5.20	0.39	3.02	.05	1.33	120
130	11.62	12.41	4.89	8.70	1.70	5.63	0.45	3.27	.06	1.44	130
140	13.33	13.37	5.61	9.37	1.95	6.07	0.52	3.52	.07	1.55	140
150	15.14	14.32	6.38	10.04	2.22	6.50	0.59	3.78	.08	1.66	150
160			7.19	10.71	2.50	6.94	0.67	4.03	.09	1.77	160
170			8.04	11.38	2.79	7.37	0.74	4.28	0.10	1.89	170
180			8.94	12.05	3.11	7.80	0.83	4.53	0.11	2.00	180
190			9.88	12.72	3.43	8.24	0.92	4.78	0.12	2.11	190
200			10.87	13.39	3.78	8.67	1.01	5.03	0.14	2.22	200
210			11.89	14.06	4.13	9.10	1.10	5.29	0.15	2.33	210
220			12.96	14.72	4.50	9.54	1.20	5.54	0.16	2.44	220
230					4.89	9.97	1.30	5.79	0.18	2.55	230
240					5.29	10.40	1.41	6.04	0.19	2.66	240
250					5.71	10.84	1.52	6.29	0.21	2.77	250
260					6.14	11.27	1.64	6.54	0.22	2.88	260
270					6.58	11.70	1.75	6.8	0.24	2.99	270
280					7.04	12.14	1.88	7.05	0.26	3.11	280
290					7.51	12.57	2.00	7.30	0.27	3.22	290
300					8.00	13.00	2.13	7.55	0.29	3.33	300
320					9.02	13.87	2.40	8.05	0.33	3.55	320
340					10.09	14.74	2.69	8.56	0.37	3.77	340
360							2.99	9.06	0.41	3.99	360
380							3.30	9.57	0.45	4.21	380
400							3.63	10.07	0.49	4.44	400
425							4.06	10.70	0.55	4.71	425
450							4.52	11.33	0.62	4.99	450
475							4.99	11.96	0.68	5.27	475
500							5.49	12.59	0.75	5.55	500
525							6.01	13.22	0.82	5.82	525
550							6.55	13.84	0.89	6.10	550
575							7.11	14.47	0.97	6.38	575
600									1.05	6.66	600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Type "M" Copper Water Tube

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.569		0.711		1.055		1.291		1.527		ID
OD	0.625		0.875		1.125		1.375		1.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.75	1.26	0.25	0.81	.04	0.37	.01	0.24	.01	0.17	1
2	2.71	2.52	0.92	1.61	0.13	0.73	.05	0.49	.02	0.35	2
3	5.75	3.78	1.95	2.42	0.29	1.10	0.11	0.73	.05	0.52	3
4	9.80	5.04	3.31	3.23	0.49	1.47	0.18	0.98	.08	0.70	4
5	14.81	6.30	5.01	4.04	0.73	1.83	0.27	1.22	0.12	0.87	5
6	20.76	7.56	7.02	4.84	1.03	2.20	0.39	1.47	0.17	1.05	6
7	27.62	8.82	9.34	5.65	1.37	2.57	0.51	1.71	0.23	1.22	7
8	35.37	10.08	11.96	6.46	1.75	2.93	0.66	1.96	0.29	1.40	8
9	44.00	11.34	14.88	7.26	2.18	3.30	0.82	2.20	0.36	1.57	9
10	53.48	12.60	18.09	8.07	2.65	3.67	0.99	2.45	0.44	1.75	10
11	63.80	13.86	21.58	8.88	3.16	4.03	1.18	2.69	0.52	1.92	11
12	74.96	15.12	25.35	9.69	3.72	4.40	1.39	2.94	0.61	2.10	12
13			29.40	10.49	4.31	4.77	1.61	3.18	0.71	2.27	13
14			33.73	11.30	4.94	5.13	1.85	3.43	0.82	2.45	14
15			38.32	12.11	5.62	5.50	2.10	3.67	0.93	2.62	15
16			43.19	12.91	6.33	5.87	2.37	3.92	1.05	2.80	16
17			48.32	13.72	7.08	6.23	2.65	4.16	1.17	2.97	17
18			53.72	14.53	7.87	6.60	2.95	4.41	1.30	3.15	18
19					8.70	6.96	3.26	4.65	1.44	3.32	19
20					9.57	7.33	3.58	4.90	1.58	3.50	20
25					14.47	9.16	5.42	6.12	2.39	4.37	25
30					20.28	11.00	7.59	7.34	3.35	5.25	30
35					26.98	12.83	10.10	8.57	4.46	6.12	35
40					34.55	14.66	12.94	9.79	5.71	7.00	40
50							19.56	12.24	8.64	8.75	50
60							27.41	14.69	12.11	10.50	60
70									16.11	12.25	70
80									20.63	14.00	80
90											90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Type "M" Copper Water Tube

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		Size
ID	2.009		2.495		2.981		3.953		ID
OD	2.125		2.625		3.125		4.125		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.24	1.52	.09	0.98	.04	0.69	.01	0.39	15
20	0.42	2.02	0.15	1.31	.06	0.92	.02	0.52	20
25	0.63	2.53	0.22	1.64	.09	1.15	.02	0.65	25
30	0.88	3.03	0.31	1.97	0.13	1.38	.03	0.78	30
35	1.17	3.54	0.41	2.29	0.17	1.61	.04	0.91	35
40	1.50	4.04	0.52	2.62	0.22	1.84	.06	1.04	40
50	2.27	5.05	0.79	3.28	0.33	2.30	.08	1.31	50
60	3.19	6.07	1.11	3.93	0.47	2.75	0.12	1.57	60
70	4.24	7.08	1.48	4.59	0.62	3.21	0.16	1.83	70
80	5.43	8.09	1.89	5.24	0.80	3.67	0.20	2.09	80
90	6.75	9.10	2.35	5.90	0.99	4.13	0.25	2.35	90
100	8.21	10.11	2.86	6.55	1.20	4.59	0.30	2.61	100
110	9.79	11.12	3.41	7.21	1.44	5.05	0.36	2.87	110
120	11.51	12.13	4.01	7.87	1.69	5.51	0.43	3.13	120
130	13.34	13.14	4.65	8.52	1.96	5.97	0.50	3.39	130
140	15.31	14.15	5.33	9.18	2.24	6.43	0.57	3.66	140
150			6.06	9.83	2.55	6.89	0.65	3.92	150
160			6.83	10.49	2.87	7.35	0.73	4.18	160
170			7.64	11.14	3.21	7.81	0.81	4.44	170
180			8.50	11.80	3.57	8.26	0.91	4.70	180
190			9.39	12.45	3.95	8.72	1.00	4.96	190
200			10.33	13.11	4.34	9.18	1.10	5.22	200
210			11.30	13.76	4.75	9.64	1.20	5.48	210
220			12.32	14.42	5.18	10.10	1.31	5.74	220
230					5.63	10.56	1.43	6.01	230
240					6.09	11.02	1.54	6.27	240
250					6.57	11.48	1.66	6.53	250
260					7.06	11.94	1.79	6.79	260
270					7.57	12.40	1.92	7.05	270
280					8.10	12.86	2.05	7.31	280
290					8.64	13.31	2.19	7.57	290
300					9.20	13.77	2.33	7.83	300
320					10.37	14.69	2.63	8.36	320
340							2.94	8.88	340
360							3.27	9.40	360
380							3.61	9.92	380
400							3.97	10.44	400
425							4.44	11.10	425
450							4.94	11.75	450
475							5.46	12.40	475
500							6.00	13.05	500
525							6.57	13.71	525
550							7.16	14.36	550
575									575
600									600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Type "L" Copper Water Tube

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.545		0.785		1.025		1.265		1.505		ID
OD	0.625		0.875		1.125		1.375		1.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.93	1.37	0.16	0.66	.04	0.39	.02	0.25	.01	0.18	1
2	3.35	2.75	0.57	1.32	0.15	0.78	.06	0.51	.02	0.36	2
3	7.09	4.12	1.20	1.99	0.33	1.17	0.12	0.76	.05	0.54	3
4	12.09	5.49	2.05	2.65	0.56	1.55	0.20	1.02	.09	0.72	4
5	18.27	6.87	3.09	3.31	0.85	1.94	0.30	1.27	0.13	0.90	5
6	25.61	8.24	4.34	3.97	1.18	2.33	0.43	1.53	0.18	1.08	6
7	34.07	9.62	5.77	4.63	1.58	2.72	0.57	1.78	0.24	1.26	7
8	43.63	10.99	7.39	5.30	2.02	3.11	0.72	2.04	0.31	1.44	8
9	54.26	12.36	9.19	5.96	2.51	3.50	0.90	2.29	0.39	1.62	9
10	65.95	13.74	11.17	6.62	3.05	3.88	1.10	2.55	0.47	1.80	10
11			13.33	7.28	3.64	4.27	1.31	2.80	0.56	1.98	11
12			15.66	7.95	4.28	4.66	1.54	3.06	0.66	2.16	12
13			18.16	8.61	4.96	5.05	1.78	3.31	0.77	2.34	13
14			20.83	9.27	5.69	5.44	2.04	3.57	0.88	2.52	14
15			23.67	9.93	6.46	5.83	2.32	3.82	1.00	2.70	15
16			26.68	10.59	7.28	6.21	2.62	4.08	1.12	2.88	16
17			29.85	11.26	8.15	6.60	2.93	4.33	1.26	3.06	17
18			33.18	11.92	9.06	6.99	3.25	4.59	1.40	3.24	18
19			36.67	12.58	10.01	7.38	3.60	4.84	1.54	3.42	19
20			40.33	13.24	11.01	7.77	3.96	5.10	1.70	3.60	20
25					16.65	9.71	5.98	6.37	2.57	4.50	25
30					23.33	11.65	8.38	7.65	3.60	5.40	30
35					31.04	13.59	11.15	8.92	4.79	6.30	35
40							14.28	10.20	6.13	7.21	40
50							21.59	12.75	9.27	9.01	50
60									13.00	10.81	60
70									17.29	12.61	70
80									22.14	14.41	80
90											90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Type "L" Copper Water Tube

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		Size
ID	1.985		2.465		2.945		3.905		ID
OD	2.125		2.625		3.125		4.125		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.26	1.55	.09	1.01	.04	0.71	.01	0.40	15
20	0.44	2.07	0.15	1.34	.06	0.94	.02	0.54	20
25	0.67	2.59	0.23	1.68	0.10	1.18	.02	0.67	25
30	0.94	3.11	0.33	2.01	0.14	1.41	.03	0.80	30
35	1.25	3.62	0.43	2.35	0.18	1.65	.05	0.94	35
40	1.59	4.14	0.56	2.69	0.23	1.88	.06	1.07	40
50	2.41	5.18	0.84	3.36	0.35	2.35	.09	1.34	50
60	3.38	6.21	1.18	4.03	0.50	2.82	0.13	1.61	60
70	4.50	7.25	1.57	4.70	0.66	3.29	0.17	1.87	70
80	5.76	8.28	2.01	5.37	0.84	3.76	0.21	2.14	80
90	7.16	9.32	2.50	6.04	1.05	4.23	0.27	2.41	90
100	8.70	10.35	3.03	6.71	1.28	4.70	0.32	2.68	100
110	10.38	11.39	3.62	7.39	1.52	5.17	0.39	2.94	110
120	12.20	12.43	4.25	8.06	1.79	5.65	0.45	3.21	120
130	14.15	13.46	4.93	8.73	2.07	6.12	0.53	3.48	130
140	16.23	14.50	5.66	9.40	2.38	6.59	0.60	3.75	140
150			6.43	10.07	2.70	7.06	0.69	4.01	150
160			7.24	10.74	3.05	7.53	0.77	4.28	160
170			8.11	11.41	3.41	8.00	0.86	4.55	170
180			9.01	12.09	3.79	8.47	0.96	4.82	180
190			9.96	12.76	4.19	8.94	1.06	5.08	190
200			10.95	13.43	4.61	9.41	1.17	5.35	200
210			11.99	14.10	5.04	9.88	1.28	5.62	210
220			13.07	14.77	5.50	10.35	1.39	5.89	220
230					5.97	10.82	1.51	6.15	230
240					6.46	11.29	1.64	6.42	240
250					6.97	11.76	1.76	6.69	250
260					7.49	12.23	1.90	6.96	260
270					8.03	12.70	2.04	7.22	270
280					8.59	13.17	2.18	7.49	280
290					9.17	13.64	2.32	7.76	290
300					9.76	14.11	2.47	8.03	300
320							2.79	8.56	320
340							3.12	9.10	340
360							3.47	9.63	360
380							3.83	10.17	380
400							4.21	10.70	400
425							4.72	11.37	425
450							5.24	12.04	450
475							5.79	12.71	475
500							6.37	13.38	500
525							6.97	14.05	525
550							7.60	14.72	550
575									575
600									600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Type "K" Copper Water Tube

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.527		0.745		0.995		1.245		1.481		ID
OD	0.625		0.875		1.125		1.375		1.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	1.09	1.47	0.20	0.74	.05	0.41	.02	0.26	.01	0.19	1
2	3.94	2.94	0.73	1.47	0.18	0.82	.06	0.53	.03	0.37	2
3	8.35	4.41	1.55	2.21	0.38	1.24	0.13	0.79	.05	0.56	3
4	14.23	5.88	2.64	2.94	0.65	1.65	0.22	1.05	.09	0.74	4
5	21.51	7.35	3.99	3.68	0.98	2.06	0.33	1.32	0.14	0.93	5
6	30.15	8.81	5.59	4.41	1.37	2.47	0.46	1.58	0.20	1.12	6
7	40.12	10.28	7.44	5.15	1.82	2.88	0.61	1.84	0.26	1.30	7
8	51.37	11.75	9.53	5.88	2.33	3.30	0.78	2.11	0.34	1.49	8
9	63.90	13.22	11.85	6.62	2.90	3.71	0.97	2.37	0.42	1.67	9
10	77.66	14.69	14.41	7.35	3.52	4.12	1.18	2.63	0.51	1.86	10
11			17.19	8.09	4.21	4.53	1.41	2.90	0.61	2.05	11
12			20.20	8.82	4.94	4.95	1.66	3.16	0.71	2.23	12
13			23.42	9.56	5.73	5.36	1.93	3.42	0.83	2.42	13
14			26.87	10.29	6.57	5.77	2.21	3.69	0.95	2.60	14
15			30.53	11.03	7.47	6.18	2.51	3.95	1.08	2.79	15
16			34.41	11.76	8.42	6.59	2.83	4.21	1.22	2.98	16
17			38.50	12.50	9.42	7.01	3.16	4.47	1.36	3.16	17
18			42.80	13.23	10.47	7.42	3.52	4.74	1.51	3.35	18
19			47.30	13.97	11.57	7.83	3.89	5.00	1.67	3.53	19
20			52.02	14.70	12.72	8.24	4.28	5.26	1.84	3.72	20
25					19.24	10.30	6.46	6.58	2.78	4.65	25
30					26.96	12.36	9.06	7.90	3.89	5.58	30
35					35.87	14.42	12.05	9.21	5.18	6.51	35
40							15.43	10.53	6.63	7.44	40
50							23.33	13.16	10.03	9.30	50
60									14.05	11.16	60
70									18.70	13.02	70
80									23.94	14.88	80
90											90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Type "K" Copper Water Tube

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		Size
ID	1.959		2.435		2.907		3.857		ID
OD	2.125		2.625		3.125		4.125		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.28	1.59	0.10	1.03	.04	0.72	.01	0.41	15
20	0.47	2.13	0.16	1.38	.07	0.97	.02	0.55	20
25	0.71	2.66	0.25	1.72	0.10	1.21	.03	0.69	25
30	1.00	3.19	0.35	2.06	0.15	1.45	.04	0.82	30
35	1.33	3.72	0.46	2.41	0.19	1.69	.05	0.96	35
40	1.70	4.25	0.59	2.75	0.25	1.93	.06	1.10	40
50	2.57	5.32	0.89	3.44	0.38	2.41	0.10	1.37	50
60	3.60	6.38	1.25	4.13	0.53	2.90	0.13	1.65	60
70	4.79	7.44	1.66	4.82	0.70	3.38	0.18	1.92	70
80	6.14	8.51	2.13	5.50	0.90	3.86	0.23	2.19	80
90	7.63	9.57	2.65	6.19	1.12	4.35	0.28	2.47	90
100	9.28	10.63	3.22	6.88	1.36	4.83	0.34	2.74	100
110	11.07	11.69	3.84	7.57	1.62	5.31	0.41	3.02	110
120	13.01	12.76	4.51	8.26	1.91	5.79	0.48	3.29	120
130	15.08	13.82	5.23	8.95	2.21	6.28	0.56	3.57	130
140	17.30	14.88	6.00	9.63	2.54	6.76	0.64	3.84	140
150			6.82	10.32	2.88	7.24	0.73	4.11	150
160			7.69	11.01	3.25	7.72	0.82	4.39	160
170			8.60	11.70	3.63	8.21	0.92	4.66	170
180			9.56	12.39	4.04	8.69	1.02	4.94	180
190			10.57	13.07	4.46	9.17	1.13	5.21	190
200			11.62	13.76	4.91	9.66	1.24	5.49	200
210			12.72	14.45	5.37	10.14	1.36	5.76	210
220					5.86	10.62	1.48	6.03	220
230					6.36	11.10	1.61	6.31	230
240					6.88	11.59	1.74	6.58	240
250					7.42	12.07	1.87	6.86	250
260					7.98	12.55	2.02	7.13	260
270					8.56	13.04	2.16	7.40	270
280					9.15	13.52	2.31	7.68	280
290					9.77	14.00	2.47	7.95	290
300					10.40	14.48	2.63	8.23	300
320							2.96	8.78	320
340							3.31	9.32	340
360							3.68	9.87	360
380							4.07	10.42	380
400							4.48	10.97	400
425							5.01	11.66	425
450							5.57	12.34	450
475							6.15	13.03	475
500							6.77	13.71	500
525							7.41	14.40	525
550									550
575									575
600									600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Schedule 40 Aged Steel Pipe

C = 100

Pressure Loss per 100 feet of pipe (psi)

Size	½"		¾"		1"		1¼"		1½"		Size
ID	0.622		0.824		1.049		1.380		1.610		ID
OD	0.840		1.050		1.315		1.660		1.900		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
1	0.91	1.05	0.23	0.60	.07	0.37	.02	0.21	.01	0.16	1
2	3.28	2.11	0.84	1.20	0.26	0.74	.07	0.43	.03	0.31	2
3	6.95	3.16	1.77	1.80	0.55	1.11	0.14	0.64	.07	0.47	3
4	11.85	4.22	3.02	2.40	0.93	1.48	0.25	0.86	0.12	0.63	4
5	17.91	5.27	4.56	3.00	1.41	1.85	0.37	1.07	0.18	0.79	5
6	25.10	6.33	6.39	3.61	1.97	2.22	0.52	1.29	0.25	0.94	6
7	33.40	7.38	8.50	4.21	2.63	2.60	0.69	1.50	0.33	1.10	7
8	42.77	8.44	10.88	4.81	3.36	2.97	0.89	1.71	0.42	1.26	8
9	53.19	9.49	13.54	5.41	4.18	3.34	1.10	1.93	0.52	1.42	9
10	64.65	10.55	16.45	6.01	5.08	3.71	1.34	2.14	0.63	1.57	10
11	77.14	11.60	19.63	6.61	6.06	4.08	1.60	2.36	0.75	1.73	11
12	90.62	12.65	23.06	7.21	7.12	4.45	1.88	2.57	0.89	1.89	12
13	105.10	13.71	26.75	7.81	8.26	4.82	2.18	2.79	1.03	2.05	13
14	120.57	14.76	30.68	8.41	9.48	5.19	2.50	3.00	1.18	2.20	14
15			24.87	9.01	10.77	5.56	2.84	3.21	1.34	2.36	15
16			39.29	9.61	12.14	5.93	3.20	3.43	1.51	2.52	16
17			43.96	10.22	13.58	6.30	3.58	3.64	1.69	2.68	17
18			48.87	10.82	15.10	6.67	3.97	3.86	1.88	2.83	18
19			54.02	11.42	16.69	7.04	4.39	4.07	2.07	2.99	19
20			59.40	12.02	18.35	7.42	4.83	4.28	2.28	3.15	20
25					27.74	9.27	7.30	5.36	3.45	3.94	25
30					38.88	11.12	10.24	6.43	4.83	4.72	30
35					51.72	12.98	13.62	7.50	6.43	5.51	35
40					66.24	14.83	17.44	8.57	8.24	6.30	40
50							26.36	10.71	12.45	7.87	50
60							36.95	12.85	17.45	9.44	60
70									23.22	11.02	70
80									29.74	12.59	80
90									36.98	14.17	90
100											100
110											110
120											120
130											130
140											140
150											150
160											160
170											170
180											180
190											190
200											200
210											210
220											220
230											230
240											240
250											250

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Schedule 40 Aged Steel Pipe

C = 140

Pressure Loss per 100 feet of pipe (psi)

Size	2"		2½"		3"		4"		6"		Size
ID	2.067		2.469		3.068		4.026		6.065		ID
OD	2.375		2.875		3.500		4.500		6.625		OD
Flow gpm	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	Flow gpm
15	0.40	1.43	0.17	1.00	.06	0.65	.02	0.38			15
20	0.68	1.91	0.28	1.34	0.10	0.87	.03	0.50			20
25	1.02	2.39	0.43	1.67	0.15	1.08	.04	0.63			25
30	1.43	2.86	0.60	2.01	0.21	1.30	.06	0.76	.01	0.33	30
35	1.91	3.34	0.80	2.34	0.28	1.52	.07	0.88	.01	0.39	35
40	2.44	3.82	1.03	2.68	0.36	1.73	0.10	1.01	.01	0.44	40
50	3.69	4.77	1.55	3.35	0.54	2.17	0.14	1.26	.02	0.55	50
60	5.17	5.73	2.18	4.02	0.76	2.60	0.20	1.51	.03	0.67	60
70	6.88	6.68	2.90	4.69	1.01	3.03	0.27	1.76	.04	0.78	70
80	8.82	7.64	3.71	5.35	1.29	3.47	0.34	2.01	.05	0.89	80
90	10.96	8.59	4.62	6.02	1.60	3.90	0.43	2.27	.06	1.00	90
100	13.33	9.55	5.61	6.69	1.95	4.33	0.52	2.52	.07	1.11	100
110	15.90	10.50	6.70	7.36	2.33	4.77	0.62	2.77	.08	1.22	110
120	18.68	11.46	7.87	8.03	2.73	5.20	0.73	3.02	0.10	1.33	120
130	21.66	12.41	9.12	8.70	3.17	5.63	0.85	3.27	0.12	1.44	130
140	24.85	13.37	10.47	9.37	3.64	6.07	0.97	3.52	0.13	1.55	140
150	28.24	14.32	11.89	10.04	4.13	6.50	1.10	3.78	0.15	1.66	150
160			13.40	10.71	4.66	6.94	1.24	4.03	0.17	1.77	160
170			15.00	11.38	5.21	7.37	1.39	4.28	0.19	1.89	170
180			16.67	12.05	5.79	7.80	1.54	4.53	0.21	2.00	180
190			18.43	12.72	6.40	8.24	1.71	4.78	0.23	2.11	190
200			20.26	13.39	7.04	8.67	1.88	5.03	0.26	2.22	200
210			22.18	14.06	7.71	9.10	2.05	5.29	0.28	2.33	210
220			24.17	14.72	8.40	9.54	2.24	5.54	0.30	2.44	220
230					9.12	9.97	2.43	5.79	0.33	2.55	230
240					9.87	10.40	2.63	6.04	0.36	2.66	240
250					10.64	10.84	2.84	6.29	0.39	2.77	250
260					11.45	11.27	3.05	6.54	0.42	2.88	260
270					12.28	11.70	3.27	6.80	0.45	2.99	270
280					13.13	12.14	3.50	7.05	0.48	3.11	280
290					14.01	12.57	3.73	7.30	0.51	3.22	290
300					14.92	13.00	3.98	7.55	0.54	3.33	300
320					16.81	13.87	4.48	8.05	0.61	3.55	320
340					18.81	14.74	5.01	8.56	0.68	3.77	340
360							5.57	9.06	0.76	3.99	360
380							6.16	9.57	0.84	4.21	380
400							6.77	10.07	0..92	4.44	400
425							7.58	10.70	1.03	4.71	425
450							8.43	11.33	1.15	4.99	450
475							9.31	11.96	1.27	5.27	475
500							10.24	12.59	1.39	5.55	500
525							11.21	13.22	1.53	5.82	525
550							12.22	13.84	1.66	6.10	550
575							13.27	14.47	1.81	6.38	575
600									1.95	6.66	600

Note: Shaded areas of charts indicate velocities over 5 feet per second (fps).

Pressure Loss through Water Meters

Pressure Loss (psi)

Flow gpm	5/8"	¾"	1"	1½"	2"	3"	4"	Flow gpm
1	0.2	0.1						1
2	0.3	0.2						2
3	0.4	0.3						3
4	0.6	0.5	0.1					4
5	0.9	0.6	0.2					5
6	1.3	0.7	0.3					6
7	1.8	0.8	0.4					7
8	2.3	1.0	0.5					8
9	3.0	1.3	0.6					9
10	3.7	1.6	0.7	0.1				10
11	4.4	1.9	0.8	0.2				11
12	5.1	2.2	0.9	0.2				12
13	6.1	2.6	1.0	0.3				13
14	7.2	3.1	1.1	0.3				14
15	8.3	3.6	1.2	0.4				15
16	9.5	4.1	1.4	0.4				16
17	10.7	4.6	1.6	0.5				17
18	12.0	5.2	1.8	0.6				18
19	13.4	5.8	2.0	0.7				19
20	15.0	6.5	2.2	0.8	0.4			20
25		10.3	3.7	1.3	0.5			25
30		15.0	5.3	1.8	0.7			30
35			7.3	2.6	1.0			35
40			9.6	3.3	1.3			40
50			15.0	4.9	1.9	0.8		50
60				7.2	2.7	1.0		60
70				9.8	3.7	1.3		70
80				12.8	4.9	1.6	0.7	80
90				16.1	6.2	2.0	0.8	90
100				20.0	7.8	2.4	0.9	100
110					9.5	2.9	1.0	110
120					11.3	3.4	1.2	120
130					13.1	3.9	1.4	130
140					15.0	4.5	1.6	140
150					17.3	5.1	1.8	150
160					20.0	5.8	2.1	160
170						6.5	2.4	170
180						7.2	2.7	180
190						8.0	3.0	190
200						9.0	3.2	200
220						11.0	3.9	220
240						13.0	4.7	240
260						15.0	5.5	260
280						17.3	6.3	280
300						20.0	7.2	300
320							8.1	320
340							9.0	340
360							11.0	360
380							12.0	380
400							13.0	400
450							16.2	450
500							20.0	500

Note: Shaded area of chart indicates more than 75% of the maximum safe flow through the meter.

Pressure loss figures shown are to maximum safe flow capacities. Pressure losses may vary with different brands and models.

Friction Loss of Fittings

Shown in equivalent feet of pipe

Size	Tee-Run	Tee-Branch	90 Ell	45 Ell
½”	1.0	4.0	1.5	0.8
¾”	1.4	5.0	2.0	1.0
1”	1.7	6.0	2.3	1.4
1 ¼”	2.3	7.0	4.0	1.8
1 ½”	2.7	8.0	4.0	2.0
2”	4.3	12.0	6.0	2.5
2 ½”	5.1	15.0	8.0	3.0
3”	6.3	16.0	8.0	4.0
3 ½”	7.3	19.0	10.0	4.5
4”	8.3	22.0	12.0	5.0

This chart is based on a Hazen and Williams coefficient of 150. The values stated are bases on the equivalent schedule of pipe friction loss. However, this information should be used for reference only, since variations may result from installations techniques, actual fitting geometry, and inside diameter of adjacent piping system.

F.

References

American Water Works Association. California – Nevada Section. Guidelines for the On-Site Retrofit of Facilities Using Disinfected Tertiary Recycled Water. 1997.

American Water Works Association. Water-Efficient Landscape Guidelines. 1993.

Arizona Landscape Irrigation Guidelines Committee. Guidelines for Landscape Drip Irrigation Systems. Jul. 2001. < http://www.adwr.state.az.us/dwr/Conservation/LandscapePros/>.

Center for Irrigation Technology. Goods & Services. 1 Apr. 2008. <http://cati.csufresno.edu/cit/good/>.

Choate, Richard B. Turf Irrigation Manual. 5th Edition. 1994.

City of Santa Fe. Chapter 14 Land Development. Dec. 2001 < http://clerkshq.com/default.ashx?ClientSite=Santafe-nm>

Hunter Industries Inc. Handbook of Technical Irrigation Information. 2001. < http://www.hunterindustries.com/Resources/PDFs/pdf_english_educational.html>.

International Association of Plumbing and Mechanical Officials. Uniform Plumbing code 1997 Edition. 1996.

The Irrigation Association. Advanced Head Layout and Zoning. Aug. 1998. < http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Advanced Irrigation Design for Water Conservation. 2005. < http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Certification. Bulletin of Information: Certified Irrigation Designer (CID) Program. 31 Mar. 2008. <http://irrigation.org/certification>.

The Irrigation Association. Certification. Bulletin of Information: Certified Landscape Irrigation Auditor (CLIA) Program. 1 Apr. 2008. <http://irrigation.org/certification>.

The Irrigation Association. Certified Landscape Irrigation Auditor. Sep. 2004. http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Certified Irrigation Contractor. Feb. 2002. <http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Drip Design in the Landscape. Jul. 2007. <http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Foundations of Landscape Irrigation Design. Sep. 1999. http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Predicting and Estimating Landscape Water Use. Oct. 2001. <http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Principles of Irrigation. Jun. 2002. <http://www.irrigation.org/bookstore/default.aspx?pg=bookstore.ascx&id=49>.

The Irrigation Association. Water Management Committee. Turf and Landscape Irrigation Best Management Practices. Apr. 2005. < http://www.irrigation.org/gov/default.aspx?pg=BMPs.htm&id=104>.

Las Vegas Valley Water District, Conservation Office. Guidelines for Turf and Landscape Irrigation Systems. Aug. 1993.

Netafim. Subsurface Dripperline Guide. 2009. < http://www.netafimusa.net/index-lnd-down-design-guides.php>.

New Mexico Regulation and Licensing Department. Board of Landscape Architects. 31 Mar. 2008. <http://www.rld.state.nm.us/Landscape/index.html>.

Rain Bird. Landscape Dripline Design & Installation Guide. 1999. <http://www.rainbird.com/drip/literature/index.htm>.

Rain Bird. Low Volume Irrigation Design Guide. 2000. < http://www.rainbird.com/drip/literature/index.htm>.

The Toro Company. Subsurface Irrigation Design. Feb. 1998. <http://www.toro.com>.

Weather Reach. Landscape Water Management. Irrisoft, Inc. Jan. 2004. <www.weatherreach.com>.

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