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STATE OF HAWAII**

Surface Water Use Permit Applications,	)	Case No. <u>CCH-MA15-01</u>
Integration of Appurtenant Rights and	)	
Amendments to the Interim Instream Flow	)	MMK MAUI, LP'S EXHIBITS
Standards, Na Wai Eha Surface Water	)	2186-MMK-1 THROUGH
Management Areas of Waihee, Waiehu, Iao	)	2186-MMK-11; CERTIFICATE OF
and Waikapu Streams, Maui	)	SERVICE
	)	

MMK MAUI, LP'S EXHIBITS

2186-MMK-1

THROUGH

2186-MMK-11

AND

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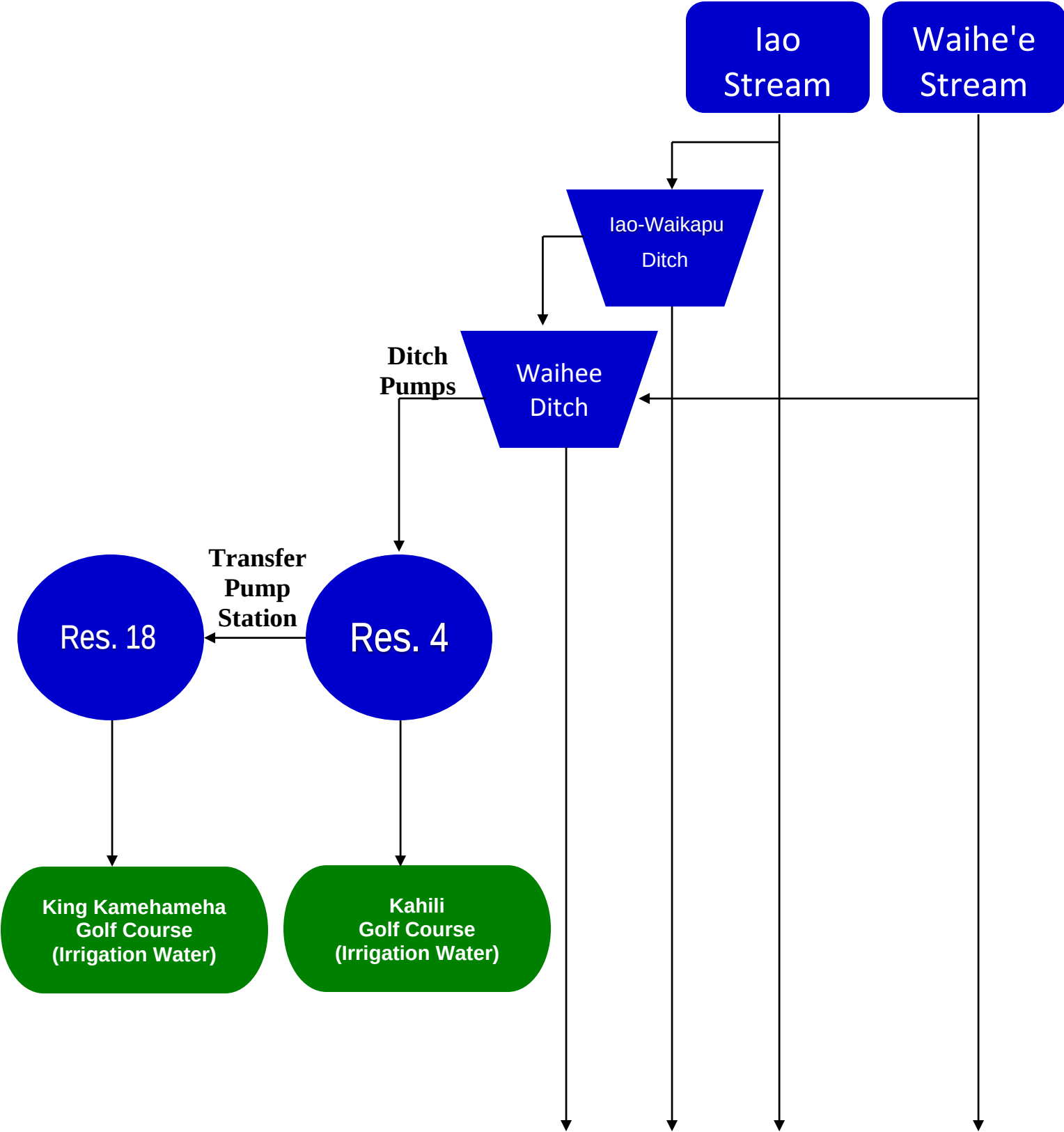
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Golf Course Irrigation System





SECOND EDITION

TURF MANAGEMENT FOR GOLF COURSES

JAMES B BEARD

Exhibit No. 2186-MMK-3



Turf Management for Golf Courses

Second Edition

by

James B Beard

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Texas A&M University*

**A Publication of
The United States Golf Association**

with illustrations by Steven M. Batten

Ann Arbor Press
Chelsea, Michigan

Exhibit No. 2186-MMK-3

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CHAPTER 9

The Irrigation System

Proper turf irrigation is the most difficult day-to-day agronomic decision the golf course superintendent makes.

A PERSPECTIVE

Water comprises 80 to 85% of the weight of a grass plant. Supplemental water is needed to maintain quality golf turfs throughout the season in most locations. Essentially all grass greens are irrigated, as are a majority of all tees. Fairway irrigation has been increasing and is now the norm, with some roughs also being irrigated. The irrigation of roughs may be reversed in the future as water supplies become more limited and costly.

When to irrigate is one of the most difficult decisions in all of golf course turfgrass culture. Often the decision must be made daily for various turfs and locations on the golf course. Golf course irrigation problems are unique because the variables are numerous and many are beyond any reasonable degree of control.

Unfortunately, irrigation practices and systems are too often misunderstood and misused. Many golfers tend to rate the golf course superintendent's ability by the greenness of the turf. Too frequently a lush, green golf course is expected at all times. However, such a turf is not the most healthy or playable, with the result frequently being soggy, wet conditions. Proper irrigation practices are essential for good playing conditions in terms of a firm, fast surface as well as a uniform, dense turf.

A golf course irrigation system is a complex, costly capital investment. It must be properly designed, engineered, installed, and operated to achieve maximum return on the investment in terms of a quality turf that is uniformly irrigated at the optimal water application rate and timing. The decision-making processes involved in development of a golf course irrigation system are summarized in Figure 9.1. This chapter is not intended as a comprehensive text on the design and installation of golf course irrigation systems. Rather, the objective is to discuss the procedural steps involved in development of an irrigation system and the range of alternatives available in design, type of systems, and system components, plus their advantages and disadvantages. The information presented should provide guidelines for those in decision-making positions to confirm they are proceeding in an organized manner that minimizes the chance of encountering unanticipated problems and costly design or construction errors.

WATER SOURCE

The first priority in development of an irrigation system is to secure an adequate water source in terms of both quantity and quality. Restrictions in the amount of water available per unit of time may alter key aspects of the system design.

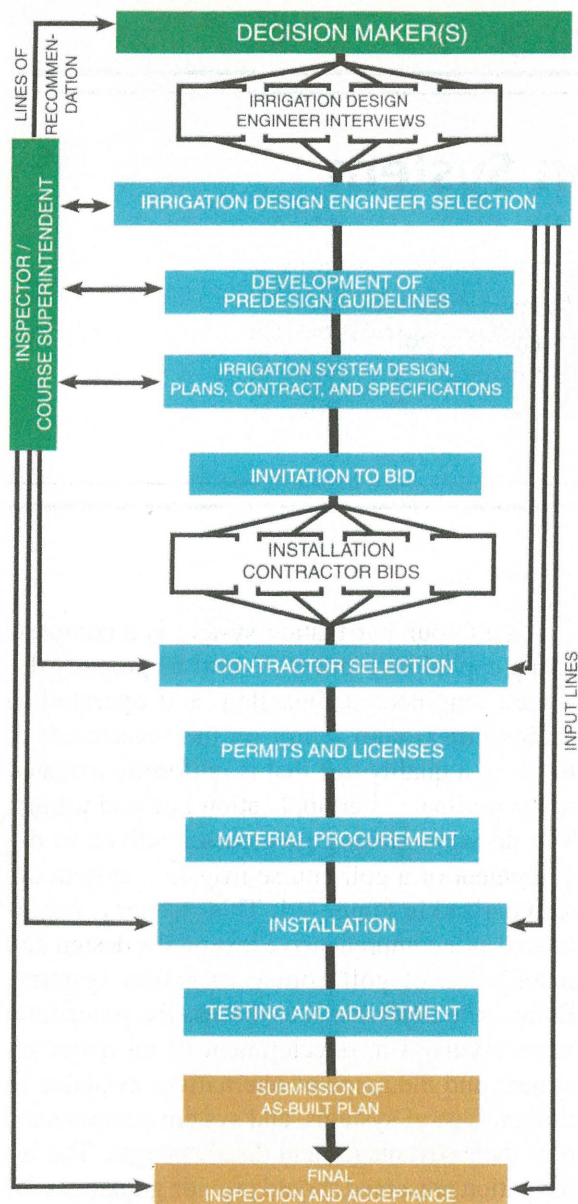


Figure 9.1. Flow diagram for development of a golf course irrigation system.

The total golf course water needed for a year must be estimated before assessing the potential water sources. This is especially important for ponds, lakes, and streams. In regions where the annual rainfall is highly variable, the estimate should be based on one of the drier years rather than an average over the years. Also, the water

surplus during the winter and spring may be of no value in certain parts of the country. When calculating the evapotranspiration (ET) loss from the turf areas, be sure to make similar evaporative loss calculations for the ponds and lakes used for water storage for irrigation.

The presence of particulate matter may necessitate the installation of settling ponds, strainers, filters, sand separators, or holding tanks. Finally, the presence of soluble salts or sodium (Na) in a water source indicates substantial long-term turfgrass culture and soil management problems. Thus, the following discussion provides the basis for considering alternative water sources.

- This section on water sources offers general guidelines only.
- The technical services of a specialist who has legal jurisdiction for the development of water sources for irrigation should be obtained.
- Appropriate steps must be taken to (a) ensure full compliance with all applicable laws and (b) secure any permits.

Wells

Underground water sources usually prove to be excellent for turfgrass irrigation purposes. A common source of water for golf course irrigation is from one or more wells. Wells 20 to 50 feet (6–15 m) in depth may supply ample quantities of water in some locations, while in other locations wells must be drilled 1,500 to 2,500 feet (457–762 m) deep at a substantial cost to obtain an adequate sustained capacity. The water yield in gallons per minute (gpm) and drawdown level of the well must be determined. For example, wells having a flow rate in the 500- to 1,000-gpm (1,893–3,786 Lpm) range generally are adequate for an 18-hole automatic irrigation system, which typically requires 2,000 gpm (7,572 Lpm) when in full operation. In some states, for example Colorado, it must be ascertained whether water drilling rights are held by the property under consideration and also the relative priority of water rights assigned to the site. Governmental water allocation laws are becoming more restrictive

throughout the arid and semiarid regions, even for wells on one's own property. Most states or local authorities require a permit to drill a well.

Wells usually have the advantages of being in close proximity to where the water is used and having less variability in yield than most surface sources. Well water typically is more uniform in temperature and soluble mineral content. On the other hand, wells are more expensive to develop than are surface water sources. Also, groundwater levels are dropping in many areas due to ever increasing demands of agriculture, industry, and urban housing development. Finally, water quality problems may be encountered in certain wells, with the most common concerns being high soluble salts, sodium levels (Na), carbonates, and bicarbonates. Salt water intrusion into fresh groundwater supplies is becoming a problem in coastal areas. Processing of saline water is a costly, but sometimes necessary approach. Acidulation at the pump and reverse osmosis (RO) are used to lower the salt content or offset excess carbonates or bicarbonates in the water. Also, blending of fresh and salt water may be used to extend the fresh water supply.

It is imperative that an antisiphon device be installed to prevent backflow into the well. Well water may be pumped directly into the irrigation system or into a reservoir, and then into the irrigation system. With the former, some type of pump station and flow/pressure regulation or relief valve arrangement must be incorporated into the system design. The latter is used when the water delivery rate of the well does not meet the water application rate demand of the irrigation system. Use of a reservoir also may permit use of smaller-capacity pumps, which may increase pump efficiency and decrease pumping costs. The latter may be achieved by use of a small jockey pump or with a variable-frequency drive when there is less demand on the system, such as during manual watering. Variable-speed transmissions have been replaced by the more efficient variable-frequency drive (VFD). The VFD actually operates the electric motor as a variable-speed motor, thereby eliminating the transmission and requiring less energy. This is accomplished by a

microprocessor and an inverter that work together to manipulate the number of AC cycles and in turn operate the electric motor at different speeds.

If an irrigation pond or reservoir is used as an intermediate storage source, it may be desirable to locate the water body where it also may serve as an aesthetic attribute and/or water hazard that comes into play on one or more golf holes. However, if the source is reclaimed effluent water that may have poor aesthetic qualities, the reservoir should be placed out of sight.

Lakes, Ponds, and Reservoirs

Surface water from a natural or man-made lake, pond, or reservoir, if of sufficient size, is an excellent water source for golf course irrigation purposes. The water may originate from springs and/or surface runoff from the surrounding watershed. The minimum size for a lake water source where there is no pumping from wells is 10 to 20 acre-feet in cooler climates and 30 to 40 acre-feet in warmer climates for a fully irrigated 18-hole golf course (1 acre-foot equals 325,850 gallons or 1,233,342 L). In relatively high-rainfall areas, the minimum size of a pond with a good recovery rate could be as small as 5 acre-feet. It is preferable for the lake to be located entirely within the boundaries of the golf course property to avoid drawdown restrictions (Figure 9.2). A problem with smaller ponds is the periodic drawdown of several feet, which results in unattractive, exposed banks and bottoms that are objectionable to golfers.

One of the main problems encountered in water from lakes—particularly for an automatic irrigation system—is particulate matter, including algae, aquatic weeds, sand, organic debris, fish, frogs, and snails. The problem usually is greater in small, shallow reservoirs and ponds than in large, deep bodies of water. Water circulation, oxygenation, and water temperature may be enhanced by installation of a subsurface aeration device, oxygen pump, or ozone systems. Aquatic herbicides are available that may be used to control water weeds and algae, but are not harmful to fish, aquatic animals, and turfgrasses. Certain



Figure 9.2. Pond serving the dual purpose of a reservoir for irrigation water and an aesthetic hazard that influences the playing strategy of a golf hole.

herbicides need to be retained in the lake for several days to achieve adequate control and/or avoid turf injury. For this reason, some architects develop a 2-lake system, with both lakes being available as a water source for golf course irrigation. Each lake should be of sufficient size to meet the irrigation needs for at least 3 to 4 days. Through this arrangement it is possible to isolate one reservoir for chemical aquatic weed control while the other serves as the water source for golf course irrigation. A discussion of ponds and their management is presented in Chapter 12.

The severity of problems that may develop—in the form of clogged nozzles, valves, and intake pipes—as a result of a high concentration of debris and particulate material in the lake or reservoir should not be underestimated. The use of filters at the water intake just ahead of the pumping station is discussed in the water quality section.

Perennial Flowing Rivers and Streams

Surface water from perennial flowing rivers and streams is an acceptable source if the rate and permanence of flow are reliable and approved by the appropriate governing agencies. The pattern of

stream flow during both wet and dry years as well as the flood stage must be determined. State hydrological engineers and the U.S. Geological Survey can make such a determination. A permit usually is required for use of water from streams and rivers, especially in states where riparian rights prevail or if part of the water eventually enters a municipal water reservoir. To secure a permit, evidence must be shown that adequate water flow will continue for downstream users. Typically, it has become increasingly difficult to obtain the required permits to pump water from a river or stream.

A potential problem with flowing streams is water quality. Industrial plants located upstream may dump waste water into the stream

that is potentially toxic to turfs. Actions by the US Environmental Protection Agency (EPA) are minimizing this problem. Another problem is the organic debris and solids frequently carried in flowing streams and rivers. Appropriate precautions to remove this objectionable particulate matter must be made to ensure that the materials do not enter the irrigation system. The use of filters at the water intake just ahead of the pumping station is discussed in the water quality section.

Water from a river may be pumped directly into the irrigation system if the flow rate is adequate, or into a pond on the golf course and then into the irrigation system, as in the method previously described for wells. Pumping directly from a flowing stream into the irrigation line generally is impractical because of difficulties encountered with stream velocity, changing water level, and varying amounts of debris, silt, and sand. Thus, best results will be obtained by the construction of a pond or holding basin located at least 50 feet (15 m) from the river. A channel or large pipe is then constructed to connect the river to the pond. Typically, the reservoir depth should be from 6 to 8 feet (1.8–2.4 m) below the mean low water level of the river. The reservoir must be of suffi-

cient size to hold a 6-day supply of irrigation water and so located that fluctuating water levels are not a visual concern. Construction of this type of reservoir provides a water source relatively free of debris and sand compared with water pumped directly from the river.

Canals

Drainage canals serve as a source of water in some parts of North America, such as Florida. Typically these water lanes are under public control, which increases the potential for restrictions to be placed on the quantity of water that may be used, particularly during periods of drought. Problems with debris and particulate material are similar to those previously discussed for rivers.

Water Utilities

Public and private water companies function as a source of water for many golf courses. Public sources are less desirable because of a high potential for restrictions in water supplies during prolonged drought. Another disadvantage is that public water sources are becoming more expensive. Although the initial hookup cost is modest in comparison to the cost of drilling a well or constructing a reservoir, the long-term expense of purchasing water may be higher. An advantage of obtaining water from an outside agency is that it is delivered under pressure and—if the source is dependable—may be connected to the golf course irrigation main line at a considerable cost savings. Another advantage is the better quality and greater freedom from debris problems and removal devices compared with perennial flowing rivers and lakes.

The purchase of water from public utilities may be difficult to avoid in some areas. Construction of an intermediate reservoir into which the water is pumped, similar to that described for wells, may be advisable for partial protection against potential water restrictions. Whether the water is pumped directly into the irrigation main line or through an intermediate storage reservoir, a reduced-pressure principle device (RPPD) or an air

gap should be installed to prevent backflow into the domestic water supply. The distance of the air gap may vary depending on who is regulating the installation. This procedure may be mandated by a regulation or code enforced by the public health department or water supplier.

Reclaimed Effluent Water

A water source that is being used increasingly for the irrigation of golf courses is reclaimed effluent water. Turfgrasses tolerate reclaimed effluent water containing moderate levels of heavy metals and other elements that cannot be used in crop/vegetable production because of potential problems of entering the human food chain or restricting crop yield. Also, many golf courses are within reasonable delivery distance of urban sewage treatment plants. Thus, turfgrass irrigation offers one of the best approaches to disposing of certain types of reclaimed effluent water.

Sewage treatment plants have three levels of possible treatment (Figure 9.3). The primary level is concerned with removal of solids. The secondary level removes many organic impurities, while the tertiary level removes even more suspended and dissolved impurities. Each treatment level adds more expense, but improves water quality. Turfed soils (a) function as good water filters, (b) enhance ground water recharge, (c) offer an economical means of advanced water treatment, and (d) have a great capacity to accommodate and degrade organic wastes. Some sodic soils have been reclaimed through the use of sewage effluents having good inorganic qualities.

The reliability of a reclaimed effluent water supply can be a positive factor. However, a supplier may seek a contract under which the user must accept a certain amount of reclaimed effluent water year-round. Unfortunately, the seasonal growth cycle of turfgrasses may dictate that the water requirement will be substantially reduced or nonexistent during the winter. Consequently, nearby spray fields and/or holding ponds must be developed to accommodate the excess water supply in order to avoid a very wet golf course at certain times of the year. Contracts stipulating ac-

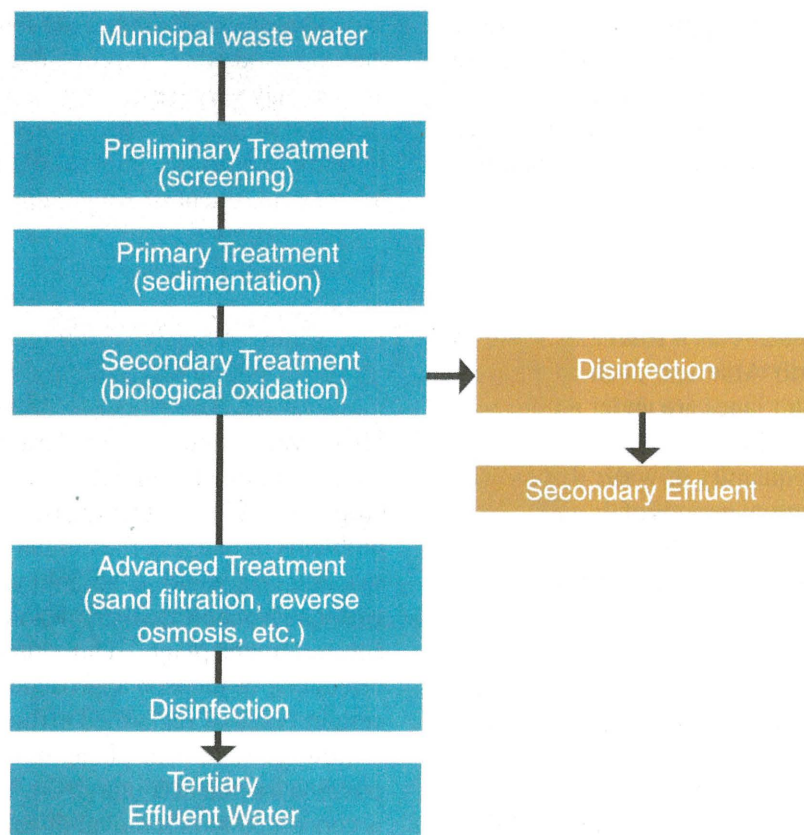


Figure 9.3. Typical steps in sewage/waste water treatment.

ceptance of a mandatory amount of reclaimed effluent water per week or month year-round must be carefully studied and adjusted to the seasonal turfgrass needs.

The cost of reclaimed effluent water generally is less than that of potable water, especially in arid regions. In some areas, reclaimed effluent water is available at no cost or at only the pumping charge involved, while in other areas it is sold at near the price of domestic water. Overall, the cost of reclaimed effluent water has risen, but remains economically attractive compared with potable water.

The content of nutrients, heavy metals, organic compounds, and salts in reclaimed effluent water may vary substantially from week to week and even day to day. This dictates the need for regular analytical monitoring. Chemical analyses of many reclaimed effluent water sources reveal that the nitrogen (N) content of these waters varies

considerably, but in most cases can contribute significantly to turfgrass nutrition. Even at low levels, these nutrients have considerable effect on turfgrasses because they are applied on a frequent, regular basis. In most cases, turfgrasses will receive all the phosphorus (P) and potassium (K), and a large part of the nitrogen they may need from reclaimed effluent water. Sufficient micronutrients also are supplied by most reclaimed waters. Thus, reclaimed effluent water may serve as a bonus source of beneficial nutrients for turfgrass growth and should be monitored for plant nutrient content.

Some chemicals present in reclaimed effluent water may be injurious to turfgrass growth, and for this reason the water used for turfgrass irrigation should be monitored on a routine basis. Tertiary-treated effluent is preferred for use in turfgrass irrigation due to possible wind drift and

less odor concerns. The main chemical problems in reclaimed effluent water may come from industrial wastes. The reclaimed effluent also causes corrosion problems with equipment.

A state and/or local health or water agency usually monitors for biological constituents, e.g., viruses, coliform, etc. Almost all effluent treatment plants use chlorination or other methods to disinfect water prior to delivery.

Water Rights

Simply stated, a so-called water right is the right to the use of water accorded by law. A review of water laws across North America reveals a crazy quilt pattern of water rights. Each state has its own system of water laws. In some cases, conflicting laws are operative within the same state. Basically, the rights to surface water and to underground streams are subject to the law of water courses. These rights are governed by two conflicting doctrines—riparian and prior appropriation.

The **riparian doctrine** recognizes that the owner of land contiguous to a stream has certain rights to its flow. However, upstream location gives the riparian owner no preference for irrigation purposes. The right to use water for irrigation is coequal with the rights of all other riparian owners on the stream.

The **prior appropriation doctrine** accords a person who first takes water from a stream and makes use of it the right to continue diversion of the water. That person's rights take precedence over all who come later.

Water laws are evolving and can vary greatly in each state. Because of this, laws governing development, retention, and use of surface waters do not warrant further discussion here. The best advice for those planning a water source for a golf course irrigation system is to seek the advice of competent legal counsel.

WATER QUALITY

There are two major aspects of water quality from the standpoint of turfgrass irrigation. One

involves the presence of particulates and suspended solids, which affect the operating characteristics of an irrigation system. The second involves the presence of dissolved salts or chemicals that are potentially detrimental to turfgrass growth directly, or indirectly through gradual soil accumulation to adverse levels. Whenever possible, it is advisable to obtain as clean a water source as possible for turfgrass irrigation in order to minimize sprinkler system maintenance costs and to avoid adverse grass and/or soil effects that increase the difficulties of long-term turfgrass culture.

- This section on water quality offers general guidelines only.
- The technical services of an irrigation engineer and/or water chemist should be obtained.
- Appropriate steps must be taken to (a) ensure full compliance with all applicable laws and (b) secure any required permits.

Particulate Materials

Foreign debris present in the water supply results in inferior performance of the irrigation system, wear, and increased frequency of costly malfunctions. It necessitates frequent cleaning and flushing of the system, plus servicing and cleaning of sand separators and sprinkler heads. The two main types of problem particulate debris are organic materials and sands.

Organic Materials Strainers. Organic materials usually are associated with a pond, lake, or river water source. Included are leaves, stems, sticks, algae, duckweed, fish, clams, mussels, and relatively undecomposed peats, such as peat moss. Fouling, plugging, and abrasive wear of the irrigation system components by these particulate materials are minimized by construction of the proper type of water intake. Clogging of orifices and sticking of valves are malfunctions that require costly flushing and cleaning.

Where problems with organic materials in the lake or river water source are anticipated, installation of a strainer just prior to when the water



Figure 9.4. A mechanical strainer used to clean a raw water supply containing debris.

enters the pumping station is advisable (Figure 9.4). Such an intake strainer usually is positioned aboveground to facilitate cleaning. For serious contamination problems, intake pipes have a coarse-screened initial strainer. The water is then passed through a series of finer strainer screens. An important factor in strainer selection is the screen opening size, or mesh. It should be sufficiently small to remove the anticipated objectionable particulate material from the water source. The screens will generate a known pressure loss, which should be considered in the original design of the irrigation system. The frequency of strainer cleaning varies depending on the amount of irrigation water pumped and the amount of organic material present in the water source. The rate of strainer clogging may be monitored by means of pressure gauges installed on both sides of the strainer. Automatic self-cleaning strainers also are available and preferred. They should be considered for golf course irrigation systems that will be operated unattended for long periods and where organic debris in the water supply will be a continuing problem.

Sand Filters. Water from wells and reservoirs with sandy bottoms may cause problems, including sticking valves, eroded orifices, fouled orifices, sticking sprinklers, and accelerated wear of valves, impellers, and sprinkler heads. Thus, it is imperative that filter facilities be installed for sand

removal where a problem is experienced. The most common method of removing sand from water is by pumping the water into a covered holding tank or water reservoir. This approach is advantageous where pressure loss through filters and sand separators is critical.

Holding Tank With Filters. A holding or settling tank is basically a reservoir used to store water pumped from the original open water source until it is pumped into the actual irrigation system. It is particularly desirable when the water source contains objectionable quantities of organic material or sand. The size of the holding tank should be at least 10 times the anticipated maximum flow rate for the system. Thus, an 800-gallon (3,028-L)-per-minute maximum flow requirement would dictate an 8,000-gallon (30,280-L) holding tank. In case of a very dirty water source, the tank is divided into sections, each separated by a removable screen. The screens vary in mesh size, with the largest mesh being located at the end where the water enters, and with the mesh being reduced in size across the tank in increments of approximately 3/8-, 1/4-, 1/8-, and 1/16-inch (9.5, 6.4, 3.2, and 1.6 mm) mesh. A screen system of this type must be cleaned at appropriate intervals.

Introduced Particulate Contaminants. Particulate matter may be introduced into the irrigation system as a result of carelessness during the original installation or during subsequent repair of the pipelines. In addition, it may be introduced into public utility water as a result of rust particles breaking loose from inside cast-iron and steel pipes. Rust and scaling can be devastating problems associated with irrigation pipes. The continual clogging of sprinkler heads is so disruptive and costly to correct that the best long-term solution may be to replace the piping. Otherwise, the situation may be corrected through the installation of filters where the water enters the golf course.

The best prevention for particulate matter problems incurred during irrigation system installation is proper flushing of the water distribution lines before the irrigation heads are connected and

Table 9.1. The Relative Tolerances of 18 Turfgrass Species to Soil Salinity.¹

Sensitive (<3 dS/m)	Moderately Sensitive (3 to 6 dS/m)	Moderately Tolerant (6 to 10 dS/m)	Tolerant (>10 dS/m)
annual bluegrasses colonial bentgrass Kentucky bluegrass rough bluegrass centipedegrass	annual ryegrass creeping bentgrass fine-leaf fescues bahiagrass	perennial ryegrass tall fescue buffalograss, American zoysiagrasses	alkaligrass bermudagrasses seashore paspalum St. Augustinegrass

¹ Adapted from M.A. Harivandi, J.D. Butler, and L. Wu. 1992. Salinity and turfgrass culture. In *Turfgrass*, Series No. 32, American Society of Agronomy, Madison, Wisconsin, USA.

the system put into operation. Similarly, it is important to avoid the introduction of particulate material into distribution lines during repair activities. If some debris has been allowed to enter the system during repair, it should be flushed out before the irrigation system is returned to its normal operational level.

A modern problem relating to high particulate levels in irrigation water involves the upper-profile clogging of high-sand root zone constructions, which adversely affect the soil water infiltration rate. The two main concerns are (a) the increased use of reclaimed water that may contain high levels of suspended solids and (b) the effects of undissolved solids, both organic and mineral.

Dissolved Salts and Chemicals

Essentially all irrigation water contains some dissolved mineral salts and chemicals. Some of the soluble salts are nutrients and thus beneficial to turfgrass growth, but others may be phytotoxic. The rate at which salts accumulate to undesirable levels in the soil depends on the concentration of soluble salts in the irrigation water, the amount of irrigation water applied annually, and the physical/chemical characteristics of the soil in question. The major salt problems of concern in water quality are the (a) total concentration of soluble salts, (b) sodium (Na), (c) relative proportion of sodium (Na), carbonate (CO_3), and bicarbonate (HCO_3)

to calcium (Ca) and magnesium (Mg), and (d) the amounts of chloride (Cl) and boron (B).

Salinity. Most water of acceptable quality for turfgrass irrigation contains from 200 to 800 parts per million (ppm) soluble salts. Soluble salt levels above 2,000 ppm are very undesirable and may be directly injurious to turfgrass. If the soil has exceptional permeability and good subsoil drainage characteristics, and depending on the turfgrass species grown (Table 9.1), irrigation water with salt levels up to 2,000 ppm may be tolerated. Exceptional permeability and good subsoil drainage permit the turf manager to leach excessive soluble salt concentrations from the root zone by periodic, intense irrigations. The USGA Method of high-sand root zone construction fits these criteria very well.

The total concentration of soluble salts in the soil and the water also is measured as **electrical conductivity** (EC), which is expressed in units as decisiemens per meter (dS/m), with dS/m = millimhos per centimeter (mmhos/cm). The general equation used to convert electrical conductivity to parts per million is $1 \text{ dS/m} = 640 \text{ ppm total salts}$. This type of soil and water quality information may be obtained by submitting representative samples for analysis to either a reputable government or commercial laboratory. A water EC (EC_w) of 0.75 dS/m (mmhos/cm) is the approximate upper limit for growing turfgrasses without potential problems that necessitate costly

specialized adjustments in the cultural program. In contrast, soils having an EC_s (soil EC) analysis below 3 dS/m are considered satisfactory for growing most turfgrasses. Soils with an EC_s of 3 to 10 dS/m will restrict the growth of many turfgrass species and cultivars, while soils with levels of over 10 dS/m support only a few salt-tolerant turfgrass species or a very sparse population of turfgrass plants sensitive to salt (Table 9.2).

Sodium. The presence of sodium (Na) in irrigation water is of great concern in turfgrass culture. The effect of sodium in deflocculation of clay soils is particularly critical on intensively trafficked turfgrass areas because of the decrease in aeration, water infiltration, and soil water percolation. The rate at which a soil adsorbs sodium from water is known as the **sodium adsorption ratio (SAR)**, and is expressed as

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

with the values for sodium, calcium, and magnesium in millimoles per liter (mmole/L). This ratio is used for classifying the sodium hazard of water sources. Depending on its soluble salt content, water with an SAR above 6.0 may produce a sodium buildup in certain soils, unless replaced by calcium or a calcium producing amendment.

Bicarbonate. Reduced soil permeability also can occur when a water with high bicarbonate (HCO_3^-) content is used for irrigation. Bicarbonates at high levels facilitate calcium precipitation in the soil, i.e., they form calcium carbonate, which in the presence of sodium may cause a significant reduction in soil permeability. Also, high bicarbonates can cause deterioration of brass sprinkler heads and fittings. In addition to calcium, magnesium, and sodium, therefore, water also should be analyzed for its bicarbonate content.

A good indicator of a potential negative impact from bicarbonate in irrigation water is the

residual sodium carbonate (RSC). RSC is calculated in meq/L by the formula:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

When the RSC is less than 1.25, the bicarbonate will have minimal impact on soil permeability. At RSC levels above 2.5 there is considerable danger of soil impermeability occurring. At RSC values between 1.25 and 2.5, other factors—such as both the water and the soil sodium and salt contents—will determine the magnitude of the problem.

Chlorides. Chloride (Cl^-) in irrigation water contributes to its total soluble salt concentration. Excessive concentrations of chlorides may cause turfgrass tip burn and even total kill of the shoots. Concentrations of 355 ppm and higher are considered undesirable for irrigation of some salt-sensitive grasses. Turfgrasses tend to be more tolerant to chlorides than is the case for many landscape plants. Fortunately, chloride salts are quite soluble and thus may be leached from well-drained soils if there is a functioning subsurface drainage system.

Boron. Boron (B) is an essential micronutrient for plant growth, but is required in very minimal amounts. It is water soluble and is found in many water sources used for irrigation. Turfgrasses generally are tolerant of boron, but it may become toxic to non-turfgrass plants if the concentration in the irrigation water exceeds 1 to 2 ppm. An additional problem is soil accumulation, since boron may form chemical complexes that are not readily leached from the soil. Most turfgrasses will grow in soils with boron levels as high as 10 ppm.

Interpreting Water Quality Hazards

The best approach to interpreting water quality hazards is to arrange for a qualified, independent soil and water quality chemist to analyze and properly interpret the water and soil analysis reports. Water quality problems should be analyzed

Table 9.2. Outlines for the Interpretation of Water Quality for Irrigation.

Potential Irrigation Problems	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity: EC_w TDS	dS/m mg/L	<0.7 <450	0.7 to 3.0 450 to 2,000	>3.0 >2,000
Soil Water Infiltration (Evaluate using EC_w (dS/m) and SAR together): if SAR = 0 to 3 and EC_w = if SAR = 3 to 6 and EC_w = if SAR = 6 to 12 and EC_w = if SAR = 12 to 20 and EC_w = if SAR = 20 to 40 and EC_w =		>0.7 >1.2 >1.9 >2.9 >5.0	0.7 to 0.2 1.2 to 0.3 1.9 to 0.5 2.9 to 1.3 5.0 to 2.9	<0.2 <0.3 <0.5 <1.3 <2.9
Specific Ion Toxicity: Sodium (Na): root absorption foliar absorption	SAR meq/L mg/L	<3 <3 <70	3 to 9 >3 >70	>9 — —
Chloride (Cl ⁻): root absorption foliar absorption	meq/L mg/L meq/L mg/L	<2 <70 <3 <100	2 to 10 70 to 355 >3 >100	>10 >355 — —
Boron (B)	mg/L	<1.0	1.0 to 2.0	>2.0
Miscellaneous effects: Bicarbonate (HCO_3^-) (unsightly foliar deposits) pH Residual chlorine	meq/L mg/L — mg/L	<1.5 <90 normal range <1.0	1.5 to 8.5 90 to 500 6.5 to 8.4 1 to 5	>8.5 >500 — >5

Adapted by A. Harivandi of the University of California, Hayward, California from D.W. Westcot and R.S. Ayers. 1984. Irrigation water quality criteria. (In G.S. Pettygrove and T. Asano (eds). *Irrigation with reclaimed municipal wastewater—A guidance manual*. Report No 84-1 wr. Calif. State Water Resources Control Board, Sacramento, California, USA). and from D.S. Farnham, et al., 1985. *Water quality: Its effects on ornamental plants*. Univ. of Calif. Coop. Ext. Leaflet 2995. Div. of Agric. Nat. Resources, Oakland, California, USA.

and solved on an individual basis after an assessment of all related factors. The concentrations of individual constituents must be known before water quality can be properly evaluated. In the case of sodium as well as of several other salts, the indirect effects on the soil and the direct effects on turfgrass growth must be considered. There also is a question of the combined effects from several salts. For example, high concentrations of both sodium and bicarbonates are especially undesirable. Similarly, it is difficult to set precise limits on the maximum acceptable sodium level because its reaction is influenced by the quantity of calcium and magnesium in the soil, and the salt content of the irrigation water.

A lengthy discussion on managing problem irrigation waters is beyond the scope of this chapter, particularly when each environment is unique and must be evaluated separately. In most cases, however, marginal irrigation water can be used for golf course irrigation if practices such as (a) acid or gypsum injection or (b) gypsum, sulfur, or other chemical amendments are added to the soil.

TYPES OF IRRIGATION SYSTEMS

There are three types of turfgrass irrigation systems in use on golf courses in North America: (a) automatic, (b) semiautomatic, and (c) less commonly, manual quick-coupler. All are basic forms of aboveground irrigation. The automatic irrigation system is by far the most popular type being installed on today's golf course. The comparative advantages and disadvantages of each type of system for golf course use are discussed in this section.

Automatic Irrigation System

An automatic irrigation system is comprised of fixed pop-up sprinkler heads automatically activated by control valves based on signals from a satellite, usually operated from a master controller (Figure 9.5). Most modern automatic irrigation systems have computerized controls with the appropriate software for (a) monitoring net ra-

diation, air and soil temperature, relative humidity, and wind speed as sensed at one or more microenvironmental stations sited on the golf course, (b) calculating the daily evapotranspiration (ET) rate of the turf(s) based on the appropriate prediction model, and (c) activating appropriate irrigation sprinklers based on flow management concepts. The valves are operated by electric or hydraulic controls. The controls in turn may be activated electrically or by radio signal. That is, the specific day, time of day, and operating duration may be established for any one or more of the control valves, each of which controls one or more sprinklers. The automatic irrigation system may or may not be integrated with a soil moisture sensing device and an on-site microenvironmental monitoring station.

Although the automatic irrigation system is automatic in terms of operating the heads at the time water is applied, experience has proven that it requires regular programming and maintenance. Nevertheless, it is by far the most effective type of golf course irrigation system installed today. When properly designed, engineered, installed, and operated, it has the capability of irrigating a golf course in the most timely and water-efficient manner. In this situation, a continually overwatered golf course is the fault of the superintendent.

Automatic irrigation has the initial appeal of greatly reducing labor costs for the actual irrigation activity. This supposition is met to a degree. However, an automatic system still requires substantial labor for maintenance, repair, and fine adjustment of the program. The golf course superintendent also must devote time to irrigation decisions and ensuring proper programming of the control units. The cost for repair and parts may increase after 5 to 10 years.

What are the advantages of an automatic, electronically operated irrigation system? First and foremost, this type of system places the essential control of golf course turf irrigation directly with the most competent individual on the green staff—the golf course superintendent or an appointed representative. Second, there is more precise timing of each sprinkler head in operation.

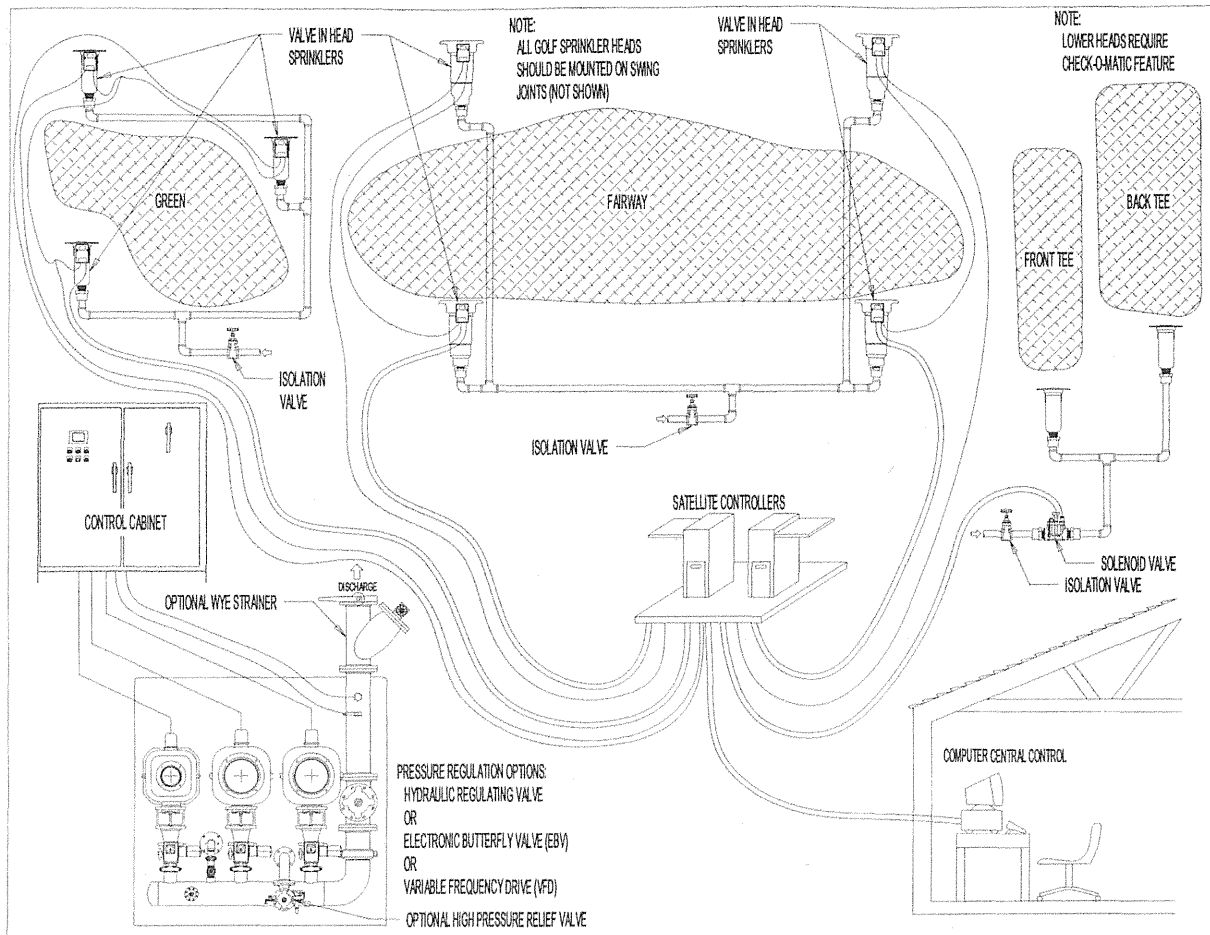


Figure 9.5. Diagram of the key components of a golf course automatic irrigation system. (Courtesy of T.J. Emmerich and Associates.)

When a green requires 15 minutes of water it receives 15 minutes, not 10 or 20. Therefore, a properly designed, engineered, installed, and operated automatic system brings greater control and dependability to irrigation practices. This in turn promotes water conservation, since only the appropriately prescribed amount of water is applied at each irrigation. A third advantage is that an automatic system does not require one or more night irrigator(s).

Even fully automatic irrigation systems require some quick-coupling valves and keys, typically 2 valves at each putting green, preferably off separate laterals, 1 to 2 valves at each tee, and at intervals of 200 to 300 feet (61–91.4 m) along

fairways, to provide a manually activated source of water for emergencies and other uses.

An automatic irrigation system is the most expensive type to purchase and install. Thus, there is a tendency to cut costs, which leads to compromises in the design of the system and later to difficulties in irrigation coverage and flexibility. This tendency must be avoided.

Semiautomatic Irrigation System

A semiautomatic irrigation system consists of valves that respond directly to a manually operated remote control switch or valve. Such a system usually is installed on golf courses where

long-range plans call for conversion to a fully automatic system when additional monies are available. The semiautomatic system has the advantages of low initial cost with potential for future upgrading. It is important for the system to be properly designed and installed so that conversion to an automatic system may be achieved with minimum difficulty and expense. There are two variations of a semiautomatic system:

1. Only the pop-up sprinkler heads and control valves are permanently installed. Irrigation operations are conducted manually.
2. A portion of the golf course, such as the greens, is designed with a fully automatic system—in terms of pop-up heads, valves, and automatic controllers—while the fairways and tees have a semiautomatic system that may be converted to a fully automatic arrangement later.

Manual Quick-Coupler Irrigation System

A quick-coupler system requires the manual insertion and removal of each sprinkler head unit into quick-coupling valves positioned at appropriate intervals throughout the golf course. The quick-coupling valves are connected to water distribution lines that may be under constant water pressure. The valve is opened as the manual coupler key is inserted into the valve and turned. The quick-coupler sprinkler head is activated immediately and operates continuously until the head unit is manually disengaged from the quick-coupler valve. The most common quick-coupler sprinkler head used is an impact type. The quick-coupler system is adaptable to manually set hose sprinklers and to traveling sprinklers via connection to the quick-coupler outlets.

The initial cost of a quick-coupler system is the lowest of the three types of irrigation systems. This is because there is no need for electronic equipment and only as many sprinkler heads are purchased as can be operated at one time. The main disadvantages of a quick-coupler system are the lack of reliable labor and the ever increasing costs of labor to operate the system: from 1 to 2

night irrigators usually are employed on an 18-hole golf course for operation of a quick-coupler system. Other disadvantages are the (a) difficulties in employing people to work at night, (b) time required to train them, (c) typically low reliability, (d) potential for human error, (e) greater amount of water used in comparison with an automatic system, (f) safety/liability, and (g) expense of utility vehicles to move the irrigators around the course.

COMPONENTS OF AN IRRIGATION SYSTEM

The principal components of an irrigation system in sequence are: (a) pump station, (b) water distribution lines with associated gate and drain valves, (c) control valves and control lines, (d) controllers, and (e) sprinkler heads. A fully automatic irrigation system uses all of these components, while other types of systems may use selected portions. Auxiliary components that may be used include an automatic microenvironment monitoring center, moisture-sensing devices, filters, sand separators, and injection system.

Pump Station

The function of a pumping station is to draw water from a source, such as a tank, lake, or stream, and subsequently release the water into the irrigation system at the pressure and rate required by the irrigation system design specifications. In addition, a pump sometimes is installed in a pressurized line to increase the pressure to the level needed for operation of the irrigation system. This is referred to as a booster pump and usually is of a centrifugal or vertical turbine type. Most golf course pumping stations are mounted on a permanent concrete base, and should be constructed with a protective pump house (Figure 9.6). Use of a pump house is dictated by the need for protection from weather, vandalism, and animals, and for safety/liability. The pumping station may range from a single main pump with booster to an elaborate multiple pump arrangement with the appropriate controls and valves. The



Figure 9.6. Typical multiple pump station with jockey pump and pressure tank.

particular type of pump station selected depends on the design needs of the irrigation system, plus the location and type of water source.

Pump Types. Most pumps used in turfgrass irrigation involve an impeller to achieve pressure by centrifugal action. Energy is imparted to the water by means of the impeller rotating within a pump housing which controls velocity. The water enters the impeller and is forced to rotate outward in a circular motion, and is discharged through openings at the outer rim of the impeller. The force of the water discharged from the outlet of the pump housing is translated to pressure relative to the prevailing conditions. The pressure generated by the impeller is a function of the impeller-imparted velocity at the rim, which in turn depends on the diameter and speed of the impeller. The pump discharge rate is determined by the width, diameter, and rotating speed of the impeller. Centrifugal pumps characteristically possess a high efficiency over a wide range of operating conditions. Nevertheless, each pump design has a certain head and discharge at which it operates most efficiently. Most centrifugal pumps used for turfgrass irrigation are either of the volute or turbine type. The major difference

between the two is the type of device that receives the water from the rotating impeller.

Volute Pump. The volute-centrifugal pump design involves a volute or spiral case that surrounds the impeller rim to receive and conduct water away from the rotating impeller. The volute increases in size in the direction of water rotation until the water is released into the discharge pipe (Figure 9.7). The progressive enlargement of the volute functions in converting velocity energy to pressure energy. The volute centrifugal pump is a single-stage operation involving one bowl housing. It performs efficiently over a wider range of

speeds than does a turbine pump. Both the drive motor and pump are mounted aboveground in some form of closed or flexible coupling, often on the same base frame, with a suction line extending into the water source. The volute-centrifugal pump generally is most effective in a flooded suction situation or when the water source is no greater than 20 feet (6 m) below the pump. It also may be used in a booster pump arrangement.

Turbine Pump. The discharge outlet design of a turbine centrifugal pump consists of diverging passages or diffusers formed by veins to direct the water and to change the velocity energy to pressure energy. The pump consists of a multi-stage bowl assembly in which a series of rotating impellers impart increasing centrifugal forces on the water until the desired water pressure is achieved (Figure 9.7). With this design, the turbine pump operates over a more limited range of speeds than does the volute centrifugal pump. The most common turbine pump employed for water sources at a depth of more than 20 feet (6 m) is the vertical type. The deep-well vertical turbine pump consists of (a) a drive motor installed aboveground, (b) a drive shaft positioned within

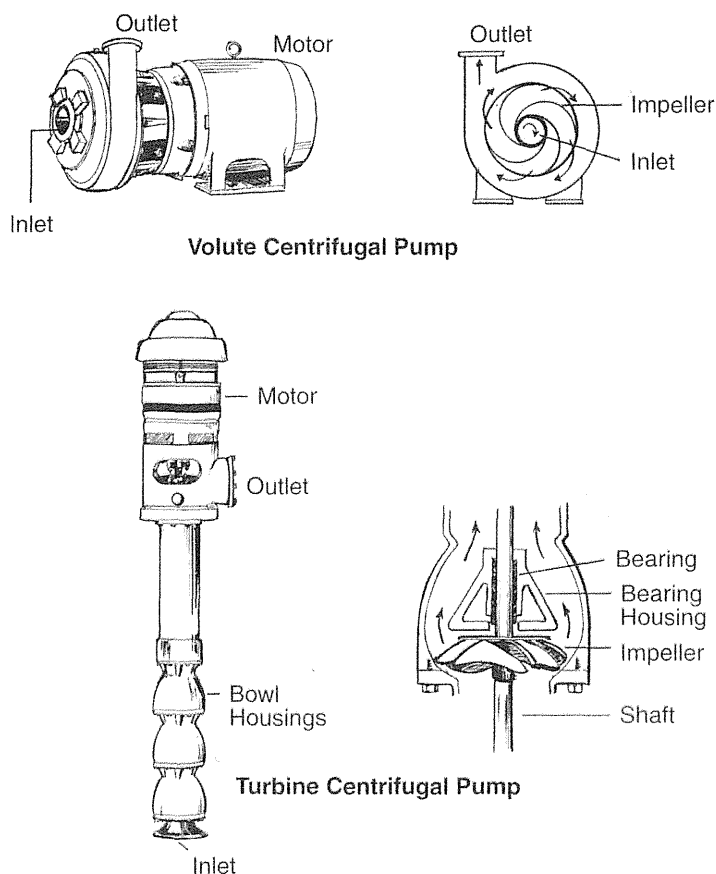


Figure 9.7. Basic design features of a volute centrifugal pump (top) and a turbine centrifugal pump (bottom).

a discharge column or pipe assembly that extends from the base of the motor, and (c) a centrifugal turbine pump suspended from the base of the discharge-column-drive shaft assembly (Figure 9.8). The shaft transmits power from the drive motor to the pump and may be either oil or water lubricated. The pump itself extends into the water in the form of a flooded sump; thus there are no problems with the pump losing prime. Performance characteristics of this type of pump are determined primarily by the design of the bowl assembly and the speed of the impeller shaft. The advantages of a vertical-turbine centrifugal pump are good efficiency and elimination of the suction pipe, foot valve, and priming system, plus a variable-speed feature. This pumping system may have an added cost for construction of a wet well.

Pump Selection. A qualified pump engineer should select the type and size of pump to be used based on the site conditions and the requirements of the irrigation system as furnished by an irrigation design engineer. Site conditions include the topography and the highest and lowest known water levels. In addition, potential sources of power for the drive motor should be assessed.

The pump engineer and the irrigation design engineer will confer once the preliminary design phase for the irrigation system has been completed. The pump engineer should be provided with information concerning (a) the maximum discharge rate or flow anticipated for the design layout, plus any significant variations in discharge rate where the pressure requirement remains relatively constant, (b) the maximum head or pressure required for the system at the pump discharge outlet, and (c) the maximum vertical height of water lift required. A pump and drive motor with sufficient horsepower are then selected with a performance rating suitable for the operating conditions proposed by the irrigation design engineer.

With the preliminary pump specifications in hand, the irrigation design engineer proceeds with final design of the system. The pump engineer and irrigation design engineer then meet again to confirm that the final design specifications of the irrigation system will be met by the proposed pumping station. Pump selection should be based on the maximum anticipated, or worst case, discharge rate and head specifications calculated by the irrigation design engineer. Performance curves of the pumps should be carefully evaluated. In addition, all combinations of operating conditions should be reviewed to ensure the pumping system will provide the desired flexibility under these varying conditions. Economy of pump operation also should be assessed prior to final selection. The pump engineer can calculate the fixed and operating costs for both the

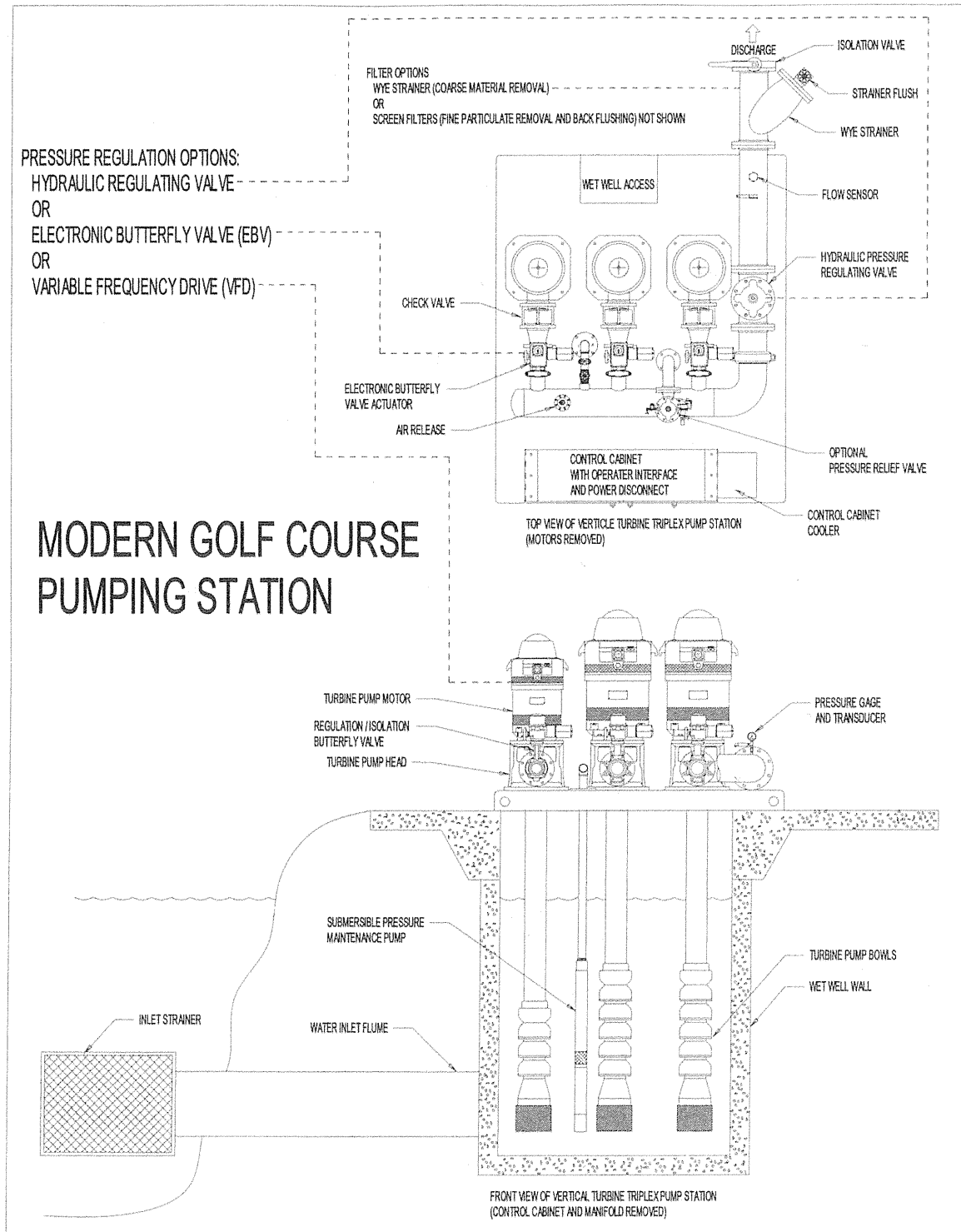


Figure 9.8. Profile of a vertical-turbine centrifugal pump installation. (Courtesy of Watertronics.)

pump(s) and drive motor(s) proposed. Comparisons among several proposed pump systems may reveal significant savings in pumping costs without any deficiencies in meeting the irrigation system design specifications in terms of discharge rate and head.

Pump Components. In addition to the basic pump(s), drive motor(s), variable-speed motor(s), and power source, the pumping station may include such components as a jockey pump, check valve, gate valve, pressure-reducing valve, automatic-vent valve, bypass-control valve, pressure gauge, pressure switch, drain valve, shutoff valve, pump-control valve, pressure tank, filter, and the associated electrical system (Figure 9.8). The actual pump station design varies in complexity depending on which of these components is incorporated into the design. It is important that the pumps and associated drive motor-power units be properly matched over a full range of speeds and pumping conditions.

Where variable-speed motors and controls—commonly referred to as variable-frequency-drive (VFD)—are used, the jockey pump may be within the 30- to 50-hp range on pump stations from 2,200 to 3,500 gpm (8,327–13,248 Lpm).

Proper installation of the pump station requires a qualified electrician experienced with pumps, as well as appropriate plumbing personnel. Because knowledgeable installation personnel are not available in many locations, purchase of a preassembled pump station may be advantageous. With such a station, all components are designed and built at the factory to the specifications of the particular golf course irrigation system. On-site installation is accomplished with minimal professional expertise.

Most large golf course irrigation systems require a multiple-pump station (Figure 9.7). It involves a set of either centrifugal pumps with individual suction pipes or vertical turbine pumps, each drawing from a single pit with the discharge pipes connected into the main irrigation system. Multiple pumps connected in series give a constant discharge rate but a cumulative pressure, while multiple pumps connected in parallel main-

tain a constant pressure with the discharge gallonage being cumulative. A typical 18-hole golf course multiple-pump station has 2 to 3 main pumps plus a jockey pump. In a representative 3-pump station, each pump is selected with a capacity to provide one-half the maximum discharge requirement for the irrigation system. This provides a very important backup capability in case one of the pumps or drive motors fails. Activation of one or more of the drive motor pump units is accomplished automatically by pressure switches designed to maintain the programmed pressure. The jockey pump functions in (a) maintaining pressure in the system at all times to minimize water hammer caused by water being pumped into empty lines, (b) meeting small discharge requirements needed in filling water and spray tanks, deep watering of trees and shrubs, and irrigation of selected small zonal areas of turf, thus avoiding start-up of the main pumps, and (c) supplementing the pressure and flow requirements of one or more main pumps when the demand is not large enough to require activation of an additional main pump.

The pump operation may be automatically controlled by means of the appropriate pump matched with the proper-sized pressure tank and the necessary control devices. The variable-speed and variable-frequency-drive pump stations for maintaining constant pressure have a number of advantages (Figure 9.9). They are very energy efficient, with proven effective performance on golf courses, and may be interfaced with a computerized central controller.

A pressure tank is used in certain system designs to dampen water hammer caused by the closing of automatic valves and activation of pumps. Typically, the pressure tank is filled with 50 to 60% water and the remainder with compressed air. The compressed air functions in absorbing water energy generated by the pump station. Pressure switches and time-delay mechanisms are adjusted with a high and a low pressure requirement to maintain system pressure within the desired operating range. Associated with the pressure tank is a pressure switch and air valve. The pressure switch is used on smaller systems

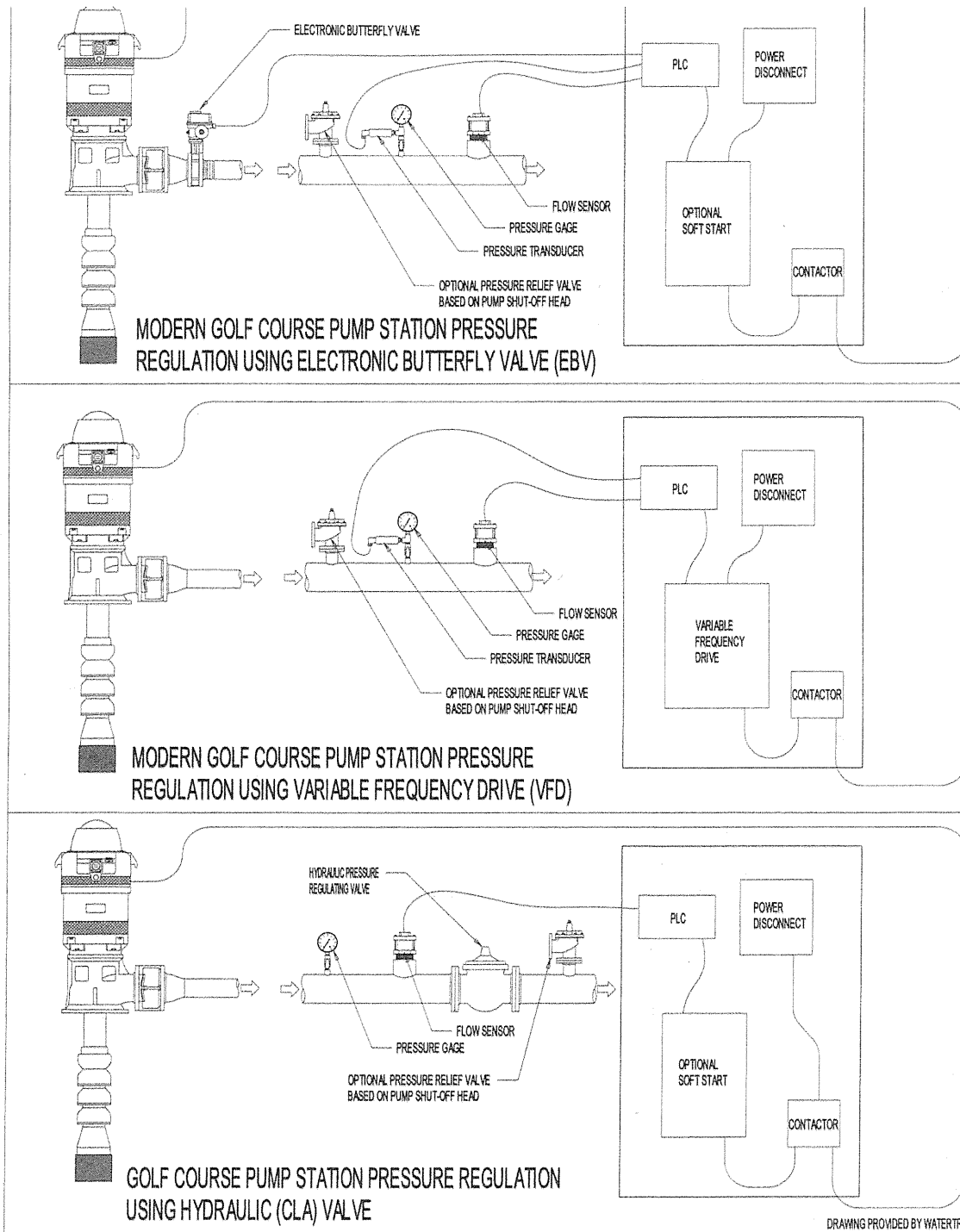


Figure 9.9. Component diagrams of three different types of pressure regulation for vertical turbine pumping stations. (Courtesy of Watertronics.)

not utilizing pressure regulation valves, such as clayton valves. Clayton valves are not used with variable-frequency-drive systems, except as a high-pressure bypass system should the solid state controls fail. The air valve is used when filling the system. It is critical that the pressure tank not be undersized. A smaller pressure tank may be used if a variable-speed pump is incorporated into the pumping station. The use of strainers at the water intake just ahead of the pumping station during normal operation was discussed earlier in the water quality section.

A pump station with electronic flow meters that activate the pumps—combined with a pressure regulation valve (PRV) to monitor the system pressure—often eliminates the need for large pressure tanks. Pump stations are being installed with a data logger and phone dialer system with the electronic capability to monitor and diagnose developing problems, such as high-pressure, low-pressure and electrical difficulties, and to notify individuals it is programmed to call. An acknowledgment call back normally is required.

Gauges. Allied with the pump system and water distribution lines is an assortment of gauges whose function is to ensure that the water pressure and flow characteristics are maintained at specified levels in relation to the original irrigation system design. Pressure gauges are needed to monitor the pressure at various points throughout the system in order to detect leaks. One or more pressure gauges are permanently installed in the pumping system, including the pressure tank and point of water discharge from the pump into the main line. Portable gauges also are available to check the pressure of individual heads or other points along the lateral water-distribution lines. Occasionally, pressure lines are run from sites along the irrigation system to pressure gauges in the operations building. Consideration should be given to installation of a data logger and computer or 7-day electric pressure recorder at the pumping station to monitor pressures in the system during periods, such as night cycles, when the superintendent is not present. Allied with certain pumping stations is a vacuum gauge positioned on the suction inlet

of the pump to indicate the level at which the pump is functioning.

Finally, a water meter or digital counter should be installed on the main outboard side of the pump station to monitor the amount or gallonage of water being used in golf course irrigation. The recording and reporting of water use is required by law in certain states.

Water Distribution Lines

Pipe. Most water distribution lines for turfgrass irrigation systems are permanently installed underground. The piping involves relatively large main lines at the pump discharge point, with the piping gradually sized downward through the more distant lateral lines to the most distant sprinkler heads. Two terms associated with pipe are pressure rating and schedule. **Pressure rating** is the estimated maximum pressure the water in a pipe can exert continuously with a high degree of certainty that the pipe will not fail. It is commonly referred to as "class," such as class 160, 200, and 315. This pressure rating encompasses both the maximum static pressure and pressure surges caused by water hammer action. Thus, the pressure rating and the working pressure of a pipe are related. **Schedule** designates a standard series of wall thicknesses for all diameter sizes in which a specified type of pipe is manufactured. The wall thickness increases with the schedule number from 40 to 80 schedule series. A larger internal pipe diameter is associated with a smaller pressure rating for the same pipe material. In the western U.S., piping of 1.25 inches (32 mm) diameter or larger normally is specified to be a minimum of class 200. Piping of 1.0 inch (25 mm) diameter and smaller is schedule 40. Also, threaded connections for valves and swing joints are schedule 80.

The most common material used in the manufacture of irrigation pipe is plastic. Plastic pipe has the advantages of being relatively low in cost and completely inert. Thus, such debilitating actions as rust and electrolytic corrosion are avoided. Also, its relatively light weight facilitates easy installation, the life expectancy is excellent, and

the flow capacity for a specified pipe size is greater than that of other piping materials due to a very smooth interior finish. Plastic pipe is characterized in terms of the **standard dimension ratio (SDR)**, which is a ratio of pipe diameter to wall thickness. The lower the SDR, the higher an internal pressure the pipe withstands. Pipes manufactured of one material and having the same SDR rating have the same pressure rating regardless of pipe diameter, with only the wall thickness varying. Plastic pipe is marked at intervals of not more than 5 feet (1.5 m) along its length, with the following specifications: nominal pipe size, type of material, standard dimension ratio, pressure rating in pounds per square inch (psi) of water at 74.3°F (23°C), and whether potable water may be transported in the pipe.

Although numerous kinds of plastics have been utilized in the manufacture of pipe, only one is currently of significance in turf irrigation systems—the polyvinyl chloride (PVC). Upon selection of a particular pipe material, it is important for the manufacturer's recommendations to be followed in terms of the specific kinds of fittings—e.g., couplings, reducers, caps, tees, crosses, and inserts—that may be used in association with that pipe.

PVC pipe is semirigid, which allows it to be bowed somewhat during installation. In comparison with the other types of plastic pipe, PVC possesses (a) greater strength, (b) the most durability, (c) more resistance to a wider range of chemicals, (d) greater carrying capacity, and (e) a simpler way of attaching fittings. PVC pipe is typically available in 20-foot (6 m) lengths; pressure class ratings of 160, 200, and 315; and schedules of 40, 80, and 120. Most lateral piping of 4 inches (100 mm) or less in diameter used on golf courses is PVC class 200. There also is a trend toward use of PVC on main lines as large as 30 inches (760 mm). Fittings used on smaller-diameter PVC pipe are of the exterior type and are

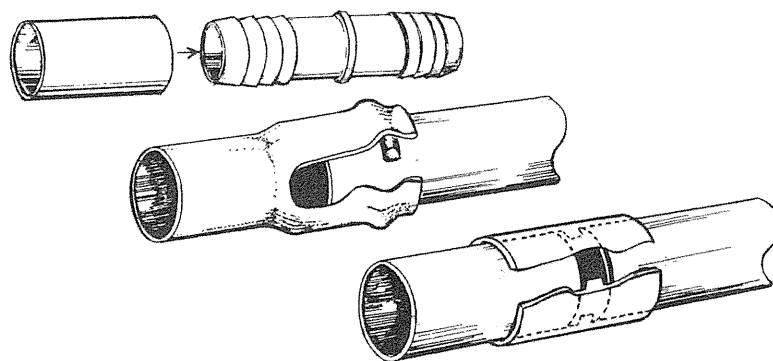


Figure 9.10. Diagrammatic representation of a polyethylene insert fitting (*top*), a socket-and-bell type coupling (*center*), and a PVC solvent weld (*bottom*).

chemically fused to the pipe by what is termed a solvent weld (Figure 9.10). It is critical that the procedures followed in the solvent welding of fittings to PVC pipe are in accordance with the manufacturer's specifications, since this is typically the weakest point in the pipeline.

The high rates of expansion and contraction of PVC pipe present a problem when there is a long run of pipe sized 3 inches (75 mm) and larger. Thus, there is a likelihood that the pipe may be pulled apart at its weakest point, usually a fitting. To avoid this problem, PVC fittings of the socket-and-bell type are available (Figure 9.10). One end of each pipe section is designed with an O gasket to prevent leaks. The normal end of another section is inserted into this fitting to form a movable joint that expands and contracts within itself, yet avoids pulling apart.

Risers. A riser functions in connecting a sprinkler head or quick-coupler valve to an underground lateral pipe. There are various types of riser arrangements, ranging from short lengths of pipe extending directly upward into the base of a sprinkler head to more complex single and double swing-joint assemblies. The latter are more commonly used in golf course installations, since they function in protecting both the underground pipe and the sprinkler head from damage when wheels of vehicles and equipment pass directly over the sprinkler head. The swing-joint assembly is a

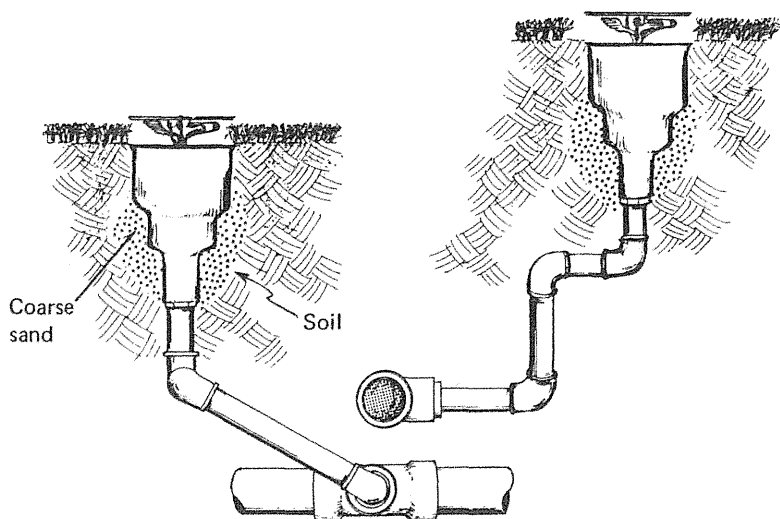


Figure 9.11. Diagram of a typical swing-joint riser assembly.

combination of elbows that flex under pressure and thereby (a) absorb the surface shock from wheels passing over the attached sprinkler head and (b) flex with frost heaving (Figure 9.11). The swing-joint assembly also allows post-installation adjustments in sprinkler head height as turfgrass growth and soil settling alter the surface grade surrounding each sprinkler head. Prefabricated swing-joints are available.

Control Valves

Valves are used to release water into either the distribution lines or into a sprinkler head, to retain water in a certain portion of the water distribution system or pumping station, to maintain a specified pressure, and to drain lines. A valve may be (a) manually controlled, (b) actuated by remote control, or (c) automatic. Various types of valves will be discussed in terms of their functional relationships to water distribution lines, sprinkler heads, and the pumping station.

A manually controlled irrigation system usually involves either globe or angle-type valves turned by hand to release water to the nearby sprinkler heads. In contrast, automatic irrigation systems employ remote-control valves whereby actuation of the sprinkler heads is controlled from

a central or field satellite controller. Although most remote-control valves are designed for underground burial, their placement in a valve box allows easy access for servicing and for manual operation when necessary.

Opening and closing of remote-control valves may be done either hydraulically or by an electrically operated solenoid valve. The control valve itself is operated by hydraulic pressure. Most remote-control valves are of the globe design. Valve operation is based on a pressure differential between the top and bottom of a diaphragm or a piston. Control of water movement through specially designed

ports and chambers within the valve allows water pressure to be applied in such a manner as to open or close the valve assembly, which may be of either a diaphragm or piston type. The diaphragm valve is used more commonly due to minimal wear problems compared with the piston valve. The latter have washers and rings that require periodic servicing and replacement.

The manner in which the automatic valve is actuated is termed either normally open or normally closed. This is the position a valve assumes if the electric or hydraulic control lines are cut or broken. Should an electric or a hydraulic line be severed or broken for any reason in a normally closed system, the valve closes itself automatically. Electric valves are all normally closed, while hydraulic valves may be of either type. The water used to operate remote valves through hydraulic control tubing must be clean. In regions of the country where freezing is a possibility, all water must be blown out of hydraulic control tubing with an air compressor.

Large pop-up sprinkler heads are available with a valve-in-head design. The valve may be an electric or a hydraulic type and is incorporated into the base of the sprinkler head housing. This positioning offers the advantage of independent control for each sprinkler head. Also, the

valve-in-head unit may be used in the economical conversion of existing quick-coupler irrigation systems to an automatic system. However, proper spacing is of utmost importance in implementing the conversion.

Other types of valves used in association with the water distribution lines include gate, drain, pressure-regulation, pressure-relief, air-release, and vacuum-relief valves. The gate valve typically is a manually operated type that functions in shutting off water flow in a line. A gate valve should be positioned at the start of each major lateral line. If a break occurs, the problem line may be isolated, shut down, and drained without affecting the entire irrigation system. A new type of gate valve has become very popular for golf courses. It is the resilient wedge style, which uses a rubber wedge as opposed to a cast gate. This minimizes small leaks when isolating lines. This type of valve currently is available in 3 inches (75 mm) and larger sizes.

Drain valves may be manually operated and opened as needed to drain a line. There also are automatic drain valves that are adjusted to open when subjected to very low pressures. They permit the line to drain whenever the pressure drops to near zero. Automatic-drain valves are used on pipelines that are not constantly pressurized, while manual-drain valves are used on lines that are normally under constant pressure. A third type of drain valve involves a manually operated, flushing type positioned on the outer end of a line for the purpose of flushing out dirt and debris.

The pressure-relief valve usually is a spring-loaded type adjusted to open at pressures above the normal operation level for the purpose of relieving excessive pressure surges. There also is a vacuum-relief valve, which is positioned on main lines that drain downhill for the purpose of preventing a vacuum stress that could collapse the pipe.

Quick-coupling valves are positioned at the upper terminus of risers, usually of a swing-joint type. The line connected to the quick-coupling valve normally is under constant water pressure. A spring assembly holds the valve closed. A coupler is used to activate the valve by means of a

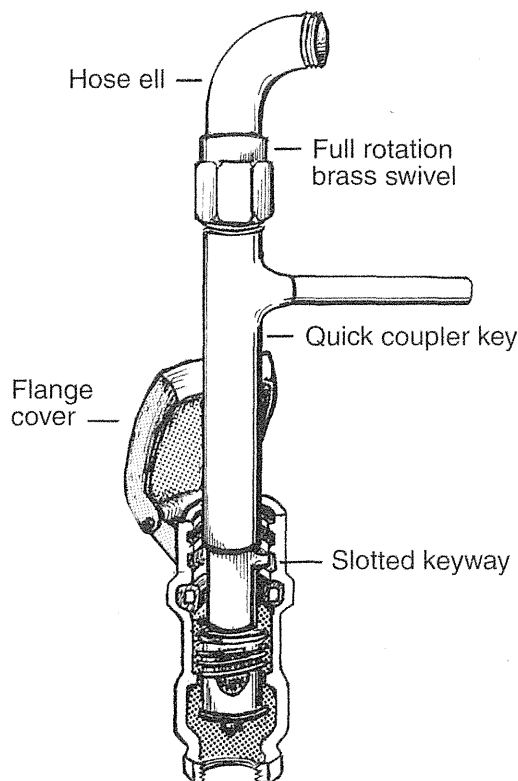


Figure 9.12. Diagram of a quick-coupler assembly with a swivel hose connection.

screw or notched key that forces the spring-loaded valve seat down and thus opens the valve for water to flow through the coupler (Figure 9.12). Mounted on the coupler may be either an above-ground rotary sprinkler or a swivel assembly to which a hose connection may be attached. The quick-coupling valve normally has a hinged cover positioned so that the top is flush with the turf.

Air-release valves are located at the highest points of the property, on the main lines, and—if the system is not looped—at the farthest points from the pump station. Air that rapidly escapes from the sprinkler can damage both the sprinkler head and pipe from the water hammer that takes place. An air-release valve controls the velocity and amount of air released and releases air trapped in the system following shutdowns and repairs when the system is recharged.

Three types of valves are associated with the pumping station. A foot valve is positioned at the

base of the suction intake pipe to maintain water in the pump and suction pipe when the pump is not in operation. As a result, the foot valve serves to keep a pump in a primed condition. There also may be a manually operated discharge valve, which generally is kept closed for priming. A check valve is positioned on the discharge side of the pump, where it maintains water in the pipeline above a pump when the pump is not in operation. These only apply to raised centrifugal pump stations; constantly pressurized systems with vertical turbine pumps will not include these components.

Finally, there are accessories such as pressure-regulator valves. A unit located at the pump station regulates pressure at that point, but has no control over losses or gains of pressure in the downstream water distribution lines. Pressure-regulator valves located in the base of each sprinkler head or at a remote location may be used to maintain a constant operating pressure through the sprinkler head where an excessive water pressure occurs due to pressure gains from downhill runs.

Controllers

A vital component in automatic irrigation systems is the master controller, which actuates the remote valves. Controllers are available with varying numbers of stations. The golf course superintendent programs each station timing to the specific duration of irrigation desired for the turf area controlled by that station. A signal goes out from the controller by means of (a) electric wire, (b) hydraulic tubing, or (c) radio signal to activate a remote valve and in turn initiate operation of one or more sprinkler heads. More specifically, a solid state unit channels 24-volt electric power to the valves, in the case of an electric control system, and a rotary selector valve may either apply or release hydraulic pressure to the remote valves, in the case of a hydraulic control system.

Most automatic irrigation systems designed for golf courses use a variation of this control system, usually involving a central programmer combined with a series of satellite field controllers.

The satellite field controllers may be either solid state or electromechanical units. Solid state controllers offer the advantage of increased timing precision and permit complex programming and communications based on automatic monitoring of key microenvironmental data, such as net solar radiation, temperature, relative humidity, and wind speed. A further refinement in the central programmer is a precipitation-sensing device that countermands the controller program and thus shuts off the irrigation system when a specified amount of precipitation occurs. Most computerized central controllers will allow the adjustment of individual station run times from one central location. The central programmer may initiate cycles for the satellite controllers. Finally, a touch-tone type of portable FM band radio may be linked to the central controller, allowing the operation of sprinkler heads or the central controller from anywhere on the golf course. This approach facilitates testing of the irrigation system and syringing.

On command, the satellite controllers may assume the actual programming and operation of that portion of the irrigation system under their control. Each satellite controller should be positioned at a strategic location overlooking the sprinkler irrigation heads under its direct control. The satellite controller may be operated independently or overridden by the connecting central programmer. The satellite controller also may be operated manually at its field station, giving added flexibility to activate a specific portion of the irrigation system.

The central programmer located in the operations center may be designed with accessories that permit monitoring of key components in the irrigation system. Included may be (a) gauges indicating pressure levels in various portions of the system, (b) operating indicators for the pumps associated with the pumping station, (c) automatic cutoffs when a predetermined high- or low-pressure condition occurs, (d) an automatic signal system to indicate which portion of the system is operating at a given time, (e) gauges indicating instantaneous flow, and (f) an automatic rain cutoff control. The automatic control system has the

advantage of placing the golf course superintendent in direct control of the irrigation practices employed throughout the golf course. The net result, if the system is properly designed and operated, is increased efficiency of water use, more uniform irrigation within each type of turfgrass area, and avoidance of overwatering with its associated soil compaction, disease, and playing problems.

Sprinkler Heads

The sprinkler head is at the end of a long chain of automatic irrigation system components. The sprinkler is a key component of the irrigation system because its function is the distribution of water over the turf area. How uniformly the water is distributed determines the effectiveness and efficiency of the system. Types of sprinkler heads include rotary, pop-up spray, fixed spray, bubbler, and stream spray. The rotary sprinkler head is the type used most commonly on golf course turfs. It produces a slowly rotating, fine stream of water that is distributed relatively uniformly over a large circular to semicircular area of 50 to over 200 feet (15–60+ m) in diameter. The midrange in performance of rotary pop-up sprinkler heads is 70 to 170 feet (21–52 m) in diameter. Many types of drive mechanisms are used in rotary sprinklers, including gear, cam, impact, ball, friction, and reaction drive. In one way or another they all depend on flowing water to create the drive force in a sprinkler head. Sprinkler nozzles are available in various sizes, shapes, and descriptions to meet the needs of different pressure, gallonage, wind, and soil infiltration conditions. The trend is to lower-gallons-per-minute, more water-efficient sprinklers.

Most rotary sprinkler heads used on golf courses are of the pop-up type, with many of a valve-in-head design. The head is completely concealed belowground, except for a cover plate positioned level with the turf (Figure 9.13). On activation of a valve, pressure on the pop-up assembly causes the sprinkler head to be elevated. A spring assembly sometimes is used to ensure that the sprinkler head and cover plate retract into

the sprinkler housing when the control valve is closed. A wide range of rotary sprinkler heads are available to choose from. Factors to be considered in selection of sprinkler heads include the (a) condition of areas to be irrigated, (b) available water volume in the water distribution lines, (c) anticipated operating pressure at the sprinkler head, (d) distribution pattern of the head, and (e) reliability and serviceability. There are sprinkler head designs available with both part-circle and variable-speed features.

The rate and pattern of water distribution from a sprinkler head are the primary concerns in golf turf irrigation. The normal distribution curve is highest near the head and gradually declines toward the extremities (Figure 9.14). Thus, proper spacing and overlap of fixed automatic sprinkler heads are critical in achieving uniform water application. Improper operating pressure may adversely affect the water distribution pattern of a sprinkler. An additional complicating factor is that the water distribution curve becomes unreliable when wind velocities exceed 11.5 miles (18.5 km) per hour. The use of low-pressure heads of an intermediate distribution diameter saves energy and provides more uniform application of water with less loss from wind diversion, when compared to higher-pressure, larger-diameter heads.

In terms of uniform water distribution, the sprinkler heads can be the weak link among the system components. It is advisable to have the candidate sprinkler heads that are under consideration for installation on an 18-hole golf course be independently evaluated. Sprinkler heads can now be quantitatively characterized as to their sprinkler distribution profiles and also tested and analyzed for their projected efficiency at the Center for Irrigation Technology at California State University, Fresno, California, USA.

Chemical Injection. Fertilizers and certain other chemicals may be applied to golf course turfs through the irrigation system. The approach to chemical injection involves use of a proportioner pump with the capability to adjust to variances in the flow rate. The relatively small orifices in valves and nozzles of the typical turfgrass sprin-

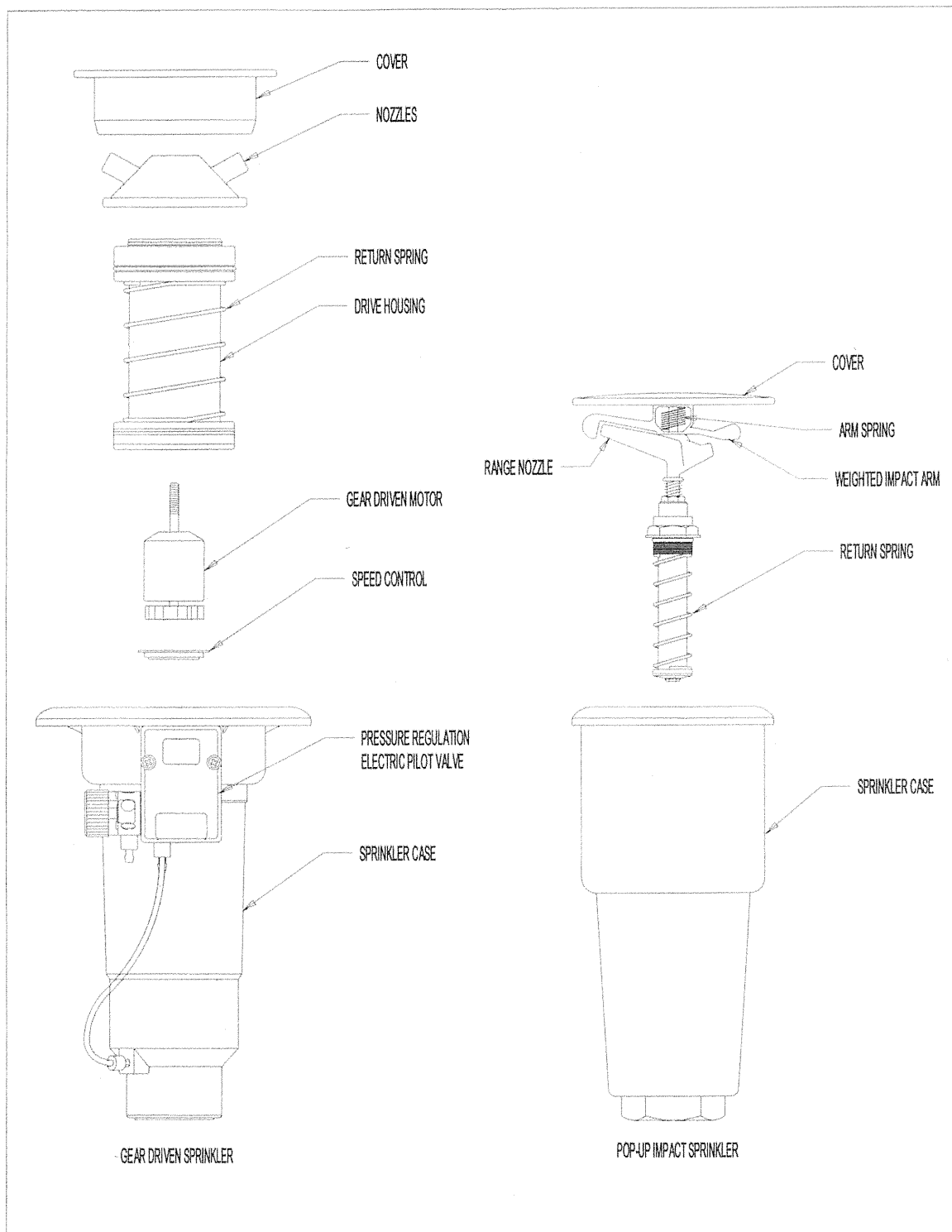


Figure 9.13. Diagram of a gear-driven, rotary pop-up sprinkler head (*left*) and an impact-driven, rotary pop-up sprinkler head (*right*). (Courtesy of T.J. Emmerich and Associates.)

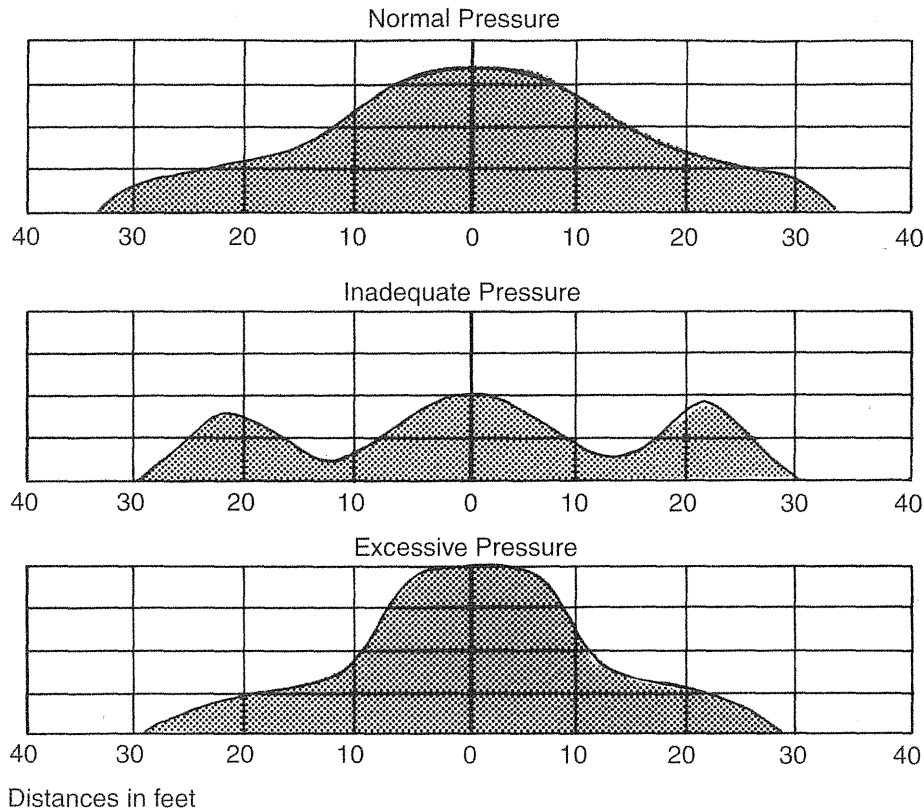


Figure 9.14. Typical water distribution patterns from a rotary sprinkler head operating at the correct pressure (*top*), with inadequate pressure (*center*), and with excessive pressure (*bottom*).

kler irrigation system dictate the injection of chemicals in liquid form. The key to successful use of chemical injection is an irrigation system that is properly designed and installed to ensure uniform application of water and the chemical throughout the targeted turf area. Unfortunately, most irrigation systems fail to meet this important criterion. Chemical action on certain types of existing pipe, valve, riser, and sprinkler head materials also must be assessed when injection is being considered.

DESIGN OF AN IRRIGATION SYSTEM

A properly designed and engineered irrigation system is essential in meeting the ultimate objectives of uniform water application at the rates desired for varying conditions found on individual

golf courses. The complexities of an automatic irrigation system necessitate incorporation of sound design and engineering principles. This is especially true since the system must function under a wide range of climatic, soil, and turfgrass cultural variables.

Selecting an Irrigation Design Engineer

The first step in development of a golf course irrigation system is selection of a qualified, licensed design engineer. Applicants for the project position should be interviewed by a selection committee. In addition, the committee should visit with officials at golf courses where each qualified applicant has designed an irrigation system. The golf course superintendent should be interviewed regarding the design engineer's compe-

tence, cooperativeness, and type of plans and specifications prepared. It also is advisable to inspect some of the original designs, plans, specifications, and final as-built plans developed for earlier projects.

It is preferable that the design engineer be an independent professional who has nothing to sell except engineering and design services. Willingness to work closely with both the golf course superintendent and the irrigation installation contractor is important. It is the design engineer's responsibility to provide detailed plans, bid documents, cost estimates, material lists, component specifications, and installation specifications for development of the golf course irrigation system. After installation of the system, the engineer must prepare an accurate as-built plan of the system based on daily records kept by the contractor. The goal is to integrate all aspects of the irrigation system design into a final functioning facility that is both efficient and reliable.

Individual irrigation companies may employ their own irrigation design engineer. This may partially reduce costs associated with an independent engineer. Because some objectivity may be sacrificed in specifying system components, a competent, reputable, independent design engineer should review the plans and specifications to ensure they meet the course owner's needs.

Contract. A contract should be prepared that specifies the design engineer's responsibilities to the client during the design and construction phases of golf course irrigation system development. Included are statements regarding the (a) fee structure and payment schedule for the engineer, (b) specific types of plans, specifications, bid documents, and installation contracts to be prepared, as well as the degree of detail desired, (c) comprehensiveness of the irrigation system design, such as who is responsible for planning and development of the water source, pumping station, and any associated ponds or reservoirs that must be constructed, (d) who has responsibility for staking the location of sprinkler heads and (e) who is responsible for the as-built plan? Also, the contract may call for the design engi-

neer to inspect the system periodically during the installation phase. Actually, the design engineer's contract should be just as comprehensive as that previously discussed for the golf course architect (see Chapter 2).

Design Decisions

The first step in design development is for the architect, the decision-making committee or individual, and the golf course superintendent to thoroughly study and decide on the irrigation performance expectations and the system capabilities. A statement of objectives and needs is then written. The type of system desired should determine the cost, rather than cost determining the type of system installed. Once the predesign guidelines have been prepared by the decision-maker(s), the design engineer evaluates and proposes a basic system design concept. In assessing and approving the design concept proposed by the engineer, it is important to evaluate it on an optimal operating basis, rather than on the maximal performance basis sometimes presented. Counsel of the golf course superintendent should be sought at this point, especially regarding practical turf maintenance aspects. Once approval is given, it is the engineer's responsibility to develop the irrigation system design, plans, contracts, specifications, and bid documents.

Design Development

Much thought and time must be given to developing a sound system design concept before preparation of detailed engineering specifications. The steps in system design are summarized as a flow diagram in Figure 9.15. The first step in a design procedure is selection of the method to be used to operate the sprinkler heads. This decision influences not only the type of sprinklers selected, but also the types of valves, piping, fittings, and control lines. There are times when even competent design engineers will disagree over which method is best in a given golf course situation, as well as which design techniques and data interpretation methods should be employed.

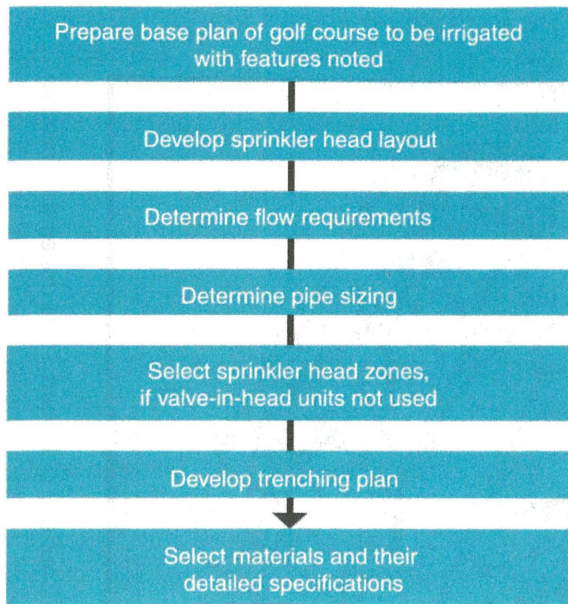


Figure 9.15. Flow diagram of steps involved in the design of a golf course irrigation system.

Criteria in the design of a golf course irrigation system include the (a) maximum daily turfgrass water use rate for the particular situation, (b) amount of water available from the source per unit of time, (c) number of hours available per day for irrigation, (d) anticipated amount and frequency with which irrigation is to be employed, (e) water infiltration characteristics of the soil projected under intense traffic, (f) topography of the area, (g) size of irrigated area, and (h) desired intensity of culture. The design usually is based on the supplemental water required for the peak water requirement, especially in arid climates. The design engineer must have a basic understanding of turfgrass cultural principles and practices to design an effective irrigation system from a practical turfgrass culture standpoint. It is extremely important to ensure that the operating pressure specified for the sprinkler heads selected can be maintained throughout the entire system under maximal operating conditions.

The design engineer must walk every hole on a golf course and make specific notes of features that might affect the irrigation system's effectiveness. Unfortunately, too many golf course irriga-

tion systems have been designed at the drawing board with little or no field investigation. This typically results in increased installation costs that could have been avoided through studious on-site inspections. It is possible to design a system for a new golf course prior to actual construction with the aid of construction drawings. However, this design will need to be closely supervised and altered as necessary to fit the topography during installation. Accurate field staking based on actual constructed course features will determine the system's ultimate success or failure. The designer—not the construction contractor—is the best one to do the staking. Also, designs often are bid with the knowledge that field staking may change the number of heads or controllers. In this case, unit prices become an important part of the bid document, if within specified numerical limits.

It is critical that an accurate irrigation plan be prepared (Figure 9.16). Key permanent and semi-permanent structures, including buildings, major tree groupings, rock outcroppings, fence lines, and roads, should be accurately positioned on the plan. Attention to detailed accuracy at this time will avoid errors in sprinkler head layout and cost estimates.

Once the design, plans, and specifications are completed, it is the responsibility of the design engineer to prepare the appropriate bid documents, issue an invitation to bid, and distribute the appropriate design plans, specifications, and construction contracts to the irrigation installation contractors qualified to bid on the project.

Water Requirement

A frequently used term related to irrigation practices is the **evapotranspiration rate (ET)**, which is a measure of the total amount of water lost by evaporation from the soil plus the water lost from plants through transpiration. The daily ET rate varies substantially from region to region and even from location to location within an individual golf course. Atmospheric environmental factors controlling the ET rate include the net solar radiation level, surface temperature, atmospheric humidity, and wind velocity. ET rates are highest on sunny days characterized by high tem-

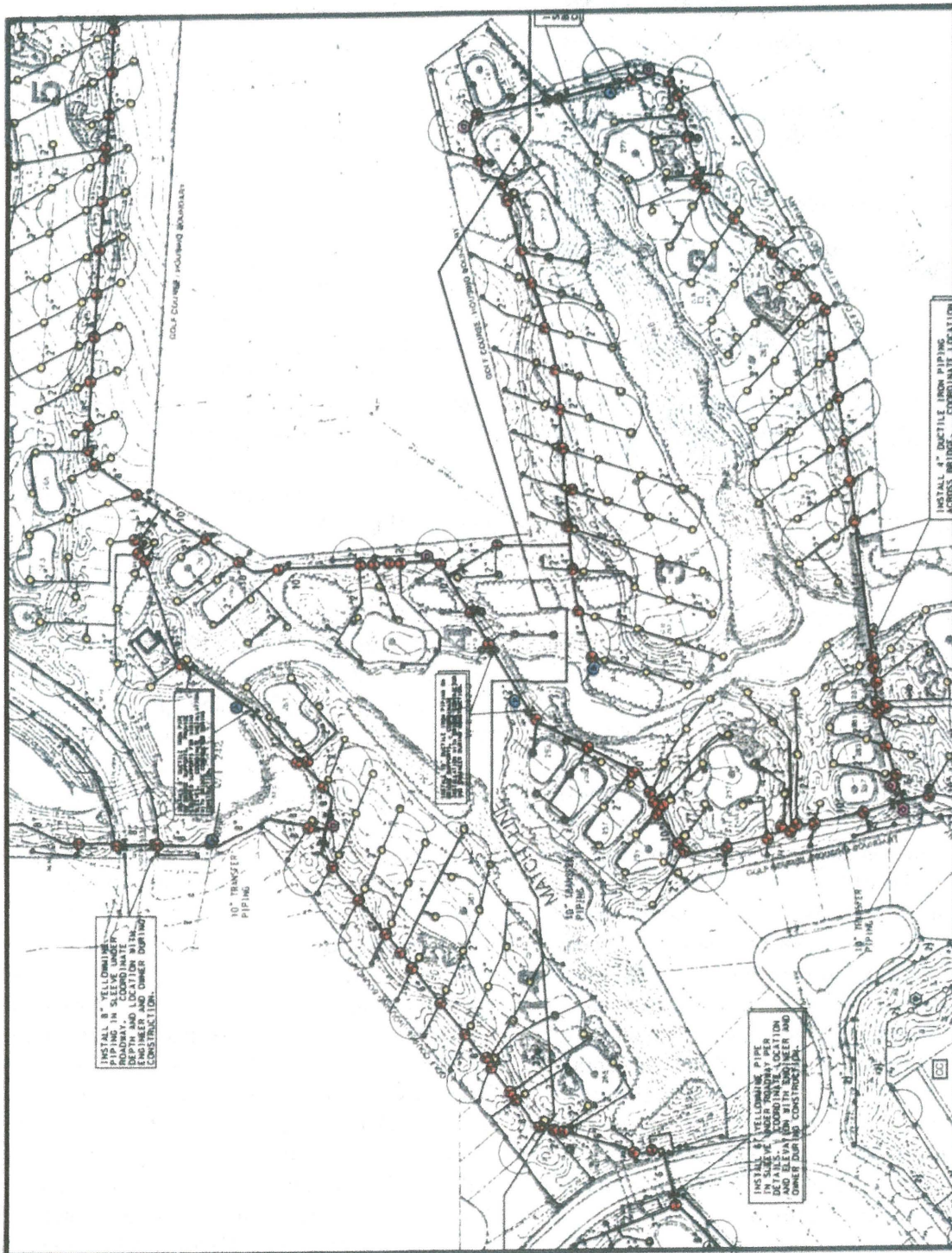


Figure 9.16. Representative design plan for a golf course irrigation system. (Courtesy of Robert Trent Jones II, American Society of Golf Course Architects.)

peratures, low relative humidities, and moderate wind velocities. The highest ET rates typically occur during the summer, with comparatively low ET rates occurring during the spring and autumn as well as during the winter in warm climates. The actual ET rate depends on the amount of available soil water, rooting depth, and particular turfgrass species being grown.

An assessment of how much water is needed for irrigation of a golf course is essential in designing the system and in obtaining an adequate water source. The assessment includes both the maximum daily turfgrass water requirement and the total seasonal turfgrass need. ET rates and resultant water use requirements of turfs relative to the average rainfall vary substantially across North America (Table 9.3). In some locations, irrigation is used only to supplement natural rainfall, while in other areas irrigation is the sole source of water during the turfgrass growing season.

The ET rate data may be related to irrigation requirements as follows. Using an ET rate of 0.1 to 0.2 inch (2.5–5.0 mm) per day and the fact that 1 acre-inch of water equals 27,154 gallons (102,778 L), a daily water requirement of 2,715 to 5,430 gallons per acre (4,161–8,322 L/ha) per day is calculated.

Once estimates of the daily and seasonal turfgrass water requirement patterns have been established, the average contribution expected from natural rainfall is determined. These data may be obtained from the long-term precipitation records. The supplemental irrigation requirement is then determined. Across the United States, the annual supplemental irrigation requirement may range from a maximum of 45 inches (1,140 mm) in arid regions with a 12-month growing season to 6 inches (150 mm) in the northern cool-humid regions having a 6-month growing season. An additional leaching fraction also may be needed if a saline water source is being used for irrigation.

Design Guidelines

Entire books are available on golf course irrigation system design, and there is no intent to cover the detailed steps in this section. However,

some of the more obvious, but frequently overlooked, guidelines in the design of an automatic irrigation system are mentioned.

- A. Main lines should be looped, or interconnected, where possible to assist in balancing pressures throughout the system. Looping is a valuable feature of any golf course design layout, even if additional costs are involved. The cost for an increased amount of pipe usually is offset by the use of smaller pipe.
- B. A three-row system is preferred as the minimum to ensure uniform fairway coverage, especially in drier climates. Most single-row systems are unable to furnish an overall pattern of equal precipitation rates, especially in arid-semiarid regions or areas subject to high-velocity winds.
- C. **Overlap**, which is the radius of coverage for a sprinkler head in relation to the distance between heads expressed as a percentage, is critically important in relation to head spacing. Experience has proven that 100% overlap, in which each sprinkler throws to the base of those adjacent to it, affords the best overall coverage. An overlap of only 70 to 80% stretches the coverage and has not proven adequate under most turfgrass irrigation circumstances.
- D. The most practical spacing, in an equilateral triangular arrangement, for automatic pop-up sprinkler heads on putting greens, tees, fairways, and roughs is no more than 60 to 70 feet (18–21 m), with the shorter spacing desired in arid-semiarid climates. Larger sprinkler heads at greater spacings may reduce the total cost of the system, but frequently apply too much water too rapidly for most soil types. A gentle precipitation rate is far more effective than a heavy downpour and is less affected by wind.
- E. The equilateral triangular spacing of 60 to 70 feet (18–21 m) among sprinkler heads is important for putting green irrigation. It provides relatively uniform coverage because of the triangulation. Very large greens may preclude use of this design, although its use

Table 9.3. Average Monthly Rainfall Minus the Potential Turf Evapotranspiration Surplus or Deficit for 35 Locations in North America.¹

Location	Inches of Water per Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Alabama, Birmingham	4.9	4.8	4.2	1.2	-1.8	-3.2	-2.7	-2.9	-1.9	-0.1	2.6	4.4	9.5
Arizona, Phoenix	0	-0.4	-1.8	-3.8	-6.3	-8.2	-9.1	-7.4	-5.9	-3.5	-1.3	-0.2	-47.9
British Columbia, Vancouver	8.3	5.3	4.0	1.5	-0.2	-1.6	-3.5	-2.4	0.9	4.1	7.5	8.3	32.2
California, Los Angeles	2.3	2.4	0.5	-1.5	-3.8	-4.9	-6.1	-5.6	-4.3	-2.5	-0.6	2.0	-22.1
California, San Francisco	3.3	2.7	0.9	-1.2	-3.1	-4.3	-5.0	-4.5	-3.7	-1.9	0.2	3.0	-13.6
Colorado, Denver	0.5	0.6	1.0	0.7	0.3	-1.8	-2.7	-2.3	-1.3	-0.3	0.6	0.5	-4.2
Florida, Ft. Lauderdale	0.1	-0.3	-1.0	-1.3	-1.1	0.2	-1.2	-0.7	3.1	3.1	-0.5	-0.2	0.2
Florida, Jacksonville	1.2	1.6	1.0	-1.1	-3.0	-1.4	-0.3	-0.7	0.5	0.1	-0.4	1.0	-1.5
Georgia, Atlanta	4.4	4.2	3.8	-1.4	-1.6	-3.0	-2.2	-2.7	-1.7	0	2.0	4.2	8.8
Illinois, Chicago	1.9	1.6	1.9	1.3	-0.2	-1.8	-3.6	-2.7	-1.0	0.6	1.5	1.9	1.4
Iowa, Des Moines	1.2	1.1	1.5	0.6	0.1	-1.0	-3.5	-2.4	-0.7	-0.1	1.3	1.1	-0.8
Kansas, Kansas City	1.0	0.7	1.0	0.3	-0.1	-1.3	-4.1	-2.8	-0.9	-0.3	0.6	0.9	-5.0
Louisiana, New Orleans	3.1	3.0	2.3	0.4	-1.7	-2.2	-0.4	-0.9	0.6	-1.1	1.6	3.5	8.2
Maryland, Baltimore	3.0	2.4	2.8	1.1	-0.2	-2.2	-2.7	-1.6	-0.4	1.0	2.3	2.8	8.3
Massachusetts, Boston	4.0	3.4	3.5	2.2	-0.1	-1.8	-3.3	-1.6	0.1	1.3	3.2	3.4	14.3
Michigan, Detroit	1.9	1.9	1.7	1.2	-0.3	-2.2	-3.8	-2.8	-1.1	0.7	1.6	1.9	0.7
Michigan, Traverse City	1.9	1.5	1.7	1.1	-0.0	-1.6	-2.9	-2.0	0.5	1.3	2.4	1.9	5.8
Minnesota, Minneapolis	0.9	0.9	1.8	0.6	0.1	-0.9	-3.2	-1.7	-0.3	0.1	1.3	0.9	0.5
Missouri, St. Louis	1.8	1.5	1.8	1.0	-0.5	-1.9	-4.0	-3.3	-1.3	0.5	1.5	1.6	-1.3
Nevada, Las Vegas	0	-0.3	-1.5	-3.2	-5.4	-7.4	-8.8	-7.6	-5.4	-2.9	-1.0	-0.2	-43.5
New Mexico, Albuquerque	0	-0.2	-1.0	-2.3	-4.0	-5.7	-5.7	-4.8	-3.2	-1.7	-0.6	0	-29.2
New York, New York	3.4	2.8	3.5	1.7	-0.2	-2.3	-3.1	-1.3	-0.2	1.1	3.0	3.3	11.7
North Carolina, Raleigh	3.1	2.9	2.5	0.4	-1.5	-3.1	-2.0	-1.7	-0.9	0.2	1.7	2.9	4.5
Ohio, Columbus	2.9	2.1	2.4	1.4	-0.4	-1.8	-3.0	-2.9	-1.3	0	1.7	2.2	3.3
Oklahoma, Tulsa	1.4	1.4	1.1	0.9	0.5	-2.1	-5.0	-4.6	-1.1	0.5	1.0	1.2	-4.8
Ontario, Toronto	2.7	2.4	2.6	1.3	0	-1.7	-2.5	-2.0	-0.3	0.8	2.3	2.6	8.2
Oregon, Portland	7.3	5.5	4.6	1.1	-0.6	-2.0	-4.7	-3.9	-1.5	2.9	6.4	8.1	23.2
Pennsylvania, Philadelphia	3.0	2.4	2.9	1.2	-0.4	-2.1	-2.7	-1.5	-0.6	0.9	2.6	2.8	8.5
Quebec, Montreal	3.8	3.0	3.5	1.5	0	-1.3	-1.7	-1.3	0.6	2.0	3.5	3.6	17.2
Tennessee, Nashville	5.5	4.4	3.8	1.1	-1.2	-3.1	-3.4	-3.5	-1.7	-0.2	2.8	4.0	8.5
Texas, Dallas	1.4	1.3	-0.1	-0.2	-1.2	-4.6	-6.6	-6.4	-3.1	-0.8	0.6	1.4	-18.3
Texas, El Paso	-0.1	-0.7	-1.8	-3.2	-4.6	-6.1	-5.8	-5.5	-3.6	-2.2	-1.2	-0.4	-35.2
Texas, Houston	2.2	2.1	-0.2	-1.1	-2.4	-4.3	-4.0	-3.3	-1.7	-0.6	1.2	2.5	-9.6
Utah, Salt Lake City	1.6	1.2	0.8	-0.2	-2.0	-4.0	-6.3	-5.2	-3.0	-0.5	0.8	1.3	-15.5
Washington, Seattle	5.2	3.9	2.8	0.4	-1.4	-2.4	-4.1	-3.4	-1.1	2.3	4.8	5.8	12.8

Source: Rainfall-Evapotranspiration Data, The Toro Company, Minneapolis, MN, USA. 1966, 63 pp.

¹ Potential turf evapotranspiration rate calculated from modified Blaney-Criddle formula.

- may be possible if the putting green perimeter is reshaped. Simply spacing the heads every 60 feet around the perimeter of a green will not provide uniform coverage.
- F. An equilateral triangular arrangement of sprinkler heads is preferred over square or rectangular patterns (Figure 9.17). The latter two patterns cause a more unequal precipitation rate. The ultimate goal in any golf turf irrigation system is uniform coverage.
- G. It is inappropriate to have any combination of putting green, green surrounds, tee, or fairway sprinkler heads controlled by the same zonal remote control valve or controller station. These distinct turf areas have different water requirements. Therefore, the sprinkler heads must be separated and under separate valves with individual controller stations.
- H. Unless correctly fitted with appropriate nozzles, full-circle and part-circle sprinklers are incompatible from a precipitation rate and operating time standpoint. It is poor design to place them on the same zonal control valve or controller station. There may be instances where a precipitation rate balance may be achieved through different nozzle sizes or head combinations, but complications do not warrant the effort.
- I. On putting greens, a single control station should have no more than one pop-up head under its command. This design allows maximum flexibility in meeting variations in water needs as affected by elevation dissimilarities, upwind/downwind characteristics, and shaded versus sunny areas.
- A similar design requirement is suggested for tees and green surrounds, with no more than one sprinkler head under the control of any one station. On fairways most modern computerized systems are using single head control, especially where difficult soil problems are encountered. For roughs a maximum of three heads per station is used. This degree of control adds to the initial installation cost, but enhances the versatility and effectiveness of the system, lowers the operating cost, and produces high-quality turfs.
- J. Increasingly, a dedicated zonal system is installed to back-irrigate the surrounds of putting greens and occasionally tees, especially in arid and semiarid climates. Part-circle sprinklers positioned facing away from and at the perimeter of the green/collar are used (a) to give supplemental water to banks and bunker faces, when needed (b) to aid in the germination of winter overseedings around greens, and (c) to make differential management of cool- and warm-season turfgrass species easier in the summer months. This is done by using either 1 full circle and a part circle system or 2 part-circle systems. Using part-circles to leach salts downward on greens helps prevent soil banks around greens from becoming water saturated and muddy.
- K. If valve-in-head sprinklers are not used, each group of heads, termed a **zone**, must be controlled independently by a separate controller station. Thus, the water supply delivered to a particular zone limits the maximum number of sprinkler heads that may be operated within the zone. When determining a zone, consideration must be given to differences in (a) turfgrass species and cultivar, (b) soil conditions, (c) drainage, (d) intensity of culture, (e) slope, (f) shade versus sun exposure, (g) wind, and (h) the presence of trees. The zone arrangement of sprinkler heads may be across the fairway (Figure 9.18) or parallel with the fairway when a sunlight-tree shade differential is the main problem.
- L. Each pop-up sprinkler head should have a check or backflow valve. This prevents the irrigation line from back-draining to the lowest head after each irrigation cycle. Some automatic heads include a built-in valve for this purpose. Without some type of backflow stoppage, wet areas develop at the base of the lowest sprinkler head on each line, water is wasted, and air enters the system, increasing water hammer and surge damage.

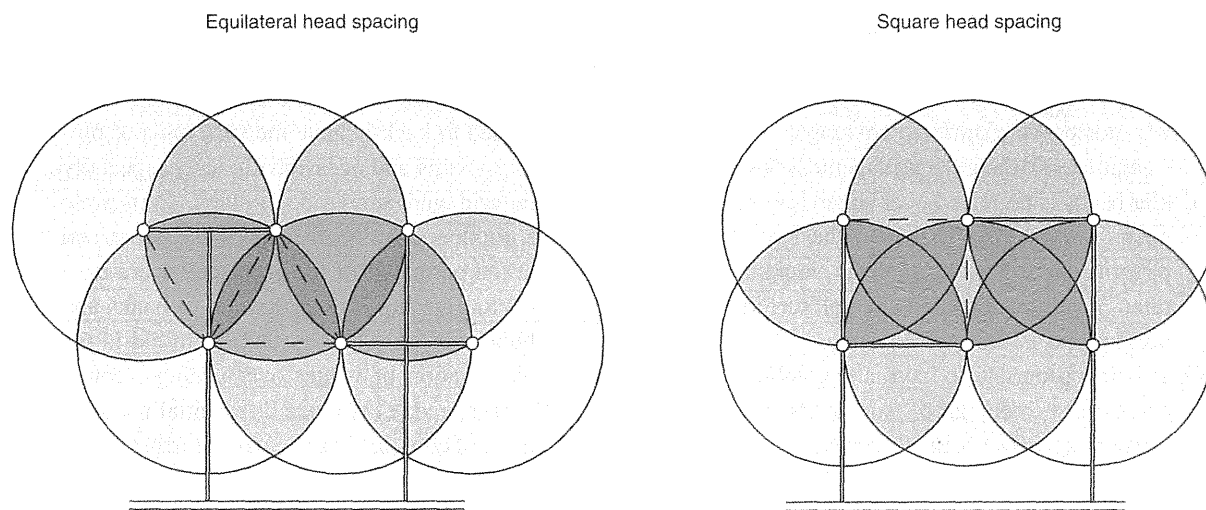


Figure 9.17. Graphic illustration of the comparative water coverage achieved with an equilateral triangular versus a square sprinkler head arrangement.

- M. For automatic irrigation systems, quick-coupling valves should be installed on live lines at every putting green and tee, plus at 200- to 300-foot (60–91.4-m) intervals along the fairway, as a minimum. A quick-coupling valve at both the front and back of each putting green is desirable. They are relatively inexpensive and will prove useful for practices such as manual watering, syringing, filling spray tanks, watering young trees, backup support, and emergency use.
- N. Sprinkler head offset to compensate for wind effects, or **windage**, seems to have been overstressed in early irrigation design. Unless the wind is constant and continually from the same direction, offset of sprinkler heads may be as much a problem as the wind variable itself. Closer spacing between heads is the better solution where wind is an important consideration.
- O. The location of satellite controllers should provide an unobstructed view of the sprinkler heads directly involved (Figure 9.19). This affords an easy visual check of system operations.
- P. Gate valves should be installed throughout the main lines of a system in a manner that permits easy main line and lateral line isolation. Gate valves are low-friction-loss valves used to control water flow. They should never be used as a throttle valve to restrict water flow in the line, since excess wear of the brass will void their use as shutoff valves when needed. Placement of gate valves in strategic locations permits isolated shutdown for repairs without inactivation and draining of the entire irrigation system, such as the middle of a loop system.
- Q. Every golf course has isolated areas where automatic irrigation coverage is difficult. A turfed tee isolated in a wooded area or turf surrounding steeply contoured bunkers illustrate the point. Under these conditions, optimal irrigation coverage may be achieved by use of small, closely spaced, pop-up heads. It also avoids overly wet and overly dry areas.
- R. Most automatic controllers have the capability of repeating the irrigation program. Instead of one 20-minute set, it is possible to program two 10-minute sets. This is a key and often necessary option on soil with a low infiltration rate.
- S. In regions where subfreezing winter temperatures necessitate system drainage, the design engineer should provide rapid, com-

Increased Irrigation Efficiency

Split total run time into two or three cycles to maximize water infiltration into soil.

Three Row System

With proper single head control the operator can lower the running time of the center row of heads to maximize uniformity and eliminate the wet area which often develops between the two rows of a double row system.

Clay

Use individual sprinkler control to match the sprinkler to the area being irrigated.

Peat

Requires sprinkler control to match topography.

Sand

In sandy areas with a high infiltration rate, sprinklers may be grouped to run together. Cycle the running time to increase irrigation efficiency.

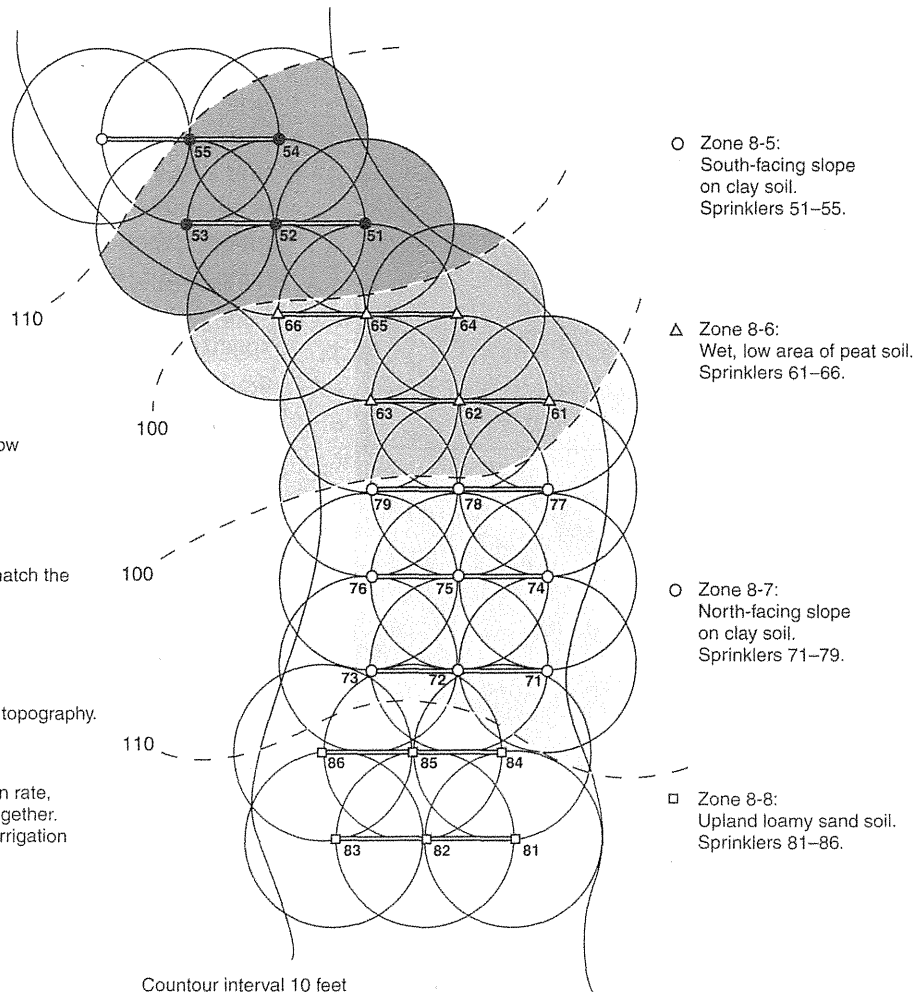


Figure 9.18. A representation of the types of single head and zonal sprinkler-head arrangements that are available for use on fairways, as influenced by topography and soil texture.

plete drainage capabilities. Use of a portable air compressor of adequate capacity to blow water out of the system in mid to late autumn is important.

INSTALLATION OF AN IRRIGATION SYSTEM

A well-designed irrigation system composed of good-quality components will not function correctly unless properly installed. Irrigation systems are installed under two distinctly different situations. One involves new construction sites,

while the second involves an established turf on an operating golf course. Some unique problems may be encountered in each case.

Selecting a Contractor

There are irrigation installation companies that specialize in golf course projects. A contract is let to accomplish the work once the design engineer has completed the plans, detailed working drawings, specifications, and bid documents. In the case of new golf course construction, the irrigation installation company may bid as a subcon-



Figure 9.19. Satellite controller positioned so that it is possible to visually assess whether all sprinkler heads under its control are operating properly.

tractor under the overall general contractor previously selected by competitive bidding. The irrigation installation company would be the prime contractor for installation of a new irrigation system on an established golf course.

The design engineer usually is responsible for preparation of the bid documents. This is followed by preparation of the invitations to bid and specific instructions to bidders. In some cases, the bid procedure may call for prequalification. The preselection of qualified bidders involves an assessment of their overall capabilities and the quality of work performed on previous projects. The basic steps in a bidding procedure and selection of a contractor are the same as those for a golf course construction contractor, which are discussed in detail in Chapter 2.

In some instances, golf course management may choose to install an irrigation system on an

in-house basis. This usually is done when there are budget restrictions and when the golf course superintendent has sufficient knowledge and experience to successfully install a quality irrigation system. If this approach is used, it generally is advisable to employ an independent design engineer experienced in golf course irrigation systems. The design engineer's responsibilities would be to (a) develop a set of accurate design plans, specifications, and materials list; (b) advise on associated technical needs; and (c) make periodic visits during the actual installation to ensure the project is being properly executed. In this way, an irrigation system may be installed on an existing golf course over an extended period as funds become available and with minimal disruption of play. The golf course superintendent will need to establish a separate capital improvement budget and employ supplemental labor to accomplish such a project with efficiency and in a reasonable length of time without adversely affecting normal golf course maintenance activities.

Contract. Preparation of the contract for installation of an irrigation system usually is the responsibility of the design engineer. The contract includes descriptive articles on the (a) contract documents, (b) installation work involved, (c) time of commencement and completion of the work, (d) inspection and acceptance criteria, (e) payment schedule, including retained percentage, (f) progress payments, (g) acceptance, and (h) final payment and sign-off. It is important for the contract to specify the time of commencement and completion of the work for installation, especially for an irrigation system to be installed on an established, operating golf course. The contract may include specifications as to how much sod removal and open trenching will be allowed at any one time. The specifications may call for the disruption of no more than one golf hole at a time on an established course. The contract also may contain a rock clause that specifies a unit cost for underground rock blasting and removal during trenching. This clause is needed because it is not possible to accurately predict the extent of rock formations. Information concerning con-

tract documents and specifications are discussed in detail in Chapter 2. The principles involved in a contract for irrigation system installation do not differ greatly.

Installation Procedure

Quality installation of a golf course irrigation system is dependent on accurate design plans and specifications. The plans should be scaled accurately; show significant topographic variations; delineate physical features such as roads, buildings, trees, and rock outcroppings; and accurately depict property line boundaries beyond which watering should not be planned. A detailed soil map will assist the installation contractor in anticipating problems that might be encountered during trenching. Examples are problems related to rock outcroppings, high-density soils, peat bogs, poorly drained depressions, swampy areas, or stony soil types.

The installation contractor may then proceed to procure the resources needed based on the specifications. This is critical, since shortages of certain irrigation components are not uncommon, with from 4 to 8 months needed to obtain materials in some locations, especially internationally. The contractor also should assess specific equipment and labor requirements and develop plans for their procurement so the project will be completed within the specified time period. On completion of these preparatory planning stages, the actual irrigation system installation may be initiated. Major phases in an irrigation system installation project are presented in Figure 9.20.

Installation Inspector. The installation of an irrigation system on an 18-hole golf course is very complex, with many possibilities for error. Employment of a full-time, independent irrigation installation inspector throughout the project life is advisable, especially for a major project. The individual selected should be fully knowledgeable and experienced in the principles of hydraulics and design engineering, able to read detailed technical plans and specifications, and experienced in civil engineering. The inspector should study the

plans and specifications thoroughly before the installation project is initiated. The irrigation inspector is responsible for certifying that all installation activities are performed in accordance with the design plans and specifications. The inspector may be employed by the golf course management or by the design engineer representing the client. The installation inspector should be careful to avoid an inflexible attitude with respect to trivial construction details, and yet be firm in ensuring that all design plans and specifications critical to effective performance and functional longevity of the system being installed are executed.

Installation Planning. System installation must be in accordance with the designer's plans and specifications. Preinstallation planning is particularly important in ensuring that an irrigation system is installed on a new golf course in time for optimal planting, or is completed on an existing golf course in the shortest possible time to minimize disruption of play. Development of a construction flow plan is helpful in completing the installation as efficiently as possible with minimal delays. Such a flow plan is particularly important in procurement of materials, especially where certain items may require excessive lead time. The contract usually specifies that it is the responsibility of the installer to be certain that (a) all codes are followed and (b) the necessary permits, application for water connection, and related preliminary arrangements are in full compliance and secured before initiation of the installation project. Finally, the installer should locate any existing underground utility lines or similar hazards that might complicate installation of the irrigation system.

If the installation involves conversion of an existing irrigation system from manual to automatic, the best approach is to initiate the conversion at the central controller and/or the power supply. This enables the installer to make an operations check and pressure test of each section as that portion of the changeover is completed. Otherwise, testing and use of completed sections cannot be done because the power supply is to be installed at a later stage in the installation. In other

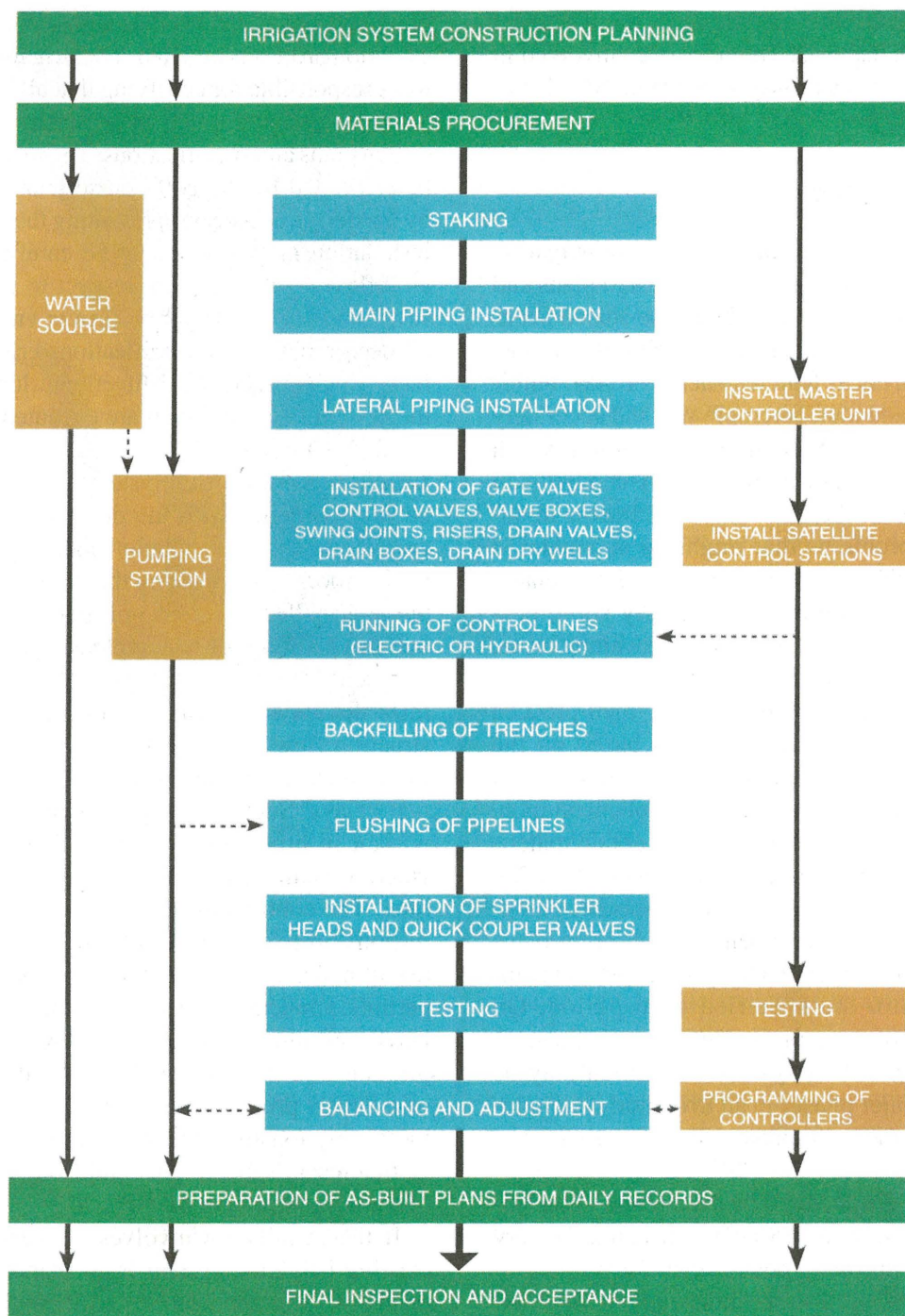


Figure 9.20. Flow diagram for the installation of a golf course irrigation system.

words, once the manual system is converted, no water is available in the system without the proper power supply.

Pump Station. Pumps must be mounted on a sturdy base, which in most cases is concrete with a rubber pad positioned between the concrete base and the pump mountings to function in absorbing vibrations during normal operation. The design specifications and installation of a pump station should be the responsibility of an expert in that field. In many locations there are no qualified specialists available to successfully design and install a golf course pumping station. Thus, the prefabricated pumping station is an attractive option, since on-site setup is accomplished with modest professional expertise. Installation involves setting the pump station in place on a concrete base, connecting it to the irrigation system water source and power supply, and pressure-testing, adjusting, and activating it (Figure 9.21). A disadvantage of the preassembled pumping station is a lack of service on an emergency basis in some locations.

In addition to the concrete pump mounting, many pumping stations are protected by an enclosed building that is a permanently constructed structure with a concrete floor plus concrete block walls (Figure 9.22). The pump house serves to protect the pumping station from damage and weathering associated with adverse weather, animals, and vandalism. The pump house should be well louvered to provide adequate ventilation for heat generated from the motor. An exhaust fan controlled by a thermostat may be necessary. Roof access, such as a hatch or door of some kind, is needed to pull the pumps through via a crane when service or repairs are required for vertical turbines. This hatch must be located directly over the pumps and electric motors.

There may be great variation in the water intake arrangement associated with a pump station.

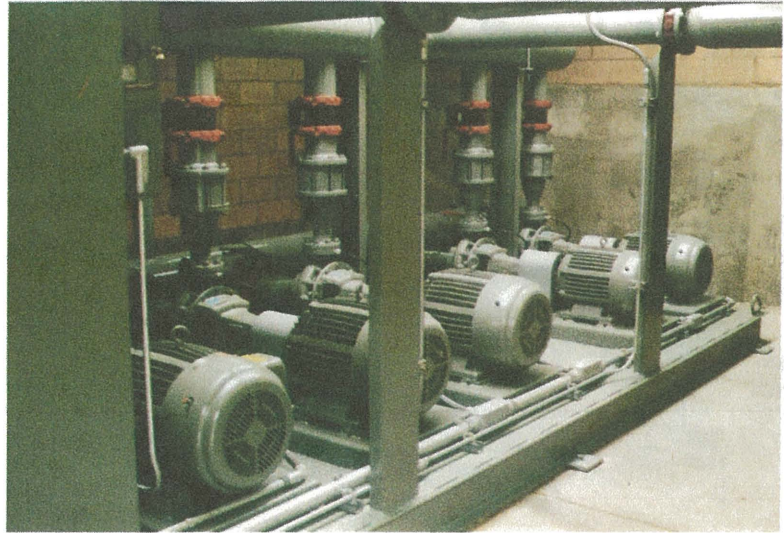


Figure 9.21. A preassembled, dual-level pump station. (Courtesy of P.M. Hathaway.)

It may be a simple suction pipe extending into the water source with the appropriate protective strainer/filter, a pump pit in the case of a vertical-turbine pump, or a direct connection to a municipal water source with backflow preventer and simple booster pump (Figure 9.23). The size and shape of a pump pit varies depending on the type of water supply, quantity of water to be pumped, and need for dissipating turbulence within the pit. The suction intake should be positioned in the midzone. If the intake is too near the bottom or surface of the water source, turbulence is created that may draw soil, debris, and air into the pumping system.

Staking. The first step in actual installation is the layout or staking of the system, including locations of main lines, sprinkler heads, valves, and other key features. Staking must be done in an exacting manner so the sprinkler head spacings are uniform and the original design specifications followed. Accurate staking is accomplished with measuring tapes and surveyors' instruments.

Staking the location of each sprinkler head enables the installer to make sure the design matches the area where the system is to be installed. Any errors in the original plan will be-



Figure 9.22. Two types of permanently constructed pump houses. (top—Courtesy of P.M. Hathaway.)

come apparent at this time and may be corrected before trenching is initiated. Correction involves moving stakes or adding extra sprinkler heads. Significant changes should be discussed and approved by the designer and client. The stakes also act as a guide for the actual trenching operation. The designer of the system should supervise the actual staking.

Trenching. Trench routing is determined by the design layout, including the zoning arrangement,

if used. The preferred trenching plan should involve the maximum number of long cuts and least number of cross-overs. Trench width is dictated by the pipe size and the space needed for workers to accomplish the installation. The trench depth varies depending on the (a) height specified for the sprinkler riser assembly, (b) soil depth needed to provide protection against freezing, and (c) slope needed to provide proper drainage for winterizing or draining lines. The width and depth of the trench should be no greater than absolutely necessary to minimize the amount of soil dug, facilitate soil compaction during backfilling, and minimize disturbances to any existing turf.

A wide range of trenching machines is available (Figure 9.24). Properly dug trenches are on grade and on line, as shown in the plan and subsequent staking. The trench bottom should be smooth, free of rocks, and in a continuous line at the specified grade. A smooth trench bottom is needed to fully support the pipe. Wedging or blocking of pipe is not advisable. Where the bottom of a trench is variable due to the presence of rocks or a hard impermeable soil, approximately 2 to 3 inches (50–75 mm)

of sand or stone-free soil should be added to the bottom of the trench before the pipe is installed.

When pipe is to be installed under an established turf, the trenching operation should be done with as little disruption as possible. The usual procedure is to cut, roll, lift, and place the sod near the planned trench for replacement after backfilling is completed. In some cases, a plastic sheet or plywood is laid parallel to the trench in such a way that excavated soil falls on the sheet. This facilitates the backfilling procedure and subsequent

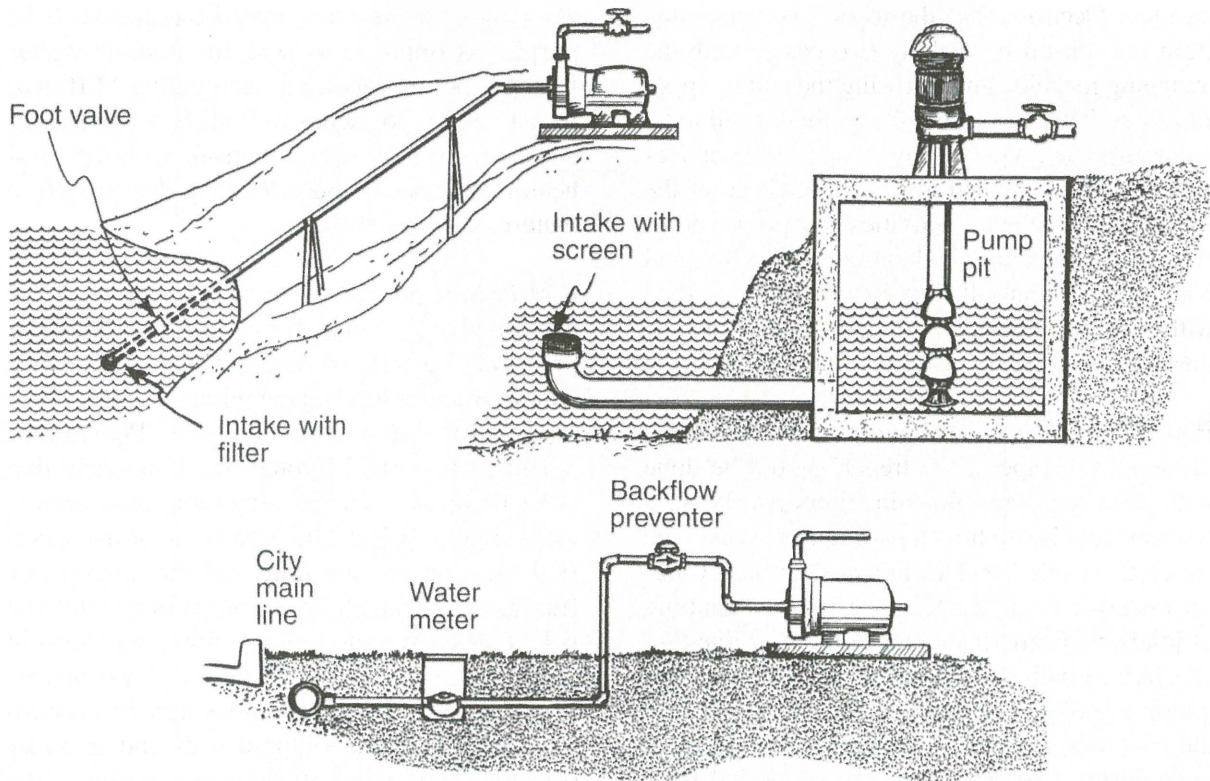


Figure 9.23. Three types of water intake arrangement: a simple suction pipe extending into the water source with the appropriate protection (*top left*), a pump pit for a vertical-turbine pump (*center right*), and a direct connection to a municipal water source with a backflow preventer and booster pump (*bottom*).



Figure 9.24. A trenching machine in operation.

cleanup. Occasionally, the topsoil is segregated from the subsoil by making two passes with the trenching machine and throwing the soil to opposite sides. This procedure allows the topsoil to be replaced on top. A good installation contractor does not cut sod and trench too far in advance of the follow-up installation activities. By proper coordination of trenching and subsequent laying and backfilling, the installation may be accomplished with minimum disruption in daily play. This may involve one golf hole per 1 to 3 days.

Pipe Laying. Storage, handling, and eventual placement of pipe in the trench should be done with great care. Most manufacturers provide suggestions relative to how a particular pipe is to be handled, installed, and the joints assembled. Careful lowering of pipe into place, proper handling of joints, and care in keeping soil out of lines are all characteristics of a quality, experienced irrigation installer. Failure to avoid getting dirt into the irrigation lines may translate into months or even years of problems in debris removal from nozzles and remote control valves, plus the likelihood of a poor irrigation distribution pattern in the interim.

Installation normally is started at the water source. The sequence involves installation of a main line, then the valves, lateral lines, and sprinkler-riser assembly. Heavy-duty plastic pipe should be laid on a sand base free of rocks or similar hard objects. It is important that thrust blocks be placed at all L's and T's, as specified by the manufacturer and design engineer (Figure 9.25). Precautions must be taken to allow for anticipated temperature expansion and contraction in the piping. Depending on the particular type of pipe, this may involve simple snaking of pipe from side to side in the trench or installation of expansion joints. The bell-and-ring connection used in certain PVC piping compensates for expansion.

Certain procedures must be followed when laying dual pipelines. For example, effluent pipes should be located in a separate trench and up to 10 feet (3.0 m) from other piping, depending on the requirements of the governing agency. Color coding of pipes also needs to be addressed. Pipe

carrying effluent water may be required to be purple, as opposed to pipe for potable water. Burial tape or stenciling designating "Effluent Water" every 36 inches (0.9 m) is acceptable in some regions. Be sure to consult with the local health department and effluent purveyor before materials are purchased.

Pipe Pulling. Pipe installation on established turf may involve a method termed **pipe pulling**. The procedure consists of digging holes at the sites where sprinkler heads, lateral line T connections, and control valves are to be placed. Pipe is then pulled underground through the previously dug holes by means of a vibrating mole-plow attachment (Figure 9.26). The pipe is cut at the specified location in each hole and the appropriate fittings are installed. This pipe pulling technique is less expensive and presents fewer problems in disruption of the turf and associated play than does trenching. However, difficulties may be encountered in dense, fine-textured soils and in rocky soils where excessive abrasion or grooving of the pipe may occur. It also is difficult to pull pipe on a specified grade so that it may be gravity drained to avoid freezing damage.

Installing Risers and Valves. It is advisable for the sprinkler riser or swing-joint riser assembly to be installed at the same time the pipe is installed to minimize the chance of soil entering the piping. Sprinkler heads should not be attached to the risers until after all piping has been flushed clean of dirt and debris that may have entered the system during installation.

Gate valves, control valves, and drain valves are installed in coordination with pipe laying. Each should be installed as outlined in the design engineer's specifications and in accordance with the manufacturer's recommendations. Most remote-control valves are designed for direct underground burial. However, the installation of valve boxes and drain boxes is advisable. In the case of larger installations with numerous valves, it is best for as large a number of valves as possible to be grouped in a box to facilitate access for servicing.

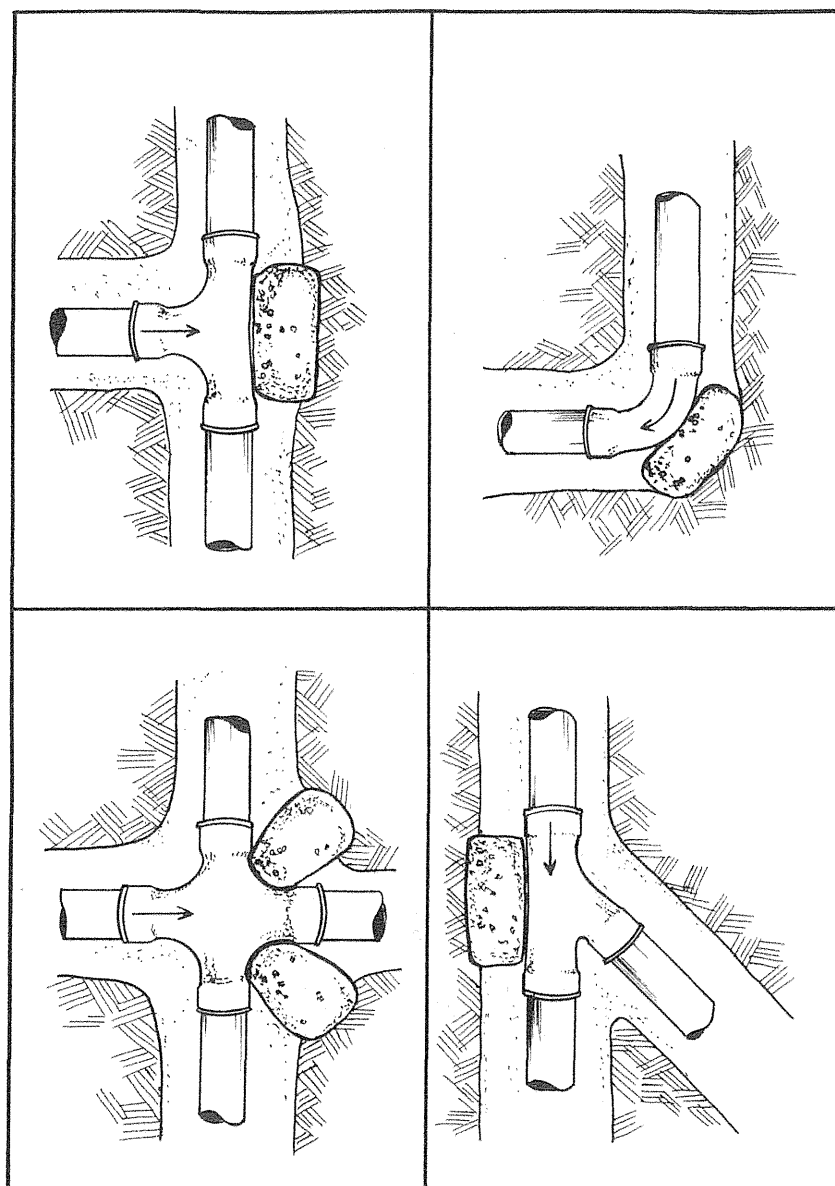


Figure 9.25. Diagram showing four uses for a thrust block.

Drain valves, either automatic or manual, are installed as specified in the design plan. They should be installed at all low points in the system and should include a sump pit in the case of small short lines (Figure 9.27) or a large pit connected to a subsurface drainage system for large mains and longer pipelines. Automatic-drain valves should be installed as specified by the manufacturer. They should be set at the proper angle and

should not be positioned on the far end of a line due to problems with dirt accumulating on the inlet screen.

Installing Control Lines. Control lines should be run in the pipe trenches whenever possible. Either electric wire or hydraulic tubing is run with the piping by the most direct route from the control point to the appropriate valves in the trenches.



Figure 9.26. A pipe-pulling machine positioned at the pipe entry point (top) and in operation (bottom).

The control lines should be installed in accordance with the engineer's and manufacturer's specifications and carefully inspected to ensure all connections are secure. Electric control lines must have waterproof connections. As with piping, it is advisable that an allowance for expansion and contraction be included at 100-foot (30-m) intervals, usually in the form of loops. The control lines should be installed in such a manner as not to crush or kink them and deep

enough to avoid disruption from turf cultivation practices, such as deep coring. Be sure to determine the regulations for installation of control lines in the same trench when they control both potable and nonpotable waters.

Controllers. The central controller typically is located in the golf course operations building. This central controller commonly is in the form of a desktop computer with the appropriate software. Thus, installation involves hookup of (a) the electrical power source, (b) control lines to all satellite controllers, and (c) other possible accessories, such as a rain shutoff switch.

Associated with the central controller is a series of satellite controllers positioned at strategic locations around the golf course so an operator may view all areas under control of each satellite. This allows the irrigation maintenance specialist to readily check the operational status of all components in the system on a regular basis. The satellite controller typically is mounted on a pedestal installed on a concrete base (Figure 9.28). A template or similar type of mount is embedded in the concrete at the time it is laid to provide a connection point for the pedestal cabinet.

Also positioned in the concrete slab are 3 underground conduits extending directly down and then horizontally outward as 3-inch (75-mm) elbows. The conduits accommodate a 1.0-inch (25 mm) diameter for 110 V.A.C., one 2- or 3-inch (50–75 mm) diameter for 24 V.A.C. control wiring or hydraulic tubing, and a 1-inch (25 mm) diameter for the computer-to-satellite signal cable. The cable, electrical wire, and/or hydraulic lines may then be pulled through the conduit

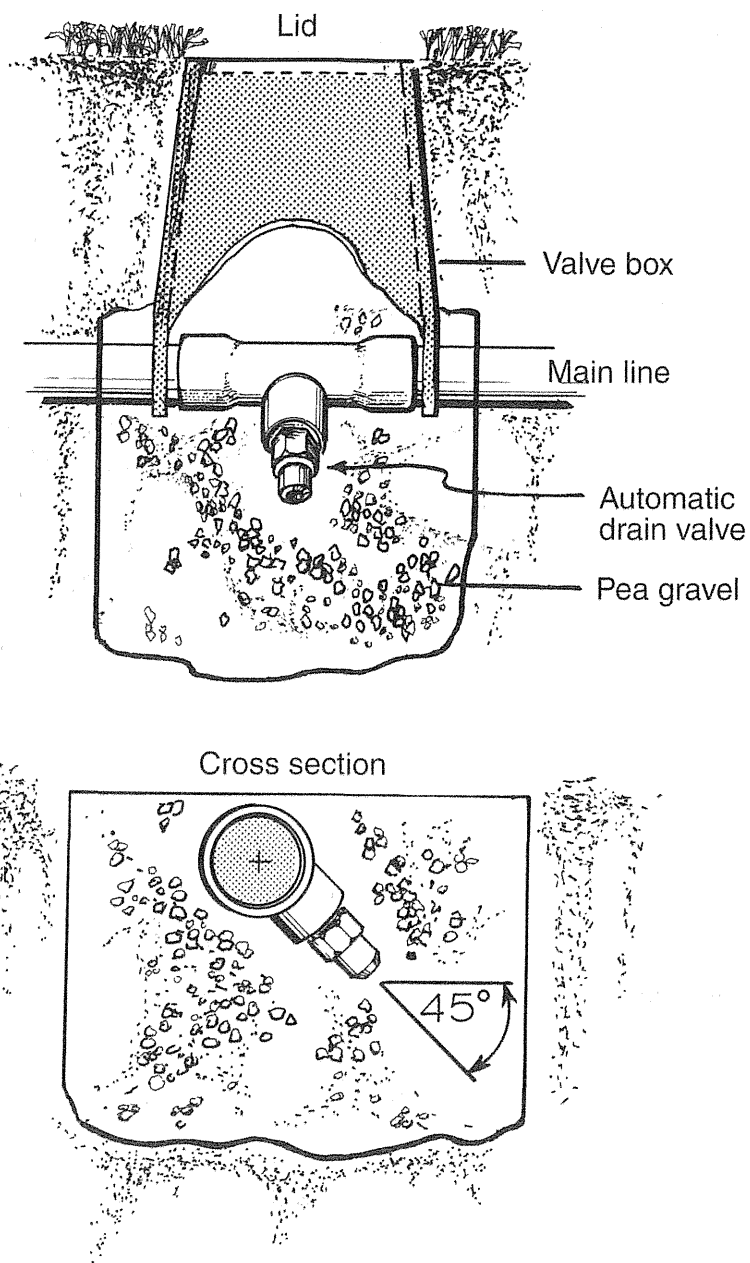


Figure 9.27. Diagram of a drain valve sump pit arrangement.

upward into each satellite controller. Plastic or stainless steel satellite controller cabinets are suggested as they resist corrosion when using effluent water.

Accessories that may be associated with the satellite controller include a heat source for pro-

tection against freezing, a master switch, a safety device in case of power failure, and a hookup for the electrical supply to the satellite controller. A constant voltage transformer may be needed to protect solid state satellite controllers from power spikes and surges in areas known to have erratic

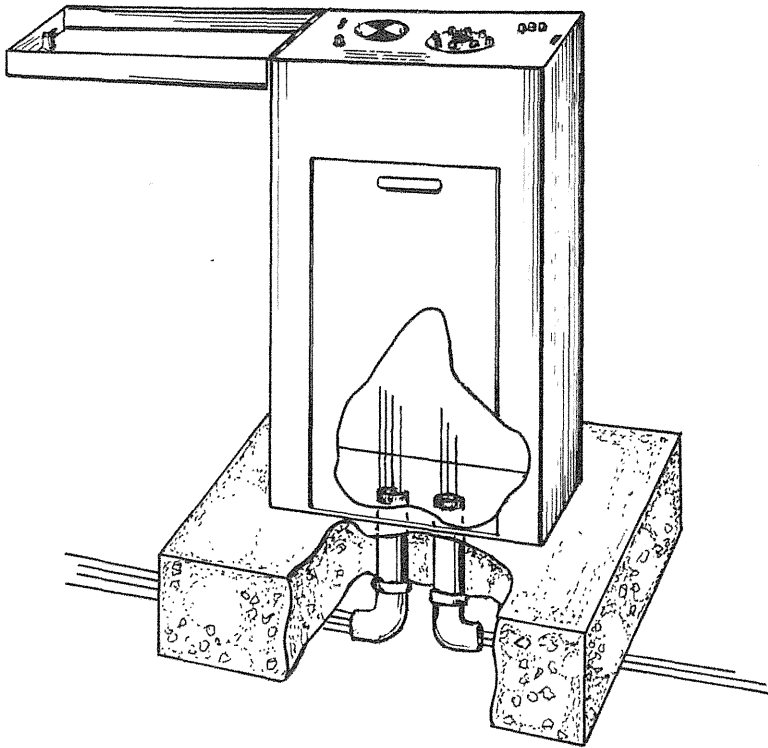


Figure 9.28. Diagram of a typical mounted satellite controller installation.

power sources. Any satellite or wall-mounted controller located outside should be weather-resistant to provide protection for the operational panel. All controllers should be grounded to the earth to eliminate the potential hazard of an electrical shock. Installation of a lightning suppression device is essential with solid state controllers.

Partial Backfilling. Sand or stone-free, fine-textured soil should be used in partial backfilling of the trench following installation of piping and associated irrigation equipment. The pipe should be covered to a depth of 3 to 4 inches (75–100 mm) so pipe damage from rocks and other debris during backfilling and compaction operations is minimal. It is advisable not to cover joints or fittings associated with the main line so that they may be checked for possible leakage. Initial backfilling should be done in the cool part of the day, especially in warm climates, to minimize the effects of heat expansion.

Line Flushing. After the piping has been installed, connected to the pumping station or main water source, and covered with sufficient soil to prevent movement, the pumping station should be activated and sufficient water passed through all piping, fittings, and risers to ensure that dirt, pipe chips, and other debris present in the lines have been flushed.

Installing Sprinkler Heads. Immediately following line flushing, the sprinkler heads are installed to minimize the chance of extraneous material entering the piping. Often the sprinkler heads are attached while line flushing is in progress. The procedure involves connecting the sprinkler head closest to the valve first and then connecting heads progressively out along the line from the valve. This approach increases the pressure and flow on the outermost reaches of the line,

thus facilitating better flushing of debris.

Following connection, the sprinkler heads should be set to the desired level. In the case of an existing turf, the sprinkler head cap normally is set flush with the soil level. In the case of new construction, the sprinkler heads may be installed slightly above the projected rough grade level. They can then be left to operate in this position until initial turf establishment has been achieved and then lowered to the permanent finished grade after soil settling has occurred. A triple swing-joint and a riser connection facilitate lowering.

Pressure Testing. Design specifications may call for testing of the main lines at pressures exceeding the normal operating pressure of the system. This is the portion of the system that is usually under constant pressure. Partial backfilling is required before pressure testing to ensure that the pipe sections remain anchored in place after pressure activation. The joints generally are left un-

covered to detect possible leaks. Pressure testing may involve a simple visual inspection for leakage at exposed joints or a more comprehensive assessment in which the system is brought to a given pressure and then the pressure and water loss are monitored over a specified time.

Finish Backfilling. After successful line flushing and pressure testing, the remainder of the pipe joints are manually covered with stone-free sand or fine-textured soil. Then the remainder of the trench is backfilled, usually by mechanical means. The subsoil should be backfilled first, then the topsoil. Most fine-textured soils require some mechanical firming, such as by use of a powered vibratory tamp, especially around sprinkler heads (Figure 9.29). If mechanical firming is done, an effort should be made to (a) duplicate a degree of firming comparable with that of the original soil and (b) accomplish the operation when the soil is moist. Uniform settling of the backfilling material is enhanced by frequent watering during backfilling. Where the pipe has been pulled in, the area usually must be releveled with a heavy roller.

Backfilling should bring the soil back to the original surface level, with a slightly higher rise in the center of the trench to provide for anticipated settling. Where the sod is to be transplanted back onto the site, final backfilling should be to a slightly lower subgrade to accommodate replacement of the sod at the original turfed surface level. If the trench is to be resodded, proper planted preparation of the surface soil zone should be accomplished prior to transplanting.

Adjustment and Balancing. At this point, any required final adjustments and balancing of the total irrigation system should be accomplished to achieve the desired operating pressure and water distribution. This includes final adjustment of the sprinkler head cap to a surface height that conforms to the surrounding conditions. Final testing also includes setup and operation of the central controller through an entire cycle to confirm that the system is fully operational. Some valve-in-head sprinklers have adjustable pressure regulators that may require adjustment.



Figure 9.29. A powered tamp being used to firm the soil around a sprinkler head. (Courtesy of The Toro Company.)

As-Built Plan Preparation. Changes in the original design plan are inevitable as work progresses through the staking, trenching, and installation phases. All such changes should be noted daily on a preliminary as-built plan. This should be done daily, rather than at some later date. Specific changes to be noted include the repositioning of piping, gate valves, remote control valves, quick-couplers, control tubing and wiring, domestic water lines, and drain valves. After successful testing and programming of the entire irrigation system, a final as-built plan must be prepared with complete accuracy. It is then submitted to the client, who should keep 2 copies in separate locations as a permanent record and future reference for use in maintenance, winterizing, repairs, or additions to the system. It is important to note that the as-built plan usually differs from the original design engineer's plan. For accuracy, flying a

“pie plate” aerial photograph following completion of the system installation is suggested to give exact locations for the heads, valves, and controllers, or global positioning (GPS) can now be used to accurately develop as-built plans.

MAINTENANCE OF AN IRRIGATION SYSTEM

A new irrigation system has an initial period of minimal maintenance, once made fully operational. However, long-range plans must be made in terms of a budget, labor, and an adequate parts inventory to maintain the system in its originally designed operational state. As with any complex mechanical device, an automatic irrigation system requires constant attention in terms of adjustment, maintenance, and repair if it is to function properly. Such components as the automatic controllers, control valves, rotary-head drive mechanisms, nozzles, hydraulic or electrical control lines, screens, fittings, and pumping system are prone to the effects of weathering, rodent damage, wear, vandalism, and damage from improper use.

Thus, a part-time or sometimes a full-time employee is required to maintain the complex components of an automatic irrigation system. The individual must be properly trained and fully knowledgeable in upkeep and repair of the system to keep it functional.

A visual operational check of all sprinkler heads and an operational check of the associated controller systems should be conducted at a 5- to 7-day interval. Some operators also make a brief daily check during the syringe cycle. Use of this maintenance check system establishes that the control system is working properly and, if it is not, gives an indication of the specific repairs or adjustments needed. It also indicates to the operator the type of water distribution being achieved both in terms of the duration the sprinkler runs in relation to the program set at the controller and the pattern of water dispersment from the sprinkler.

Nozzles should be checked periodically for excessive wear and replaced as needed. It also is important that a check be made daily for malfunctioning rotary sprinkler heads and leaky

valves that cause low-head drainage. Similarly, screens and filters must be checked and cleaned periodically, with the specific interval determined by the amount of debris and sand introduced from the water source. Appropriate adjustments or repairs are made whenever a component of the system is not functioning properly. Air-release valves should be serviced annually. Furthermore, all valves should be exercised and lubricated once per year. Sticking gate valve stems often can be loosened by prelubricating with diesel fuel.

An irrigation system maintenance checklist is used as a method of repair control (Figure 9.30). Whenever a problem is identified, it is noted on the checklist and a card is given to the individual in charge of irrigation repairs. Appropriate adjustments or repairs are then made. Once the problem is corrected and the system made functional, the card is signed, dated, and placed in a permanent file. This card system facilitates communications on the specific repair needs and provides a permanent record from which operating efficiency and repair costs are ascertained.

To ensure the irrigation system is repaired quickly when breakdowns occur, it is important to stock an adequate inventory of spare parts. The inventory should include at least 2 controller mechanisms; a working supply of remote control valves, electric lines or hydraulic tubing, sprinkler heads, and associated parts; a range in sizes and types of piping used on the course for repair of breaks, plus the associated couplings for pipe repair; and a few selected sizes of gate valves. The appropriate specialized irrigation repair tools dictated by the particular system used also are needed.

Finally, it is advisable for the pumping station to be serviced by a knowledgeable service technician on at least an annual basis, as these stations are very complex and involve high voltages. In arid climates where irrigation is practiced 12 months per year, a semiannual or quarterly servicing is advisable.

Winterizing

In most cool climatic regions, the irrigation system must be drained to prevent pipe breakage during the winter, assuming the potential soil frost

IRRIGATION CONTROL CHECKLIST						
DATE _____		ZONE _____		COURSE _____		
VALVE OR HEAD NO.	SET TIME	ACTUAL TIME	SPRAY PATTERN	NOZZLE PRESSURE	ROTATION	COMMENTS
1						
2						
3						
4						
5						

Figure 9.30. Irrigation system maintenance checklist.

depth extends below the depth of pipe burial. The irrigation system should be drained prior to the first severe freeze. The preferred method is for the irrigation lines to be blown out with compressed air, being sure to use the proper pressure. The drain outlets are positioned over a gravel sump or dry well that is preferably connected to a subsurface drainage system.

The actual procedure followed in blowing water out of an irrigation and pumping system may vary from the following outline depending on the type of equipment involved. If any aspects are unclear, it is critical that the design engineer for the irrigation system and the manufacturer of the pumping system be asked to provide a detailed written procedure for draining and winterizing the systems.

Drainage of the Irrigation System:

1. A week before the scheduled draining of the system, the golf course superintendent should study the irrigation drawings and prepare a sequence of steps planned for orderly drainage of all main and lateral pipelines, including consideration for high and low areas.
2. Turn off the water supply, open all drain outlets that flow directly into drain lines or similar outlets, and insert quick-coupler keys

in the high and low points in each line to facilitate air replacement as water drains from the lines.

3. Secure or arrange for rental of an appropriate-sized air compressor. Connect the compressor into the main line near the water source or at the highest elevation on the golf course. Irrigation lines 4 to 8 inches (100–200 mm) in diameter are blown out most readily by means of two 125- to 250-cubic feet (3.54–7.08 m³)-per-minute air compressors, while systems with 3-inch (75-mm) diameter lines or less are blown out relatively quickly with one 125 cubic feet/min air compressor. Allow the compressor to build up pressure before opening any drainage outlets.
4. Open each remote control valve, beginning at the water source on the main line, and then continuing on the lateral line nearest the water source. Allow sprinklers to drain until only air comes out. Then close the valve. Continue this procedure to the end of the line and then repeat the same steps on each more-distant lateral off the main line until all water has been removed from each lateral, riser, and sprinkler head.
5. Repeat step 4 to ensure full water removal from all irrigation lines. Again, start from

the water source and work toward the ends of each of the outlying laterals. Open each drain outlet slightly and blow out any remaining water, close for a short period, and then reopen to establish that all water has been removed.

6. Close the drain lines to prevent surface water from entering the irrigation lines through the drain valve during winter thawing.

Drainage of the Pumping System:

1. Study the water flow route through the piping, gate valves, check valves, and related portions of the pumping system, being careful to identify all drain outlets.
2. Drain pump volutes by removing the bottom plug or opening the drain cock.
3. Drain or remove the suction drop pipe.
4. Drain pressure-reducing valves by blowing out or loosening the cover bolts.
5. Turn all drive motors and cover motors off to protect windings against possible rodent damage.
6. Drain pressure gauges, switches, tank sight glasses, tank air chargers, and similar equipment that is subject to freezing.
7. Make sure all oil- or grease-lubricated bearings are well covered with lubricant.
8. Cover any exposed metal, such as shafts, with protective lubricant to eliminate corrosion.
9. Program automatic valves to operate once a day for 5 minutes to prevent the solenoid plunger from sticking and reduce moisture in the solenoid coil and automatic controller contacts.
10. Install a properly sized heater in the pump house to maintain the temperature above freezing, thereby minimizing damage to pump station components.

OPERATION OF AN IRRIGATION SYSTEM

A quality irrigation system is designed and installed to enable the golf course superintendent

to irrigate the course in a manner that provides as close to optimal turf playing conditions as possible. Note that optimal playing conditions and optimal turfgrass conditions usually are not the same. Too often golf courses are overirrigated from the standpoint of optimal golfing conditions. This is due to (a) pressure from golfers for soft greens and lush turf, (b) improper operating practices of the golf course superintendent, and/or (c) limitations or improper design restrictions of the irrigation system itself.

A fully automatic irrigation system that does not require periodic programming and maintenance does not exist. Future technology may produce such a system. In the meantime, irrigation practices remain one of the most challenging and difficult day-to-day decision-making responsibilities of the golf course superintendent. The knowledge and techniques employed by a golf course superintendent often determine the effectiveness of an irrigation system. Knowledgeable operation and total familiarity with the irrigation system capabilities are essential requirements for a qualified golf course superintendent.

Too frequently, irrigation practices fail because they have been established by habit or by calendar reference dates. Actually, good irrigation practices are dictated on a day-to-day basis by the specific turfgrass needs, soil characteristics, and projected weather conditions. Thus, the criteria affecting the decision-making process concerning irrigation involve a dynamic, ever changing set of conditions that must be assessed continually by a golf course superintendent with intimate knowledge of these criteria.

A responsible superintendent will make a daily assessment of the soil moisture levels at key indicator sites throughout the golf course. Consideration must be given to the solar radiation level, temperature, atmospheric relative humidity, and wind conditions affecting the ET rate, plus the anticipated rainfall for the next few days. Detailed monitoring of these parameters may be accomplished by one or more on-site microenvironmental stations with interpretation facilitated by a computer modeling system. Finally, an assessment must be made as to the capabilities and

weaknesses of the irrigation system in relation to applying the needed amount of water within a specific period of time. Based on these evaluations, decisions are made regarding when, where, and how much water to apply.

The situation is even more complicated when variations in soil texture cause the soil moisture content to vary at different locations on the golf course. Some sites may tend toward perpetual wetness, while others may be prone to rapid drying. Consequently, the irrigation program must be adjusted for the variable soil and drainage conditions within the golf course itself. Prolonged dry weather may dictate the use of manually set hose-end sprinklers connected to quick-coupling valves to supplement irrigation system applications on selected sites. Similarly, care must be taken to properly irrigate very wet sites and to avoid overwatering adjacent slopes from which surface runoff back onto these low, wet areas may occur.

The golf course superintendent will need to compensate for any inadequacies in the irrigation system design or for special problem sites on the golf course by supplementing the automatic or semiautomatic system with manual irrigation methods when needed. This need is more common during extremely dry periods.

Assessing the Turf Water Need

Software programs are available for computers that record key individual environmental parameters monitored by one or more microenvironmental sensing stations and then calculate the turfgrass water requirement for specific turf locations. The most accurate and reliable evapotranspiration (ET) prediction model across a broad range of climates is the Modified Penman Turf Model. It requires a microenvironmental station for sensing such needed inputs as net radiation, temperature, relative humidity, and wind speed. This approach is valuable in predicting ET rates, which in turn aid in decision-making for the best possible irrigation practices.

The ultimate decision as to when irrigation is needed requires visual assessments of the water status of both the turf and the soil. Visual turf assessment involves use of the footprinting tech-

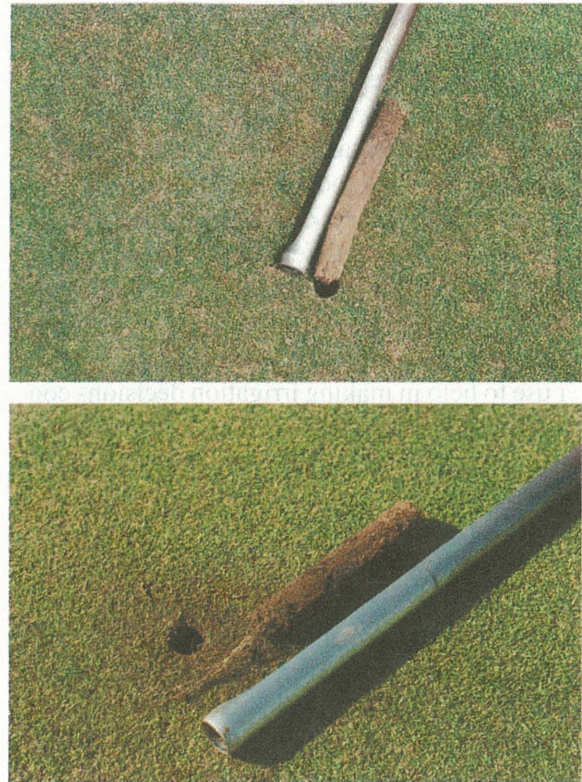


Figure 9.31. Use of a soil probe to determine the moisture status of a soil. Note the lighter dry soil (*top*) and darker moist soil (*bottom*).

nique, plus signs of visual leaf wilt. Both indicate the current water status of a turf and whether water must be applied soon. In contrast, visual assessments of the soil moisture level give a projection of potential turf water needs over the next few days and aid in planning upcoming irrigation practices (Figure 9.31). A soil probe is the best tool for this assessment, assuming the person is familiar with the appearance of soils under various moisture conditions. The depth of moist soil is of special concern.

Soil moisture should be checked with a soil probe to a 6- to 8-inch (150–200 mm) depth at a number of key locations on the golf course. By experience, the golf course superintendent identifies these indicator sites where turfgrass water stress first occurs. Thus, visual assessments of the turf and soil water status are partially an art developed through experience.

There are sensors available for determining soil moisture. In the past, these units have proven impractical as an extension of the automatic irrigation system under most field conditions. The amount of soil area sampled is so limited, the golf course soils and microclimate are so variable, and the rooting depth and cutting height of various turfgrasses are so different on different golf courses that it is difficult to use soil moisture sensors for comprehensive monitoring.

One low-cost approach for approximating water use to help in making irrigation decisions consists of an evaporative pan that indicates the evaporative demand of the atmosphere on a daily basis. The amount of irrigation water applied is based on a percentage of the pan evaporation rate, which varies with the turfgrass species/cultivar. The pan should be read at the same time daily and the original water level reestablished. This approach presents problems and is much less accurate than the Modified Penman Turf Model used in conjunction with a microenvironment sensing station and computer with an appropriate software program.

When to Irrigate

There are three dimensions to a turf irrigation strategy. They are (a) maintenance watering, which consists of replacing water in the root zone, (b) environmental watering, which involves relatively light applications for a number of different purposes, and (c) watering-in fertilizers, preemergence herbicides, and certain fungicides and insecticides.

The preferred time of day for maintenance irrigation of most golf course turfs, from an agronomic standpoint, is the late nocturnal period and early morning. However, limitations of some irrigation systems may dictate irrigating for the full nocturnal period on 2 consecutive nights to fully cover an 18-hole course. Irrigations should be scheduled so soils are not at or near saturation when intense traffic is anticipated. This minimizes the potential for soil compaction and ensures optimal playing conditions.

Midday maintenance irrigation has several disadvantages, including (a) the potential for unsatisfactory water distribution patterns due to the higher winds common at midday, (b) a higher amount of water loss by direct evaporation to the atmosphere, and (c) inconvenience to golfers. Irrigation in late afternoon or early evening also has disadvantages in that the turf remains moist throughout the nocturnal period, thus increasing the potential for fungal spore germination and invasion, with subsequent disease development.

A specific frequency of irrigation cannot be suggested on an absolute basis. Frequency is dictated by the existing turfgrass species, rooting depth, environmental status, and soil conditions. It may range from daily on putting greens in midsummer, to 3 to 5 times per week on tees during the summer, to once every 7 to 14 days during the spring and autumn on fairways. Similarly, no one diurnal time is always best because of numerous interactive factors.

A light, daily environmental irrigation is frequently applied to putting greens just prior to dawn, especially if the root zone has an adequate infiltration rate. This serves the dual purpose of a light irrigation plus removal of dew, exudates, or frost that may have formed on the turfgrass surface. This approach offers more favorable playing conditions in early morning and eliminates the need for such manual procedures as poling or hose-dragging of greens prior to mowing.

During summer heat and water stresses, watering of putting greens and even tees may be necessary at midday, particularly for cool-season turfgrasses. This very light, midday watering technique is termed **syringing**. It may be used to correct a turfgrass stress, such as wilt or heat, so the turf may survive until normal irrigation during the nocturnal period. When the turf wilt potential is high, the superintendent or the assistant superintendent should inspect all greens and tees daily near midday, and sometimes twice daily during extreme heat stress when the turfgrass root system is quite short. Syringing must be done whenever wilt is imminent. Any delay could mean an extensive loss of turf, particularly

IRRIGATION WATER VOLUME, FLOW, AND WEIGHT FORMULAE**VOLUME**

1 acre-inch = 43,560 cubic inches

= 27,154 gallons

1 acre-foot = 43,560 cubic feet

= 325,851 gallons

1 gallon = 231 cubic inches

= 0.134 cubic feet

7-1/2 gallons = 1,728 cubic inches

= 1 cubic foot

1 million gallons = 3.07 acre-feet

1 billion gallons = 1,000 million gallons

FLOW—VOLUME

1 million gallons per day (mgd) = 694.4 gallons per minute

= 1.5 cubic feet per second

= 1,120 acre-feet per year

1 billion gallons per day (bgd) = 1.12 million acre-feet per year

1 cubic foot per second = 1.98 acre-feet per day

WEIGHT

1 gallon of water at 62°F = 8.34 pounds

1 cubic foot of water at 39.1°F = 62.43 pounds

1 pound of water at 62°F = 0.1199 gallon

when the turf is composed of annual bluegrass or bentgrass.

Amount of Water to Apply

The golf course superintendent should attempt to apply an amount of water equivalent to that removed from the soil since the last irrigation to field capacity. The exception to this model is when irrigating sodic and saline soils, and especially when saline water is used. The amount of water removed is determined by the quantity of water lost to the atmosphere through evapotranspiration plus the water percolated downward through the soil in a free gravitational mode. The actual amount of water applied also depends on the water retention characteristics of the soil. Fine-textured soils have a higher water retention capability than

coarse-textured sandy soils, unless a perched hydration zone is created by the construction method.

Over-irrigation must be avoided. If continued on a long-term basis, it causes serious declines in the soil oxygen level, root growth, and overall turfgrass quality and it increases the potential for disease development and soil compaction. In addition, over-irrigation is wasteful, since much water may be lost through surface runoff and gravitational percolation. Turfgrass symptoms of over-irrigation include a yellowish, chlorotic appearance, thinning of the stand, algae, and increased annual bluegrass (*Poa annua*) encroachment.

An important dimension in irrigation is the rate of water application per unit of time. It should be adjusted to the maximal rate at which water enters the soil, termed the infiltration rate. The infiltration rate may range from as low as 0.05 inch

(1.3 mm) per hour on very fine-textured silty clay soils to more than 4 inches (100 mm) per hour on mature high-sand root zones. Failure to select the appropriate water application rate may result in costly and wasteful water loss by surface runoff. On sites where the soil infiltration rate is extremely low, an irrigation system is needed that applies water in short, frequent intervals over the nocturnal irrigation period. The rate of water application is controlled primarily by the sprinkler head nozzle size, sprinkler head spacing, type of sprinkler head, and operating time.

The soil infiltration rate may change through time, as a result of the (a) introduction of golf carts, (b) increased golfer traffic, (c) increased use of irrigation water containing sodium, which causes deflocculation of clays, (d) thatch or mat accumulation, and (e) deposition of clay and silt by flooding, wind, poor-quality irrigation water and/or poor topdressing material.

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MMK Water Usage Chart

Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2006	June	51,100,000	1,703,333	
	July	51,000,000	1,645,161	
	August	52,500,000	1,693,548	
	September	50,300,000	1,676,667	
	October	31,600,000	1,019,355	
	November	26,400,000	880,000	
	December	26,300,000	848,387	
	Year Total	289,200,000	1,351,402	214
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2007	January	28,588,100	922,197	
	February	26,968,000	963,143	
	March	15,334,100	494,648	
	April	74,538,300	2,484,610	
	May	49,999,993	1,612,903	
	June	54,700,020	1,823,334	
	July	50,999,991	1,645,161	
	August	51,999,989	1,677,419	
	September	51,500,010	1,716,667	
	October	42,500,008	1,370,968	
	November	24,758,340	825,278	
	December	18,508,085	597,035	
	Year Total	490,394,936	1,343,548	365
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2008	January	27,054,500	872,726	
	February	19,883,705	685,645	LEAP YEAR
	March	45,247,600	1,459,600	
	April	36,771,500	1,225,717	
	May	48,707,600	1,571,213	
	June	47,141,000	1,571,367	
	July	52,689,300	1,699,655	
	August	50,312,800	1,622,994	
	September	47,822,500	1,594,083	
	October	37,642,900	1,214,287	
	November	29,340,100	978,003	
	December	21,736,400	701,174	
	Year Total	464,349,905	1,268,716	366
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2009	January	17,088,000	551,226	
	February	24,382,500	870,804	
	March	24,413,300	787,526	
	April	28,479,700	949,323	
	May	34,852,200	1,124,265	
	June	35,997,200	1,199,907	
	July	42,329,400	1,365,465	
	August	36,411,400	1,174,561	
	September	44,009,000	1,466,967	
	October	26,950,200	869,361	
	November	20,982,800	699,427	
	December	20,185,040	651,130	
	Year Total	356,080,740	975,564	365

MMK Water Usage Chart

Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2010	January	23,776,360	766,979	
	February	24,243,400	865,836	
	March	23,776,360	766,979	
	April	23,379,000	779,300	
	May	31,729,200	1,023,523	
	June	41,415,000	1,380,500	
	July	44,226,000	1,426,645	
	August	44,394,400	1,432,077	
	September	40,514,400	1,350,480	
	October	41,197,600	1,328,955	
	November	27,838,400	927,947	
	December	17,144,000	553,032	
	Year Total	383,634,120	1,051,052	365
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2011	January	21,896,600	706,342	
	February	18,708,400	668,157	
	March	33,587,800	1,083,477	
	April	35,490,400	1,183,013	
	May	37,013,200	1,193,974	
	June	41,063,800	1,368,793	
	July	38,400,000	1,238,710	
	August	39,875,800	1,286,316	
	September	41,373,200	1,379,107	
	October	38,943,400	1,256,239	
	November	35,039,000	1,167,967	
	December	22,525,000	726,613	
	Year Total	403,916,600	1,106,621	365
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2012	January	29,771,800	960,381	
	February	25,649,200	884,455	LEAP YEAR
	March	25,294,000	815,935	
	April	33,619,200	1,120,640	
	May	39,635,200	1,278,555	
	June	34,036,000	1,134,533	
	July	40,699,000	1,312,871	
	August	40,924,200	1,320,135	
	September	33,396,400	1,113,213	
	October	34,879,200	1,125,135	
	November	31,740,200	1,058,007	
	December	28,902,800	932,348	
	Year Total	398,547,200	1,088,927	366

MMK Water Usage Chart

Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2013	January	20,963,800	676,252	
	February	21,777,200	777,757	
	March	24,666,400	795,690	
	April	31,098,600	1,036,620	
	May	24,850,000	801,613	
	June	38,693,200	1,289,773	
	July	39,781,600	1,283,277	
	August	27,482,800	886,542	
	September	47,688,800	1,589,627	
	October	35,219,800	1,136,123	
	November	19,407,200	646,907	
	December	15,320,800	494,219	
	Year Total	346,950,200	950,548	365
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2014	January	15,295,600	493,406	
	February	12,452,400	444,729	
	March	4,008,200	129,297	Very little irrigation due to frequent and consistent rain
	April	13,107,000	436,900	
	May	22,811,200	735,845	
	June	30,587,600	1,019,587	
	July	29,782,400	960,723	
	August	14,277,000	460,548	
	September	34,103,200	1,136,773	
	October	30,803,600	993,665	
	November	17,809,600	593,653	
	December	16,650,600	537,116	For year, reduced irrigation due to more frequent and consistent rain
	Year Total	241,688,400	662,160	365
Year	Month	Gallons Monthly or Annually	Average Daily Use (GPD)	Comments
2015	January	17,886,000	576,968	
	February	11,926,600	425,950	
	March	12,870,000	415,161	
	April	22,025,200	734,173	
	May	25,813,600	832,697	
	June	27,610,600	920,353	
	July	32,597,000	1,051,516	
	August	19,349,800	624,187	
	September	30,034,200	1,001,140	
	October	14,460,400	466,465	
	November	18,754,600	625,153	
	December	22,339,000	720,613	For year, reduced irrigation due to more frequent and consistent rain
	Year Total	255,667,000	700,458	365

Average Total Gallons per Year (2007 to 2015): **372,949,989**

Average Total Gallons per Day ("GPD") (June 2006 to December 2015): **1,036,969**

Deviation Range (GPD):

High: April of 2007 **2,484,610**

Low: March of 2014 **129,297**

Amount Requested (GPD)-2009 SWUP Application: **1,292,704**

Amount Requested (GPD)-2016 Current Request: **1,250,000**

Ikaika Bechert
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ibechert@troon.com

EDUCATION

Henry Perrine Baldwin High School (Graduated 1997)

Rain Bird Certification Course (Design and Operation of highly technical Central Control Systems for Golf Course Irrigation)

Completed UH Maui Campus Management Courses

Obtained Pesticide License and attended multiple seminars on new landscaping products and techniques.

PROFESSIONAL EXPERIENCE

1994 – Present (22 years)

Employed at:

The King Kamehameha Golf Club and Kahili Golf Course
2500 Honoapiilani Hwy
Waikapu, HI, 96793

Golf course maintenance experience with more than 22 years in Landscape, Grounds Maintenance, Irrigation, Plant Nursery, and Turf Fertilizing Techniques.

2012 – Present (4 years) - Golf Course Superintendent

Oversee the irrigation and landscaping of approximately 350 acres of golf course at the King Kamehameha Golf Club (18-hole golf course) and Kahili Golf Course (18-hole golf course), at the golf courses, around the clubhouses, and the onsite nursery. Manage over 30 employees. Oversee the daily maintenance and operation of an extensive and complex irrigation system covering two golf courses (36 holes). Oversee repairs of irrigation system controllers and over 800 sprinkler heads throughout the two golf courses. Coordinate requests for quantity of water from WWC, maintenance and repair of pumps to and from Reservoirs 4 and 18, and regular (weekly and monthly) meter readings.

2010 – 2012 (2 years) – Assistant Golf Course Superintendent

Assisted the then acting Superintendent in the same duties described above.

2006 – 2010 (4 years) – Irrigation Specialist

Maintain and Repair Irrigation lines and Controllers. Monitor watering schedules with central control system. Certified operator of the Rain Bird Central Control System

(ability to customize watering programs to manage the duration and quantity of watering for two golf courses).

2002 – 2006 (4 years) – Irrigator

Performed irrigation installations at the two golf courses and designed landscaping areas for irrigation. Worked on both native and non-native plant species in a nursery for transplant around Clubhouse landscaping areas.

1997 – 2002 (5 years) - Machine Operator/Laborer

Operated heavy machinery to maintain or improve two golf course property, including Backhoes, Bobcats, Forklifts, Lawn Mowers, Tractors, etc.

1994 – 1997 (3 years) – Laborer (part-time employment)

Performed tree trimming, weeding, and various maintenance roles at the two golf courses.

Also performed multiple residential irrigation projects involving the design and installation of irrigation systems. Designed irrigation misting system in nursery for seedlings and saplings.

SKILLS, ACHIEVEMENTS, & ASSOCIATIONS

- Rain Bird Certified on Central Control Systems for Golf Course Irrigation
- First Hand Experience with both Toro and Rain Bird Irrigation Systems
- Golf Course Irrigation Maintenance, Troubleshooting, and Repair
- Residential Irrigation Design
- Irrigation System Installation
- 6 Year Member of GCSAA (Golf Course Superintendents Association of America)
- Landscape and Plant Nursery Maintenance and Irrigation
- Extensive Knowledge in Turf and Landscape Care
- Licensed Pesticide Applicator
- Backhoe Operator
- Licensed Forklift Operator



Golf Central Control Systems



**Preferred by Golf Course Professionals
to Elevate Course Appearance and Playability**

*Irrigation is essential to
improve or maintain course
appearance and playability.
At the heart of everything is
central control.*

This is the brain.

The caretaker.

The watchdog.



Dynamic Adaptability:

*An exclusive and definitive reason why Rain Bird®
central control is preferred by more golf course
professionals worldwide.*

With Rain Bird® central control, the lines of communication are always open. The exchange of information is free flowing throughout the entire irrigation system. With up-to-the-minute information readily accessible, central control is able to take immediate action when an irrigation challenge arises.

*Maybe it is a sudden thunderstorm: central control will temporarily suspend, adjust or stop watering schedules.
Maybe it's a change in the flow rate: central control will immediately make the needed adjustments to assure optimal water use.*

These examples illustrate the dynamically adaptable nature of Rain Bird central control. This instantaneous responsiveness is why more golf professionals rely on Rain Bird to responsibly manage water use, to lower utility and labor costs, and safeguard their course investment.



Weather

Exclusive software includes **Smart Weather™** that monitors ET rates, and along with central control, modifies watering schedules based on actual turf requirements, and reactions based on user defined weather events.

RainWatch™ monitors falling rain and instantaneously pauses and/or adjusts irrigation run times as necessary.

Minimum ET™ integrates with a weather station to precisely determine central control watering cycles.



Around the Course

An exclusive **CYCLE+SOAK™** feature allows central control to precisely schedule and apply water to be consistent with the infiltration rate of the soil in each specific area around the golf course. The benefit is responsible water use.

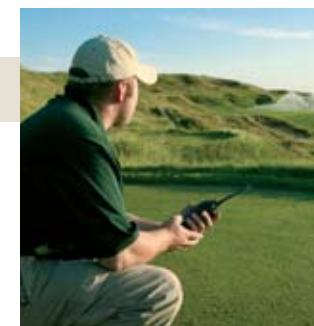


Pump Station

Pump Profiling enables central control to limit power consumption during peak periods to maximize performance efficiency.

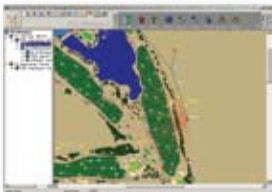
Exclusive **FloManager®** constantly communicates with central control to keep the irrigation system operating at peak efficiency, while managing flow in real time. Saving you money with the shortest, most efficient watering in the industry.

Rain Bird **Smart Pump™** provides real-time communication between the pump station and central control to adjust flow demand based on actual field conditions; this reduces pump downtime by automatically modifying system demand on the pump for optimum irrigation efficiency.



Accessibility

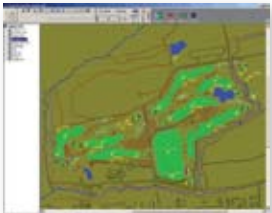
Rain Bird is continually developing systems to provide remote access to central control. One example is the **FREEDOM™ System**. FREEDOM allows the user to send commands to the central control via a handheld radio from anywhere on the course. Another example is the Rain Bird **MI Series Mobile Controller**. With just a web-enabled cell phone, central control can be accessed at any time, from virtually anywhere in the world.



Cirrus FloManager®

Cirrus™

Cirrus™ central control incorporates Computer-Aided Design (CAD) drawings generated by GPS technology which allows you to see your course like no other system can. With state-of-the-art ET-based scheduling, customized course graphics and multiple mapping options, Cirrus makes controlling your irrigation system fast and easy.



Stratus II Course Monitor

Stratus™ II

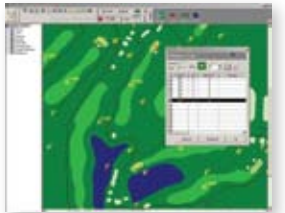
For easy-to-use, time- or ET-based scheduling there's really only one choice — Stratus™ II — the one irrigation central control system that combines the point-and-click simplicity of Windows® with intuitive Rain Bird features to control up to as many as 27 holes.



Nimbus II Course Monitor

Nimbus™ II

For a superior combination of ET-based scheduling, advanced flow management and Windows-based simplicity, Nimbus™ II is an excellent choice to efficiently control all irrigation applications on up to three individual courses with a maximum of 54 holes.



Stratus LT Map

Stratus™ LT

With Stratus™ LT you can almost immediately begin to manage all the irrigation applications on one 18-hole course — from the greens to the roughs — without having to become a computer expert or spend extensive time learning to operate the system. Stratus LT now supports ET-based scheduling with WS-PRO LT and a weather software module.

SHARED SYSTEM FEATURES					
FEATURES	CIRRUS™	NIMBUS™ II	STRATUS™ II	STRATUS LT™	GO™/GO200™
Real-time decision making	✓	✓	✓	✓	✓
Radio communication option	✓	✓	✓	✓	✓
Works with all Rain Bird® satellites	✓	✓	✓	✓	*
Works with decoders	✓	✓	✓	✓	*
Works with Rain Bird® Integrated Control™ System (ICS)	✓	✓	✓	✓	✓
Works with FREEDOM™ System	✓	✓	✓	✓	✓
Works with Rain Bird® MI Series Mobile Controller	✓	✓	✓	✓	✓
PROGRAMMING					
Standard/QuickIRR™/SimpleIRR™	✓	✓	✓	✓	✓
SOFTWARE FEATURES					
FloManager® – Dynamic Power and Hydraulic Management	✓	✓	✓	✓	✓
Flo-Guard™	✓	✓	✓	✓	✓
ET-Based scheduling	✓	✓	✓	✓	–
ET Spreadsheet™ Analysis	✓	✓	✓	✓	–
Rain Bird® MI Series Mobile Controller	✓	✓	✓	✓	✓
Wireless Satellite Radio Diagnostics	✓	✓	✓	✓	–
Comprehensive Decoder Diagnostics	✓	✓	✓	✓	–
Advanced IC™ Diagnostics	✓	✓	✓	✓	✓
Real-Time Run Log	✓	✓	✓	✓	✓
Report Generation	✓	✓	✓	–	–
Water Budgeting 0% – 300%	✓	✓	✓	✓	✓
Rain Sensor	✓	✓	✓	✓	–
RainWatch™	✓	✓	✓	✓	–
QuickStart™	✓	✓	✓	✓	✓
Help Screens	✓	✓	✓	✓	✓
Course Monitor™	✓	✓	✓	✓	✓
Hole View	✓	✓	✓	✓	–
Projected Flow (Dryrun™)	✓	✓	✓	✓	✓
Graphics – Course View™	✓	✓	✓	✓	–
Import GPS, CAD or Aerial Photo	✓	✓	✓	✓	✓
Visual Monitoring – Area	✓	✓	✓	✓	–
Precipitation Data	✓	✓	✓	✓	–
Rotor Data	✓	✓	✓	✓	✓
Cycle + Soak™	✓	✓	✓	✓	✓

*GO™ & GO200™ Centrals operate IC systems only

UNIQUE FEATURES AND OPTIONS					
FEATURES	CIRRUS™	NIMBUS™ II	STRATUS™ II	STRATUS LT™	GO™/GO200™
Number of 2-wire satellite wire groups standard	4	4	1	1	*
Number of IC™ wire groups standard	4	4	1	1	1
Maximum number of interfaces - Hybrid (same or mix)	12	3	2	–	–
Maximum number of 2-wire satellite wire groups – Hybrid	48**	12**	4**	–	*
Maximum number of 2-wire/wireless satellite stations	32,256**	8,064**	2,688†	672	–
Maximum number of IC™ stations	36,000‡	9,000‡	3,000‡	750	750/200
Number of decoders/solenoids standard	500/1,000	500/1,000	500/1,000	200/400	–
Maximum number of decoder/solenoids – Hybrid	6,000/12,000Δ	1,500/3,000Δ	700/1,400Δ	300/600 with LDI◊	–
Number of active decoder solenoids	40/LDI	40/LDI	30 with LDI	15 with SDI	–
Maximum number of weather stations	5	5	1	1 (WS-PRO LT only)	–
Maximum number of pump stations	6	6	6	2	2
PROGRAMMING					
Number of courses	3	3	2	1	1
Number of holes	54	54	27	18	18
Number of Flo-Zones™	500	500	500	50	50
Programs	Unlimited	Unlimited	500	250	250
Schedules	50 per program	50 per program	25 per program	25 per program	25 per program
Irrigation programs – active simultaneous	50	50	20	10	10
SOFTWARE FEATURES					
ET Management (fully automatic)	✓	Optional	Optional	Optional	–
Rain Bucket™ – accumulated rainfall	✓	Optional	Optional	Optional	–
Visual Monitoring – Station level	✓	Optional	Optional	–	–
Smart Weather™ Alarms	✓	Optional	Optional	–	–
SOFTWARE MODULES					
Weather Software/Automatic ET	✓	Optional	Optional	Optional	–
Smart Weather™	✓	Optional	Optional	–	–
Additional Weather Stations	✓	Optional	Optional	–	–
Smart Sensors™ with Flo-Watch™	✓	Optional	Optional	Optional	–
Rain Bird® Messenger™	✓	Optional	Optional	Optional	–
Hybrid – Additional interfaces (same or mix)	✓	Optional	Optional	–	–
The FREEDOM System™	✓	Optional	Optional	Optional	Optional
Map Utilities™	✓	Optional	Optional	–	–
Station Layers – Map/Operations	✓	Optional	Optional	–	–
Smart Pump™	✓	Optional	Optional	Optional	–
Additional Wire Groups	✓	✓	Optional	–	–

*GO™ and GO200™ Centrals operate IC™ systems only ** Possible with Hybrid Module and additional MIM™(s) ‡ Possible with Hybrid Module and additional ICI(s) † Possible with Hybrid Module and additional Wire Groups Module(s) Δ Possible with Hybrid Module and additional LDI(s)
✓ Included – Not available ◊ Possible using a LDI instead of standard SDI. Hybrid not required



Irrigation has been the only Rain Bird® focus since 1933.

Rain Bird® was the first to install an irrigation system on a golf course, specifically the Los Angeles Country Club. Rain Bird was the first to develop centralized central control. Sure, there are other central control systems on the market, but none can compare to Rain Bird's proven track record of trusted performance on courses of every shape and size around the globe.



You have a golf course that needs to be irrigated.

You need to select a central control system that is easy to use, and will continually safeguard how your investment looks and plays. This is essential, because course appearance and playability is how you entice and retain members, or encourage repeat rounds.

You also need a central control system that will responsibly manage water use, a system that will efficiently reduce utility and labor costs.

So how do you begin the selection process?



Evaluate Your Course Irrigation Needs

All too often, greens committees or superintendents purchase a central control system that exceeds the irrigation needs of their golf course. So think about the level of irrigation control you believe is necessary to maintain course appearance and playability, while reducing water, labor and energy costs.

Keep in mind, too, that Rain Bird® systems are designed so as the irrigation needs of your course change over time, it will be affordably easy to upgrade your system with the most advanced technology.



Weigh What Others Have To Say

Talk with people who have had experience with more than one manufacturer's central control system. What you will likely hear is:

- How the system is dynamically adaptable, responding immediately with the right solution to any irrigation challenge.
- How Rain Bird central control systems are much easier to use.
- How everything integrates together to responsibly manage water use, and lower utility and labor costs.
- How Rain Bird offers so many more competitive advantages to improve or maintain course appearance and playability.

There is a definite difference. To find out why more golf course professionals prefer Rain Bird central control, ask around.

The Intelligent Use of Water.™

LEADERSHIP • EDUCATION • PARTNERSHIPS • PRODUCTS

At Rain Bird, we believe it is our responsibility to develop products and technologies that use water efficiently. Our commitment also extends to education, training and services for our industry and our communities.

The need to conserve water has never been greater. We want to do even more, and with your help, we can. Visit www.rainbird.com for more information about The Intelligent Use of Water.™



Rain Bird Corporation

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Azusa, CA 91702
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Rain Bird Technical Services

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Rain Bird Corporation

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Tucson, AZ 85706
Phone: (520) 741-6100
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Specification Hotline

(800) 458-3005 (U.S. and Canada)

Rain Bird International, Inc.

P.O. Box 37
Glendora, CA 91741
Phone: (626) 963-9311
Fax: (626) 963-4287



TECH SPECS

Cirrus™ Central Control System

The Golf Industry's Only Full-Featured Central Control System. Now with Rain Watch.™



Cirrus™

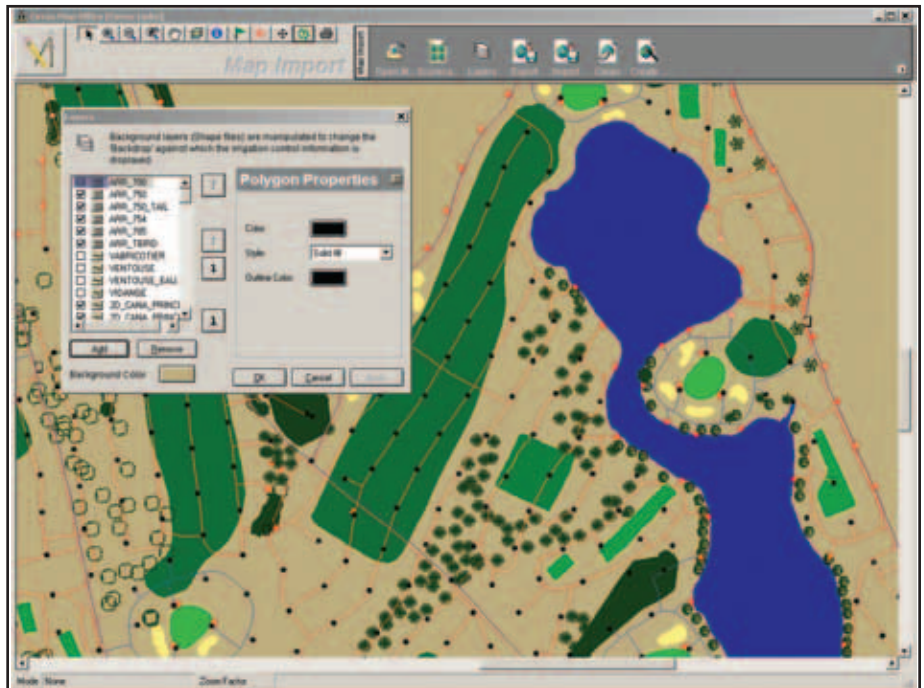
Rain Bird Golf takes a quantum leap in irrigation technology with the easy-to-use Cirrus™ central control system. With more than 3 years of field operation, Cirrus allows you to control your irrigation system with more precision than ever before. Like Rain Bird's Nimbus™ II and Stratus™ II, this multimanagement central control system takes advantage of the newest Microsoft® Windows® operating system with advanced graphics and 32-bit architecture. With state-of-the-art ET-based scheduling, customized course graphics, multiple mapping options and the ability to "see" the placement and operation of individual rotors, Cirrus makes controlling your irrigation system fast and easy. Install Confidence, Install Cirrus.

Advanced Graphical Tracking

Cirrus lets you see your course like no other central control system can. Incorporating maps generated by GPS technology and CAD,* Cirrus can graphically recreate your course with actual irrigation system layouts down to individual rotors. Then, with true 32-bit graphics, you can "zoom-in" to monitor every detail of your course. Just double-click on a rotor for a complete status report. A tree-view control allows you to visualize and manipulate programs and schedules with the support of visual graphics, colorized text and color references. Map utilities provide measurement and area calculations from the map.

Rain Watch™

Rain Watch is an exclusive new feature that is so unique it has a patent pending. Rain Watch is an intelligent rainfall reaction system that uses up to four tipping bucket

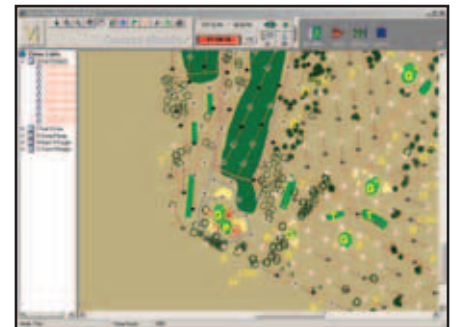


Cirrus allows you to create a custom map of your course, complete with customized layer options.



Place pumps, rotors and water distribution equipment on your map as they appear on your course.

rain cans to detect and react to local rainfall. For short duration cloudbursts, Rain Watch suspends irrigation while simultaneously measuring the real time rainfall. When the storm passes, irrigation is resumed with station runtimes reduced by an amount equivalent to the measured rain. In case of extended rainy weather, irrigation will be cancelled for a user-definable period of time.

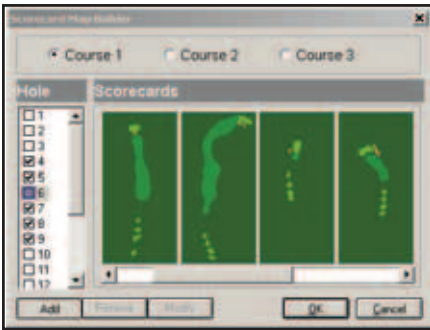


Monitor system activity using the Cirrus Course Monitor™ screen.

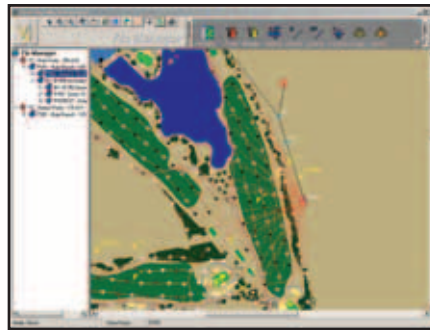
Minimum ET™

Minimum ET is another new feature that helps promote healthy turf by supporting advanced ET management techniques. With the Minimum ET feature a superintendent can define a minimum ET threshold value that must be met before irrigation will take place. Minimum ET values can be assigned globally so they affect all programs, or individually by program for the ultimate in ET management.

*In order to create GPS and AutoCAD maps, it may require a designer.



Create scorecard images of every hole on your course.



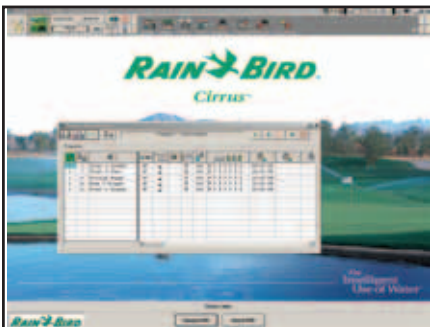
Control the flow of irrigation using the Flo-Manager® screen.



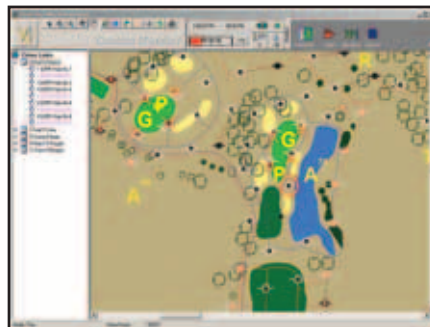
Modify irrigation schedules based on evapotranspiration rates and other Weather Station data.



Conserve water with built-in water saving features.



Easily manage your system with the intuitive programming functions in Cirrus.



"Zoom-in" on the Course Monitor™ screen to check on individual rotor activity.

Smart Weather™

Designed to take complete advantage of Rain Bird's most advanced line of weather stations, Cirrus is able to monitor and respond to climactic conditions as they occur. By tracking evapotranspiration (ET) rates and other sensory inputs, the industry's top central control system is able to quickly modify watering schedules to conserve water and reduce irrigation costs. Smart Weather™ also tracks weather conditions for future reference. The advanced warning system accepts user-defined sensor thresholds. If these thresholds are exceeded, the superintendent will be alerted that conditions are favorable for disease and pestilence.

Smart Pump™

Rain Bird's Smart Pump Software links your pump station to your central control system providing real time communication and optimizing your irrigation cycle. Smart Pump also has the ability to monitor and react to changes in station capacity. Should the pump station capacity increase or decrease, the software adjusts the irrigation cycle based on this change.

Expanded System Compatibility

Utilizing some of the most advanced software development tools in the industry, Cirrus offers excellent performance and

software/hardware compatibility. The new system architecture is designed to speed performance with future Microsoft® Windows® operating systems.

Remote System Control

Operate the Cirrus central control system from anywhere on the course using a Rain Bird FREEDOM™ System, or add the FREEDOM-Pad to get map-based field control. With a handheld, two-way radio or PDA Device you can communicate directly with Cirrus and take control of your system as conditions dictate.

Superior Monitoring

With all of the new features found in Cirrus, it's easy to overlook many of the features shared with the popular Nimbus II central control system. These include:

Flo Graph™ allows visibility of real-time graphics with individual station information presented in colorful charts. This feature monitors each or all pumps for reliable results.

Flo-Manager®—This patented feature balances system demand at maximum capacity with the efficiency of the pump station and delivery network. Flo-Manager maximizes system output without causing undue stress to your pump system and components when coupled with Smart Pump. It helps lower water demand, reduce system wear and tear and save energy—year after year.

Cycle + Soak™ works with Flo-Manager to achieve maximum efficiency and water conservation. It helps you control water application on slopes and in areas with poor drainage. Cycle + Soak maintains the pumping station demands while preventing over application in those challenging areas of the course.

QuickIRR™ will get you up and running in no time by creating schedules based on your parameters. This feature is enhanced in Cirrus by providing the ability to program multiple courses. Select the course, hole, area, sequence and run time and Cirrus will do the rest.

Smart Pump™—Rain Bird's Smart Pump Software links your pump station to your central control system providing real time communication and user interaction. The Smart Pump feature has the ability to monitor and react to changes in the pump station flow. Should the flow increase or decrease, the software can adjust the



Rain Bird's WS PRO Weather Stations allow Cirrus users to automatically modify their watering schedules based on actual environmental conditions.

irrigation cycle automatically based on user-definable thresholds.

Simple Upgrade Path

Those currently using Rain Bird's older central control systems can quickly and easily transfer the control of their irrigation systems over to Cirrus. Thanks to the graphic Cirrus interface, once your information is transferred, learning to use the Cirrus central control system is simple and easy. For the easiest upgrade in the industry, count on Cirrus central control and be confident you made the right choice.

Specifications

The computerized central control system shall be the Rain Bird Cirrus as hereinafter specified. It shall be capable of controlling three (3) independent, 18-hole golf courses, each consisting of greens, tees, fairways, approaches, perimeters, roughs and miscellaneous areas. The central shall include the Rain Bird "P" Series computer system, as hereinafter specified. The central

equipment shall include a satellite or decoder interface unit, an uninterruptible power source, a power circuit surge arrestor and a grounding network grid with surge arrestors, all as hereinafter specified.

All Cirrus central control systems shall be "Hybrid" compatible. The Cirrus Hybrid systems will have the ability to control up to four interface devices which can be any combination of 2-wire, wireless or decoder. In addition to these items, an additional Interface (MIM, MIM LINK or LDI) must be ordered.

Cirrus Software— The Cirrus software shall operate in the Microsoft® Windows 98 SE,

2000 or XP Professional environments.

Cirrus shall be capable of controlling any one or up to three (3) types of field unit systems;

(1) "hard-wired" satellite field units; (2) "radio" operated, LINK satellite field units, or (3) "hard-wired" decoder field units. The hard-wired satellite based systems shall be capable of controlling 28 channels, on each of eight (8) different two-wire communication paths. Each channel shall be capable of controlling a maximum of 672 satellite stations, or a total of 8064 (using 3 MIM interface units in Hybrid mode) satellite controller stations. The radio LINK type satellite system shall be capable of controlling four (4) different groups of LINK





satellites. A total of 112 LINK satellites shall be capable of controlling 24 stations (max.) each. Total system capacity shall be 8,064 (using 3 MIM-LINK interface units in Hybrid mode) LINK satellite stations. The two-wire satellites and LINK satellites shall be capable of expanding to 72 stations maximum, using modules of 8 stations. Total number of station outputs, for each satellite, shall be as shown on the drawings and/or as directed. The decoder-based system shall have the capacity to control a maximum of 2,000 (using 4 LDI interface units in Hybrid mode) single decoders and activate up to 4,000 solenoids.

Continuous on-line two-way communication, between central computer/interface unit and the field satellite or decoder units, shall provide true central control. Continuous field unit feedback status information shall be registered at the computer and also at the satellite interface unit. Cirrus shall be a program/schedule-based system providing maximum flexibility of programming and giving the operator absolute and full control of the entire system. The Cirrus system shall be capable of unlimited programs residing in the system at one time. Each program shall be further defined by a number of smaller schedules. A maximum of fifty (50) programs and up to 50 schedules may be operated simultaneously. All programming shall be maintained in the computer memory and on the hard drive, from which they shall be executed. Programming shall NOT be downloaded to the field units. It shall NOT be possible to change or reprogram from the field thus assuring the operator full control at all times. A time window may be defined for each individual program, confining its operation to this specific time period. Individual schedules shall be capable of being designated for up to 12 start times within the specified time window for their program. Individual programs shall be capable of being designated for up to 6 start times. It shall be possible to designate the sequence of operation of areas and the sequence of operation of stations in these areas, within a given schedule.

The Cirrus system shall provide for the selection of three (3) different flow measurement units —U.S. gallons per minute, cubic meters per hour or liters per second. It shall also provide for the selection of any one of eight (8) different languages for display.

A built-in Flo-Manager® feature shall automatically distribute and limit flow within the system, to eliminate hydraulic overload while maintaining maximum system operating efficiency. The system shall also be capable of entering complete flow management database information for up to six (6) independent pump stations; up to 250 piping network branches and up to 500 flow zones for each pump station. The system shall allow the use of a pump station monitoring software capable of providing real time data exchange with the Smart Pump feature. This shall result in the highest efficiency of pump station operation, shortest watering cycle time and conservation of water and energy. During operation, individual flow graphs shall be automatically generated, for each of the three (3) courses, with individual station activity information being presented in colorful charts. Flow graphs shall be automatically maintained on file for future access and reference.

A Rain Watch feature shall provide an intelligent rainfall reaction. The Rain Watch feature shall be capable of suspending irrigation during intermittent rainfall, and then resume irrigation with station runtimes reduced an amount equivalent to the rain that has fallen. The Rain Watch feature shall also be capable of canceling irrigation for a user definable time in the event of extended rainy conditions. To use the Rain Watch feature up to four tipping bucket rains shall be installed with one Rain Bird pulse decoder for each rain can.

The Cirrus SmartWeather™ scheduling shall monitor and respond to climactic conditions as they occur by tracking evapotranspiration (ET) rates and other sensory inputs. SmartWeather shall also track weather conditions for future reference. SmartWeather shall provide automatic response from user defined thresholds on up to 5 Weather Stations. The SmartWeather responses shall be provided to the computer for programmed response and shall be capable of sending an alphanumeric page email or text message to the user for alarm conditions.

In addition to calculating runtimes based on measured weather parameters, a Minimum ET function shall be provided which can delay program activation until a user-determined minimum ET threshold has accumulated.

The Cirrus system shall also provide for programs to be set to adhere to manual water budgeting; at the system level, at the individual program level and/or at the individual schedule level. A Watersaver™ feature shall provide water budgeting capabilities from 0 to 300% in 1% increments. Automatic rain shutdown shall be possible with the integration of a rain sensor.

The Cirrus CYCLE + SOAK™ feature should achieve maximum efficiency and water conservation. It helps control water application on slopes and in areas with poor drainage.

A dry run feature shall provide for testing of a program and will allow the user the ability to make necessary adjustments before actual operation. A printout of the dry run results shall be possible, as well as being displayed on the monitor.

A guided initialization and start-up programming method in Cirrus shall result in a customized Quick Start™ program that gets the system up and operating in a short time. Built-in rotor database tables shall provide for easy specification of station sprinklers for custom irrigation scheduling. Precipitation rates for each station shall be automatically calculated with the selection of sprinkler model, pattern and spacing. A graphic display of the golf course can be achieved using any of three (3) methods: (1) Import GPS and AutoCAD as-built drawings, (2) Create a map using the Scorecard function, or (3) Import a picture of the course as a bmp or tif drawing file. When importing AutoCAD as-built drawings, all layers of the original AutoCAD files shall be available to the user as layers in Cirrus. The layers shall provide the user the ability to measure distance and calculate areas using Rain Bird's map utilities. Each hole can be defined to indicate the areas to be irrigated such as green, tees, fairways, approaches, perimeters, roughs and miscellaneous areas. Alternatively, if you prefer, user-defined names may be used. The system shall provide for multistation programming and operation of satellite stations. A station data table shall give complete database information for each individual station. A unique QuickIRR™ method of programming shall provide for a quick and easy method to automatically build programs to meet all irrigation challenges and allow programming by specific areas and designating sequence of operation of these areas.



The Cirrus system shall be capable of direct manual access of any station, at any time. Full system remote control shall be possible with the integration of The FREEDOM™ System as well as the FREEDOM-Pad. The Cirrus system shall provide for individual course, daily and seasonal logs for record keeping and easy compliance with regulatory requirements regarding water usage. A unique Cost Estimator feature shall provide projections of water and power costs for specific irrigation cycles.

The Cirrus decoder-based system shall provide an automatic decoder and line condition testing program, for easy check-out and troubleshooting of the system.

Hardware—Computer—Furnish and install at the central location a Rain Bird “P” Series computer system, consisting of the following minimum specifications:

2.4 GHz Pentium® 4 processor
512 MB SDRAM
20 GB EIDE Hard Drive
1.44 MB floppy disk drive
Microsoft® PS2 Intellimouse
56K Internal Modem
DVD/CD ROM–R/W

32 MB Video Card
Sound card
Speakers
Quiet Key 104 keyboard
USB to Serial Adapter
Color monitor

Preinstalled software shall consist of:
The Rain Bird Cirrus program
Map Import Software
PcAnywhere Communication software
Microsoft® Windows® XP Professional

Voltage Stabilizer—At the central location, furnish and install a combination voltage stabilizer and uninterruptible power source unit. Unit shall have a rated output of 600VA and 400 Watts. It shall be suitable for 50/60 Hz operation with input power of 120VAC. Battery back-up shall have a minimum time of approximately 12 minutes minimum at half load capacity. The unit shall have four (4) electrical outlets.

Power Surge Arrestor—At the main electrical panel and on the circuit supplying the central equipment. Furnish and install a Model “Z1” Zap Trap surge arrestor. Unit shall be for 120 Volt, single-phase power rated for 100 Amps. It shall have a discharge

capacity of 15,000 Amps at an 8 x 20 second pulse. It shall have a clamping voltage of 130 Volts and a response time of 1.5 N/sec. Surge arrestor shall be as manufactured by Tyte-wadd Power Filters, www.tytwadd.com; phone 417-887-3770.

System Grounding System—At the central control location, as close to the Interface unit as possible, install a grounding system. Install a standard 12" x 18" x 12" rectangular valve box around the top of any connections in the grounding system to a surge arrestor, the grounding lug of a piece of equipment or an MGP-1 grounding plate assembly. This shall provide future access to inspect and/or maintain it properly.

A #10 gauge or larger bare copper ground wire shall be run from the grounding lug of the MIM or MIM LINK interface unit or from the LDI in a decoder-based system, out and attached to the grounding system. On each two-wire path, coming from the interface unit or line termination box and going out to the field satellite units or the field decoders. Furnish and install an MSP-1 surge arrestor, which is to be mounted in an MGP-1 grounding plate assembly that is securely attached to the grounding system. Connect



the MSP-1 arrestor into the two-wire path. A 10 OHMS or less resistance shall be maintained at the grounding system.

Hard-Wired Interface Unit—(two-wire satellite system)—The interface unit shall be a Rain Bird Interface Module (MIM) unit with all solid-state electronic circuitry. It shall provide the necessary interface between the computer and the field satellite units. The interface unit shall provide both communication from the computer out to the field satellite units and feedback communication from the field satellite units to the computer. It shall be capable of controlling four (4) two-wire paths of 28 independent channels each. Status lights shall indicate activity on the two-wire paths, as well as to channels being operated on the various two-wire paths and the individual stations in operation on each of these channels. A memory switch shall provide for past performance data. The MIM unit shall be complete with a power supply cord and an RS-232-C communication cable to be connected between it and the serial port of the computer. The unit shall be mounted near the central computer. A #10 gauge or larger bare copper ground wire from the ground lug of the MIM unit shall be attached to the grounding system.

LINK Interface Unit—(radio LINK satellite system)—The interface unit shall be a Rain Bird MIM LINK unit with all solid-state electronic circuitry and two-way radio and receiver, with _____ radio frequency. It shall provide the necessary interface between the computer and the LINK field satellite units. The interface unit shall provide true two-way radio communication from the computer out to the LINK field

satellite units and feedback radio communication from the Link field satellite units to the computer. It shall be capable of controlling up to 112 LINK satellites within a maximum of four (4) groups. The MIM LINK unit shall be complete with a power supply cord and an RS-232-C communication cable to be connected between it and the serial port of the computer. The unit shall be mounted near the central computer.

Furnish and install, outside on the building or on an antenna tower, near the central equipment location a Rain Bird model "ANT-02", "ANT-03" or Yagi type antenna. An RG8 type coaxial cable shall be attached to the antenna and routed into the building near the floor and near the MIM LINK unit location. Furnish and install, inside the building on the wall near the floor, a PolyPhaser Model IS-IE50LU-C1 surge arrestor to which the coaxial cable shall be connected to the antenna terminal on this surge arrestor. Furnish and install from the equipment terminal of the surge arrestor an RG8 type coaxial cable and connect it to the coaxial cable connection on the MIM LINK interface unit. Connect a #10 gauge or larger bare copper ground wire to the antenna and a second ground wire to the ground lug on the surge arrestor. Route each of these ground wires and connect them to the grounding system. Furnish and install all necessary mounting clamps, brackets, etc. as may be required for the antenna, coaxial cable, ground wires and the surge arrestor. A #10 gauge or larger bare copper ground wire from the ground lug of the MIM LINK interface shall be attached to the grounding system

Decoder Interface Unit—(decoder-based system)—The interface unit shall be a Rain Bird Large Decoder Interface (LDI) unit with all solid-state electronic circuitry. It shall provide the necessary interface between the computer and the field decoder units. The interface unit shall provide both communication from the computer out to the field decoder units and feedback communication from the field decoder units to the computer. It shall be capable of controlling, over a two-wire path, up to 500 (max.) single decoders and up to 1,000 (max.) solenoids. The LDI unit shall be complete with 117 VAC power supply cord and a communication cable, which shall be connected between the LDI interface unit and the serial port of the computer.

Connect a #10 gauge or larger bare copper ground wire to the ground lug of the LDI and route it out and connect it to the grounding system.

PAR+ES Field Satellite Units—(hard wired PAR+ES satellite system)—Furnish and install where shown on the drawings and/or where directed, Rain Bird model PAR+ES two-wire field satellite controllers. Furnish and install each basic satellite field unit for the total number of station outputs indicated on the drawings.

PAR+ Field Satellite Units—(hard-wired PAR+ satellite system)—Furnish and install where shown on the drawings and/or where directed, Rain Bird Model PAR+ PP (plastic pedestal) or PAR+ SS (stainless steel pedestal), two-wire field satellite controllers. Furnish and install each basic satellite field unit for the total number of station outputs indicated on the drawings and/or as directed.



MSC+ Field Satellite Units—(hard-wired MSC+ satellite system)—Furnish and install, where shown on the drawings and/or where directed, Rain Bird Model MSC+ PP (plastic pedestal) or MSC+ SS (stainless steel pedestal), two-wire field satellite controllers. Furnish and install each basic satellite field unit for the total number of station outputs indicated on the drawings and/or as directed.

PAR+ ES LINK Field Satellite Units—(radio PAR+ES LINK satellite system)—Furnish and install where shown on the drawings and/or where directed, Rain Bird Model PAR+ES LINK, radio LINK type field satellite units. Those satellite units with radio modem units shall be furnished with dome hood type antennas. Furnish and install each basic satellite field unit for the total number of station outputs indicated on the drawings. For those units indicated on the drawings, furnish and install CAM LINK units.

PAR+ LINK Field Satellite Units—(radio PAR+ LINK satellite system)—Furnish and install, where shown on the drawings and/or where directed, Rain Bird Model PAR+ LINK PP or PAR+ LINK/R PP (plastic pedestal) or PAR+ LINK SS or PAR+ LINK/R SS (stainless steel pedestal), radio LINK type field satellite controllers. Those satellite units, with radio/modem units, shall be furnished with dome hood type antennas. Furnish and install each basic satellite field unit for the total number of station outputs indicated on the drawings and/or as directed. For those units indicated on the drawings, furnish and install CAM LINK units.

MSC+ LINK Field Satellite Units—(radio MSC+ LINK satellite system)—Furnish and install, where shown on the drawings and/or where directed, Rain Bird Model MSC+ LINK PP or MSC+ LINK/R PP (plastic pedestal) or

MSC+ LINK SS or MSC+ LINK/R SS (stainless steel pedestal), radio LINK type field satellite controllers. Those satellite units, with radio/modem units, shall be furnished with dome hood type antennas. Furnish and install each basic satellite field unit for the total number of station outputs indicated on the drawings and/or as directed. For those units indicated on the drawings, furnish and install CAM LINK units.

Field Decoder Units—(decoder-based system)—Furnish and install, where shown on the drawings and/or where directed, Rain Bird Model FD-101, 102, single decoders, FD-202, double address decoders, FD-401, four address decoders, or FD-601, six-pack decoders. All types of decoders shall be solid-state electronic circuitry and epoxy potted in a sturdy plastic case suitable for direct burial. Each decoder shall be factory set for a specific response code with code number permanently and prominently marked on the decoder case. Also furnish and install in the two-wire path, where shown on the drawings, Rain Bird Model LSP-1 surge arrestors. One LSP-1 ground wire shall be attached to the solenoid core tube and the other to a 4' copper ground rod, installed near the LSP-1 surge arrestor.

Wire—(hard-wired satellite system and decoder-based system)—Furnish and install, for the two-wire communication paths, double jacketed type wire, consisting of two tin-coated type UF insulated (4/64" PVC), soft drawn, annealed solid copper conductors. The two conductors shall be color-coded (one RED the other BLACK). The second outer jacket shall be a solid color, high density, polyethylene insulation. Jacket colors and conductor sizes shall be as shown on the drawings.

Weather Station—Furnish and install, where shown on the drawings, a Rain Bird Model WS PRO SH, direct hard-wired, Model WS PRO PH remote telephone operated or WS PRO LT radio operated, On-Site Weather Station. The station shall monitor the following daily critical weather conditions: wind direction, wind speed, solar radiation, air temperature, relative humidity and rainfall. In the SH and PH stations, sensors shall be polled every 5 seconds and the data recorded in a micrologger located in the Weather Station mast. The SH and PH weather stations shall be furnished complete with a transformer and a 12-Volt battery. The WS PRO SH shall also include calling and answering modems. The WS PRO PH shall include an answering modem. The WS PRO LT shall include calling and answering radio transceivers. For the WS PRO PH unit, furnish and install a modem and a dedicated phone line at both the computer location and the Weather Station location. For the WS PRO SH unit, the communication wire between Weather Station and central computer shall be Belden #9883 direct burial type cable, consisting of three twisted wire pairs and with metal shield. Furnish and install the necessary MSP-1 surge arrestors, to be wired into the communication wire paths and power wires, at both the Weather Station location and at the central equipment location, as well as the required MGP-1 grounding plate assemblies.

Furnish and install a grounding system, at the Weather Station location, the same as previously specified for the central grounding system.





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New Rain Bird Golf Rotors With Full- and Part-Circle Performance

Omni Tucson National
Tucson, Arizona



Rain Bird® 700 and
751 Series Golf Rotors

Unmatched Durability, Uniformity and Now, Versatility

Now more than ever, performance matters

Make the most of every rotor with new Rapid-Adjust Technology featuring MemoryArc.™ Available on new Rain Bird® 751 Golf Rotors, this innovative feature allows you to easily adjust watering on greens, fairways or roughs for unmatched versatility and precise control. Offering proven Rain Bird durability and distribution uniformity, these cost-efficient rotors are also backward-compatible with existing Rain Bird rotor cases. Doing more when it matters most. That's The Intelligent Use of Water.™

Turn-of-a-Screw Versatility

Your course's watering needs seem to change by the day. Now your watering arc can change with them. Unlike competitive products, Rain Bird® 751 Golf Rotors offer easy, top-adjustable rotation settings that retain the memory of their part-circle arc setting when shifting between full- and part-circle operation. This unique feature is designed to offer quick, dry arc adjustments not just during grow-in, but for the life of the rotor. So whether you need to ramp up watering during fertigation or conserve water in response to water restrictions, you can do it all with just a simple twist of your wrist.

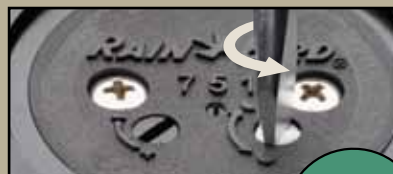
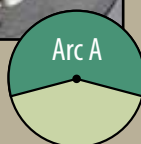
One twist and you'll see how we've once again brought The Intelligent Use of Water™ to life. Thanks to Rapid-Adjust technology featuring MemoryArc,™ Rain Bird® 751 Golf Rotors enable you to water your turf more precisely—and efficiently.



Introducing Rapid-Adjust Technology featuring MemoryArc™



Set primary rotor arc.

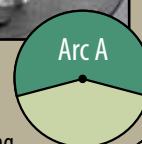


Turn the Full/Part Adjustment Screw for full-circle operation.

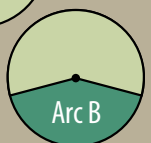


Turn to part circle again for either Arc A or Arc B setting.

No need to adjust arc when going between full- and part-circle settings.



or



More versatility. Less wire. Upgrade to the ultimate in flexibility and simplicity—order your Rain Bird® 700 and 751 Golf Rotors with optional Rain Bird® IC™ System functionality. Learn how ICS helps you use up to 90% less wire at www.rainbird.com/ICS

Proven Rain Bird Performance

New Rain Bird® 700 Series Golf Rotors feature the same highly efficient nozzle performance you've come to expect from the industry leader and deliver the best performance yet from Rain Bird golf rotors. With large droplets that cut through harsh winds and reliable and consistent pressure regulation, Rain Bird rotors deliver the even distribution you need to guarantee a healthy playing surface.

Industry-Leading Durability

You never take a day off. Neither should your rotor. Driven to deliver, built to take a beating, Rain Bird® 700 Series Golf Rotors deliver improved durability. Trust their rugged construction for year after year of reliable, hassle-free performance.

Backward Compatibility

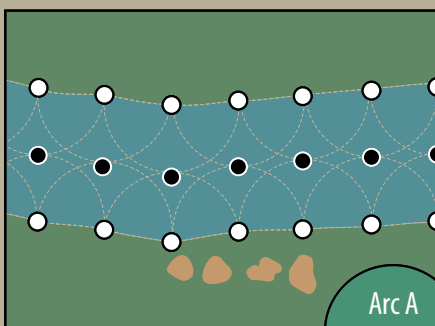
Already have Rain Bird rotors installed on your course? New Rain Bird® 700 Series Golf Rotors offer backward compatibility with every 700 Series EAGLE™ Rotor manufactured since 1992. Saving precious time and money is as simple as dropping new Rain Bird® 700 Series internal assemblies into your existing rotor cases.



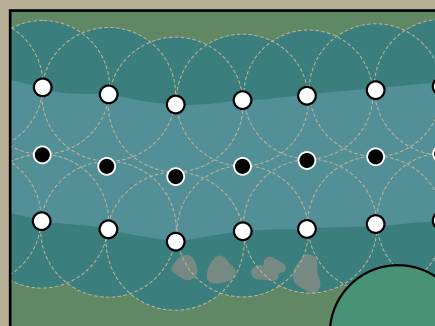
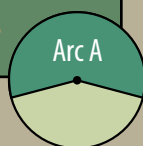
Low Cost of Ownership

These days, everyone can appreciate the value of a wise purchasing decision. All things considered, Rain Bird Golf Rotors offer a low cost of ownership through a powerful combination of versatility, performance and durability. So make the most of every dollar—install 700 and 751 Golf Rotors to optimize water consumption, simplify operation and minimize replacement, maintenance and inventory costs.

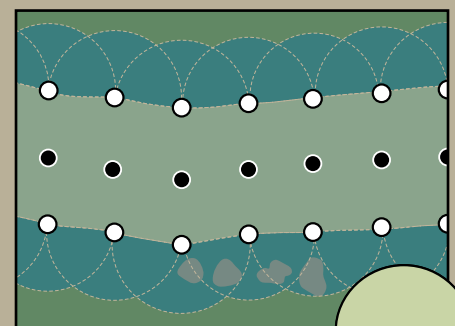
Learn more about NEW, versatile Rain Bird® 751 Golf Rotors at www.rainbird.com/twist



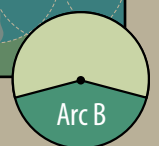
Part-circle fairway



Full-circle coverage



Part-circle rough



With a twist of your wrist, shift between three arc settings to selectively water fairways, roughs—or both.

The Intelligent Use of Water.™

LEADERSHIP • EDUCATION • PARTNERSHIPS • PRODUCTS

At Rain Bird, we believe it is our responsibility to develop products and technologies that use water efficiently. Our commitment also extends to education, training and services for our industry and our communities.

The need to conserve water has never been greater. We want to do even more, and with your help, we can. Visit www.rainbird.com for more information about The Intelligent Use of Water.™



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TEST SITE REPORT

Rain Bird 700 and 751 Series Rotors Test Site Report



Turn-of-a-Screw Versatility

Your course's watering needs seem to change by the day. Now your watering arc can change with them. Unlike competitive products, Rain Bird® 751 Golf Rotors offer easy, top-adjustable rotation settings that retain the memory of their part-circle arc setting when shifting between full- and part-circle operation. This unique feature is designed to offer quick, wet or dry arc adjustments not just during grow-in, but for the life of the rotor. So whether you need to ramp up watering during fertigation, reduce the watering area following overseeding, or conserve water in response to water restrictions, you can do it all with just a simple twist of your wrist.

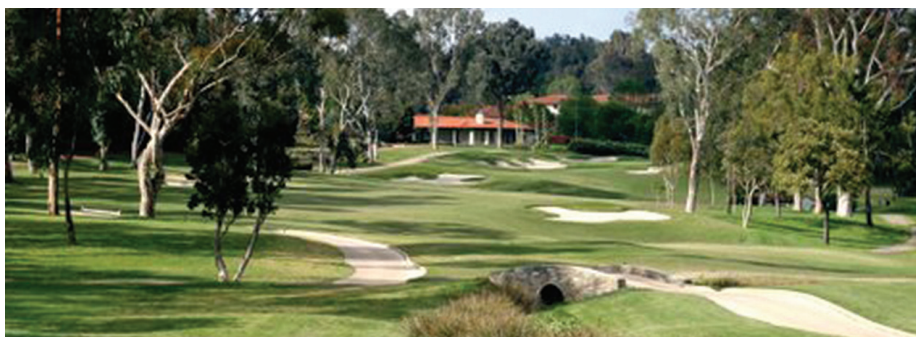


Rain Bird Corporation - Golf Division has released a NEW generation of golf rotors. Rain Bird® 700 and 751 Series Golf Rotors provide true versatility with unmatched durability and uniformity. The Rain Bird® 751 Series rotor offers the world's easiest Full- and Part-Circle adjustment with a simple turn of a screw. It delivers truly versatile customer benefits and is backwards compatible with Rain Bird® EAGLE 700 cases.

During an extensive product development process, Rain Bird subjects rotors to a broad range of tests in our Product Research Center. This testing ensures that the final product is durable and reliable. Along with other tests, rotors are subjected to a variety of temperatures, pressures, life cycles, and water quality.

The real test is when rotors are installed on a golf course under widely varying conditions. Rain Bird 700 and 751 Series Golf Rotors have been field tested on more than 15 Golf Courses around the world, many of them for over a year, to ensure that when the rotor is released to market, it is ready for your course.

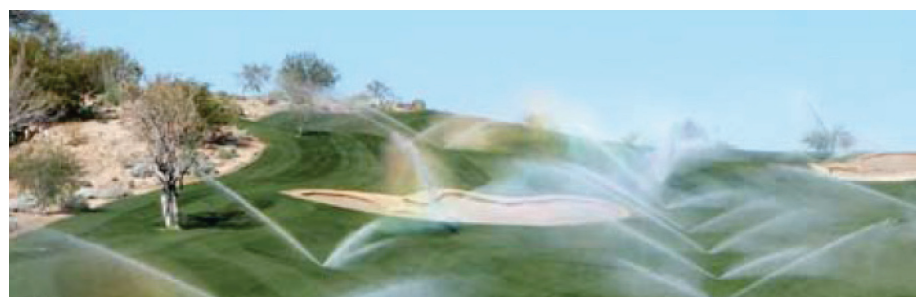
Here's what a few of the field test sites have to say about their experience with the new 700/751 Series rotors:



Rancho Santa Fe Golf Club – Rancho Santa Fe, CA

Superintendent Tim Barrier:

"The 751s have really worked well for us. We can focus more water toward our cool season grasses and away from the bermuda which is more drought resistant. In the past the outer rough would decline, this year we have much healthier conditions."



The Views Golf Club at Oro Valley – Oro Valley, AZ

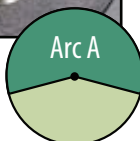
Superintendent Michael Kropf:

"During overseeding the ability to change a full circle to a part circle saves a lot of water on partial overseed. The new Rain Bird 751 is fast and easy to adjust."

Rapid-Adjust Technology featuring MemoryArc™



Set primary rotor arc.



Turn the Full/Part Adjustment
Screw for full-circle operation.

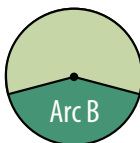


Turn to part circle again for
either Arc A or Arc B setting.

No need to adjust arc when
going between full and
part circle settings.



or



Brownwood Country Club – Brownwood, TX

Superintendent Scott Kemp:

"We used to change out full circle internals to part circle internals for part of the year, the new full and part in one is a great enhancement and time saver. I find the new Rain Bird 751 to be versatile and easy to adjust. Also, we found the distribution and uniformity of the new nozzles to be even better."



Stone Canyon Club – Oro Valley, AZ

Director of Golf Course Operation – Terry Todd:

"We used to change our internals during certain times of the year to conserve water. The new Rain Bird 751 is very versatile and has allowed us to quickly and easily change from full to part circle without having to inventory any additional parts. The flexibility this new sprinkler provides is exactly what golf courses are looking for; I think that this product will be a big hit with superintendents."

Please contact your local Rain Bird Golf distributor, or visit www.rainbird.com/twist for more details on this exciting new product.

Rain Bird Corporation

Golf Division

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Tucson, AZ 85756

Phone: (520) 741-6100

Fax: (520) 741-6522

www.rainbird.com

WS-PRO Weather Stations

Optimize Irrigation With Automatic Weather-Sensitive Scheduling

The WS-PRO2 and WS-PRO LT Weather Stations collect and store weather data from field locations. This information is retrieved by the Central Controller daily, allowing SiteControl, IQ v2.0, and Maxicom²® (WS-PRO2 only) to adjust station run time and/or schedule day cycle frequency according to each day's ET (evapotranspiration) and rainfall.

WS-PRO Weather Stations are highly accurate, durable, and reliable. They are built using the highest quality sensors available and will provide years of reliable data even in the toughest environments. An on-board data-logger continually polls the sensors which measure air temperature, relative humidity, wind speed and direction, rainfall and solar radiation.

Weather Station Features

- Rugged yet lightweight metal construction
- Powerful internal micro-logger for data collection, logging, analysis, constant communication with sensors, and storage of 30 days of data
- Sensors monitor 6 ET/weather parameters: air temperature (high & low), solar radiation, relative humidity, wind speed, and rainfall – Wind direction is also measured
- Sensors located 3 meters above ground for added vandal resistance
- Simple-to-service sensors and internal components
- Self-diagnostic test mechanisms: internal moisture, battery voltage level, and test port for local sensor check
- Internal battery charged by 100-240 VAC/16 VDC transformer or optional solar panels

SiteControl Features

- WS-PRO2 and WS-PRO-LT Weather Station compatibility is standard for SiteControl v3.0 or later software
- SiteControl can interface with up to 6 weather stations
- Automatic communication between Central Controller and Weather Station requires SiteControl Automatic ET Software Module
- SiteControl Smart Weather Software Module enables automatic, user defined reactions to weather events (rain, freeze, high wind, etc.)

IQ v2.0 Features

- WS-PRO2 or WS-PRO-LT Weather stations are compatible with IQ v2.0 or later software
- Automatic communication between the IQ v2.0 central and weather station requires the Advanced ET feature pack (IQAETFP)
- Weather data retrieval hourly up to 24 times a day or custom retrieval times up to 5 per day

Maxicom²® Features (WS-PRO2 only)

- WS-PRO2 Weather Station compatibility is standard for Maxicom²® v3.6 or later software
- Each site can have its own Weather Station or can share between sites
- Automatic communication standard
- Up to 24 automatic weather data retrievals can be configured per day

Models

- WS-PRO2-DC Direct Connect model – 2-pair wire connection with Central Controller via short-haul modem
- WS-PRO2-PH Phone Connect model – dial-up phone modem for phone communication with Central Controller
- WS-PRO2-PHS Phone Connect, Solar Power model – dial-up phone modem for phone communication with Central Controller, solar powered
- WS-PRO-LT-SH Short Haul model – 2-pair wire connection with Central Controller via short-haul modem
- WS-PRO-LT-WL Wireless model – wireless connection with Central Controller via 916 MHz radio (only available in the U.S. and Canada)
- WS-PRO-LT-WLS Wireless model – wireless connection with Central Controller via 916 MHz radio, solar powered (only available in the U.S. and Canada)

WS-PRO2 Specifications

Air Temperature Sensor:

- Range: -13° to +122°F (-25° to +50°C)
- Accuracy: +/- 2.7°F (+/- 1.5°C)

Relative Humidity Sensor:

- Range: 0 to 100%
- Accuracy: +/- 6% @ 90% to 100% RH, +/- 3% @ 0% to 90% RH



Rain Gauge Sensor:

- Resolution: 0.01" (0.25 mm)

Solar Radiation Sensor:

- Accuracy: ± 3%

Wind Speed Sensor:

- Starting threshold: 0.9 mph (0.4 m s⁻¹)

Wind Direction Sensor:

- Range: 360° mechanical, 356° electrical, accuracy ± 4°

WS-PRO2 Electrical Specifications

- **Input required:** 9.6 to 16VDC from transformer (100-240 VAC/16 VDC transformer provided with powered stations) or solar panels
- **Power backup:** "Gel-cell" 12 VDC battery (provided with station)

How To Specify

WS - PRO2 - PHS

Series WS		Power Type Blank: User Supplied S: Solar Powered
		Connection Type DC: Direct Connect PH: Phone Modem* SH: Short Haul Modem WL: Wireless
	Model PRO2: Professional Series PRO LT: Professional Light Series	

* Only available on WS PRO2 models.

WS-PRO LT Specifications

Air Temperature Sensor:

- Range: -40° to +122° F (-40° to +50° C)
Accuracy: $\pm 0.9^{\circ}\text{F}$ ($\pm 0.5^{\circ}\text{C}$)

Relative Humidity Sensor:

- Range: 0 to 100%
Accuracy: $\pm 5\%$ - 90% to 100% RH
- $\pm 3\%$ - 10% to 95% RH

Rain Gauge Sensor:

- Resolution: 0.04" (1 mm)

Solar Radiation Sensor:

- Accuracy: $\pm 2.5\%$

Wind Speed Sensor:

- Starting threshold: 0.78 ms-1 (1.75 mph)

Wind Direction Sensor:

- Range: 360° mechanical, 352° electrical

WS-PRO LT Electrical Specifications

• Input required:

16 to 22VDC from transformer (100-240 VAC/16 VDC transformer provided with powered stations) or solar panels

- **Power backup:** "Gel-cell" 12 VDC battery (provided with station)

Specifications

Model WS-PRO2-DC, WS-PRO-LT-DC

The central control system shall include an on-site weather station where shown on the plans and specifications. The unit shall be complete with the necessary instruments for recording wind run, wind direction, relative humidity, rainfall, solar radiation, and high and low temperature. A micro-logger shall continuously poll and record the data every 5 seconds.

Short-haul modems shall be used for communication between the computer and weather station. Two twisted-pair wires (4 wires total) shall be furnished for both connection to the weather station and the central controller short-haul modem. This communication path shall not exceed 20,000 feet in total length.

The unit shall be complete with a 100-240 VAC/16VDC transformer. A 120 VAC power connection shall be furnished at the transformer location.

The weather station shall be mounted on a poured concrete base and securely bolted to it. If the weather station is installed in an unsecured area, install inside a 6'-0" high (minimum) security fence with access gate. And all sides must be at least 8'-0" out from the weather station base. The security fence shall be such as not to interfere with the correct readings of the instruments.

Surge protection shall be provided for the 16 VDC power supply to the weather station. Surge protection shall be provided for the 2 twisted-pair communication lines installed for both the weather station short-haul modem and the central controller short-haul modem. The weather station shall be grounded to an earth ground. The earth ground network shall be 10 ohms or less when tested with a ground measuring device.

The weather station shall be as manufactured for Rain Bird Corporation Glendora, California.

Model WS-PRO2-PH / -PHS

The central control system shall include a remote connected weather station where shown on the plans and specifications. The unit shall be complete with the necessary instruments for recording wind run, wind direction, relative humidity, rainfall, solar radiation, and high and low temperature. A micro-logger shall continuously poll and record the data every 5 seconds.

Telephone modems shall be used for communication between the computer and weather station. A dial-up telephone line shall be furnished for both connection to the weather station modem and the central controller modem.

The unit shall be complete with a 100-240 VAC/16 VDC transformer. A 100-240 VAC power connection shall be furnished at the transformer location. If the solar powered model is specified power is not required at the weather station.

The weather station shall be mounted on a poured concrete base and securely bolted to it. If the weather station is installed in an unsecured area, install inside a 6'-0" high (minimum) security fence with access gate. And all sides must be at least 8'-0" out from the weather station base. The security fence shall be such as not to interfere with the correct readings of the instruments.

Surge protection shall be provided for the 16 VDC power supply to the weather station. Surge protection shall be provided for the telephone communication lines installed for both the weather station modem and the central controller short-haul modem. The weather station shall be grounded to an earth ground. The earth ground network shall be 10 ohms or less when tested with a ground measuring device.

The weather station shall be as manufactured for Rain Bird Corporation Glendora, California.

Rain Bird Corporation

6991 E. Southpoint Road
Tucson, AZ 85756
Phone: (520) 741-6100
Fax: (520) 741-6522

Rain Bird Technical Services

(800) RAINBIRD (1-800-724-6247)
(U.S. and Canada)

Rain Bird Corporation

970 West Sierra Madre Avenue
Azusa, CA 91702
Phone: (626) 812-3400
Fax: (626) 812-3411

Specification Hotline

800-458-3005 (U.S. and Canada)

Rain Bird International, Inc.

1000 West Sierra Madre Ave.
Azusa, CA 91702
Phone: (626) 963-9311
Fax: (626) 852-7343

The Intelligent Use of Water™
www.rainbird.com



Map & Directions



2500 Honoapiilani Highway, Wailuku, Maui, HI 96793

The King Kamehameha Golf Club is conveniently located at Waikapu, just 10 minutes from Kahului Airport and 30 minutes from the Wailea and Ka'anapali Resort Hotels.

From Kahului Airport:

- Exit the airport and continue straight onto Dairy Road (HI-380) for 6.2 miles.
- Turn right onto Honoapiilani Highway (HI-30) for 2.8 miles.
- Entrance will be on your left.

From Wailea:

- Follow Piilani Highway (HI-31) north.
- Follow Piilani Highway as it becomes N. Kihei Road (HI-310) for 3.5 miles.
- Turn right onto Honoapiilani Highway (HI-30) for 3.1 miles.

From Ka'anapali:

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Golf Course

Hugging the gentle slopes nestled amidst the deeply etched West Maui Mountains, with views of the lush green expanse connecting two ancient volcanoes, this exclusive private membership course was originally designed by Ted Robinson Sr. and refreshed by Ted Robinson Jr.

[take a course tour >](#)



GOLF COURSE

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*Experience...
Maui's pure golf lifestyle!*



GOLF + CART

\$225+
per round+tax

Limited tee times available

*Price subject to change without notice

☎ 808.249.0033

[Reservations ▶](#)



3 ROUND PACKAGE

Offer valid until 4/30/16

KAHILI MAHALO TICKET

Visitor \$345/Resident \$250

**2 x Kahili Golf Course
1 x The King Kamehameha G.C.**

Price subject to change without notice



808.242.GOLF 4653

The King Kamehameha Golf Club
2500 Honoapiilani Highway
Wailuku, Maui, Hawaii 96793

Phone: 808.249.0033
info@kamehamehagolf.com
infojp@kamehamehagolf.com



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The King Kamehameha Golf Club is Maui's only 18-hole private golf course. The course hugs the gentle slopes of West Maui Mountains, with ocean views of both the North and South shores of Maui. The 74,000 sq.ft. clubhouse is designed from plans by Frank Lloyd Wright.

web design Websites Hawaii

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Course Tour

Par: 72 Hole:18

Designed by Ted Robinson Sr. in 1991 and refreshed in 2005 by Ted Robinson Jr.

Hugging the gentle slopes nestled amidst the deeply etched West Maui Mountains, with views of the lush green expanse connecting two ancient volcanoes, this exclusive private membership course was originally designed by Ted Robinson Sr. and refreshed by Ted Robinson Jr.

Hover over the numbers to view each hole.



GOLF COURSE

[Course Design](#)

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*Experience...
Maui's pure golf lifestyle!*

GOLF + CART **\$225+**
per round+tax
Limited tee times available
*Price subject to change without notice

808.249.0033 [Reservations](#)

3 ROUND PACKAGE
Offer valid until 4/30/16

KAHILI MAHALO TICKET
Visitor \$345/Resident \$250
2 x Kahili Golf Course
1 x The King Kamehameha G.C.
Price subject to change without notice

808.242.GOLF 4653

The King Kamehameha Golf Club
2500 Honoapiilani Highway
Wailuku, Maui, Hawaii 96793

Phone: 808.249.0033
info@kamehamehagolf.com
infojp@kamehamehagolf.com



The King Kamehameha Golf Club is Maui's only 18-hole private golf course. The course hugs the gentle slopes of West Maui Mountains, with ocean views of both the North and South shores of Maui. The 74,000 sq.ft. clubhouse is designed from plans by Frank Lloyd Wright.

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[Home \(http://www.hawaiiigolf.com/\) » Golf Photo Galleries \(/photo-galleries/\)](#)

Kahili Golf Course on Maui

Located on the slopes of the West Maui Mountains, **Kahili Golf Course**

(<http://www.hawaiiigolf.com/courses/wailuku/kahili-gc/>) showcases picturesque views of the regal Haleakala and Pacific Ocean from many spots of the golf course.

Designed by architect Robin Nelson and Rodney Wright, Kahili G.C. opened in 1991 and plays a max of 6,570 yards from the championship tees.

Set on the slopes, there are a great deal of elevation changes and few flat lies. The four par 5s are short enough to afford longer hitters the chance to go for two, pending of course the strength of the trade winds, which must always be accounted for on a [Hawaii golf course \(http://www.hawaiiigolf.com/courses/\)](http://www.hawaiiigolf.com/courses/).

Considered one of Maui's better value plays, Kahili also features full practice facilities as well as a large clubhouse with banquet room and restaurant. [[read less](#)]



Kahili Golf Course on Maui - No. 1 (Courtesy of Kahili G.C.)

Kahili Golf Course's first and third holes play parallel with one another on the mountain slopes.



email address



Related Links

Kahili Golf Course (<http://www.hawaiiigolf.com/courses/wailuku/kahili-gc/>)

(based on 10 reviews)

[See all reviews \(http://www.hawaiiigolf.com/courses/wailuku/kahili-gc/#ratings-12754\)](#) | [Submit your rating](#)

(<http://www.hawaiiigolf.com/courses/rating/new/12754>)

For visitors to the West Maui Mountains, Kahili Golf Course is a must-play. Visiting and local golfers alike are fond of Kahili, a picturesque course with views of the Pacific Ocean. The 6,554-yard, par-72 course is a challenge, with elevation changes, hilly par 3s and long par 5s.

18 Holes | Public golf course | Par: 72 | 6554 yards | [Book online \(/tee-times/course/?AID=233&FID=2583\)](#) | [... details » \(http://www.hawaiiigolf.com/courses/wailuku/kahili-gc/\)](#)

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SCOTT CARROLL

Scott Carroll, PGA

54 Hui Road F
Lahaina, HI 96761
(808) 870-2551

E-mail: scottiec@pga.com

SUMMARY OF QUALIFICATIONS:

My management and leadership capabilities are complemented by strong ethics and integrity. I collaborate effectively and create healthy relationships that foster growth. I feel it important to care for people and promote a culture of friendliness and professionalism. I look forward to the opportunity to lead King Kamehameha and Kahili Golf and help them surpass their goals; including increasing memberships and driving successful top and bottom line revenues.

RELEVANT EXPERIENCE:

GENERAL MANAGER

06/15-Present

The King Kamehameha Golf Club and Kahili Golf Course – Maui, Hawaii

- Responsible for budget that generated over \$8.6 million in revenues for fiscal year 2014/2015
- Oversee approximately 130 associates and directly manage 10 supervisors or managers
- Develop strategies for sustainability and growth of business
- Create a culture of respect, learning, communication and professional growth for associates.

HEAD GOLF PROFESSIONAL

03/08-05/15

Kapalua Plantation Course – Maui, Hawaii

- Manage a team and staff of both exempt and nonexempt associates; inclusive of guest services supervisors, assistant golf professionals, guest services attendants, starters, and caddies. Collaborate with food & beverage operations, merchandise, maintenance, facilities maintenance, and sales/marketing.
- Oversee multiple facets of the Hyundai Tournament of Champions, formerly known as the Mercedes-Benz Championship, specifically, managing the locker room, the practice facility, the caddies, the all am, pro am, & assist PGA Tour Event Director with Tournament Proper
- Effectively manage a multi million dollar operating budget including total budget goals in excess of \$10 million in revenue for 2015.
- Assists with our merchandise program that has a projected budget goal of \$2.8 million for 2015
- Nominated by our General Manager into the Troon LEADer program. This is a comprehensive training program limited to 12-15 associates within Troon that have qualities and desires to move into General Manager or Director of Golf positions. Successfully completed this program.
- Mentor associates and have overseen assistant golf professionals reach their goal of becoming PGA Members. Reduced turnover of most direct subordinates to those moving on to higher paying positions.

SENIOR GUEST SERVICE SUPERVISOR

11/06-03/08

Kapalua Plantation Course – Maui, Hawaii

- Managed the practice range, locker room, golf car utilization, and bag room throughout the year; including during the PGA Season Opening Tournament- Mercedes-Benz Championship
- Effectively managed thirteen guest service employees (union employees), including payroll responsibilities, scheduling, training, hiring, discipline, staffing utilization, & support.
- Organized and executed 25-35 group outings per year with 16-144 players per group
- Implemented creative solutions to solve problems pertaining to guest experience and operations
- Created and implemented ideas to improve guest service area for employees and customers; including an extensive makeover of staging area, improved practice range operations, & rental program
- Successfully kept inventory of a reasonable amount of all Golf Operations supplies that were utilized between both golf courses while maintaining budget constraints
- Effectively managed a two million dollar budget and assist with the development of budgets

GOLF SHOP MANAGER**4/06 – 11/06*****Kapalua Village Course – Maui, Hawaii***

- Worked directly under the Vice President of Golf and Tennis
- Managed and oversaw yearly budgets for The Village Golf Course (3.3 million)
- Oversaw The Village retail operation (2.3 million)
- Oversaw and managed the outside guest service manager and staff of nine

GUEST SERVICES SUPERVISOR***Kapalua Plantation Course – Maui, Hawaii*****02/06 – 4/06*****Kapalua Village Course – Maui, Hawaii*****12/05 – 2/06*****Kapalua Bay Course – Maui, Hawaii*****06/05-12/05****ASSISTANT GOLF PROFESSIONAL*****Kapalua Village Course – Maui, Hawaii*****03/05 – 6/05****FIRST ASSISTANT GOLF PROFESSIONAL*****Glen Annie Golf Club – Santa Barbara, California*****10/02 – 10/04****GUEST SERVICE ATTENDANT*****Kapalua Golf Resort – Maui, Hawaii*****10/99 – 01/01****PROSHOP ASSISTANT*****The Creek at Qualchan Golf Course – Spokane, Washington*****04/91 – 09/99****EDUCATION:****Graduate of the PGA Professional Golf Management Program**

Attained PGA Membership in December, 2005

PGA Classification: A-1

Bachelors Degree in Business Administration

Eastern Washington University – Graduated June, 1999

JOB SPECIFIC PERSONALITY TRAITS:

- Understand business acumen
- Respect people
- Network well and create lasting relationships
- Show good judgment
- Represent the organization with the utmost professionalism
- Motivate and work cohesively with many different ethnicities and appreciate people of all origins

SPECIAL ACHIEVEMENT:

- Successfully completed the LEADer program designed by Troon to prepare me as a General Manager (2013)

From: Derek Takahashi [<mailto:Derek.Takahashi@co.maui.hi.us>]
Sent: Wednesday, January 13, 2016 9:12 AM
To: Scott C. Carroll
Subject: Re: MMK Maui, L.P. Water

Hi Scott,

The only water source that the County Wastewater Reclamation Division has jurisdiction over is the recycled water that is produced at our wastewater reclamation facilities. Unfortunately, the closest wastewater reclamation facility is located in Kahului, near Kanaha Beach Park, and we do not have any recycled water distribution systems for Central Maui. Thank you for considering using recycled water, however we are not able to provide you with recycled water due to lack of existing infrastructure in Central Maui.

Should you have any questions regarding recycled water, contact me anytime.

Thanks,

Derek Takahashi, P.E.
Recycled Water Coordinator &
Project Manager, Design and Construction Section
Wastewater Reclamation Division
Dept of Environmental Mgmt., County of Maui
Office: (808) 270-5798
Mobile: (808) 344-8241
>>> "Scott C. Carroll" <SCCarroll@kamehamehagolf.com> 1/12/2016 2:51 PM >>>
Aloha Derek,

Thank so much for your time today. I just had a couple of quick follow up questions for you in regards to water availability here at The King Kamehameha Golf Club and Kahili Golf Course.

Do we have any viable and or reasonable alternative sources of non-potable water available to us? If so, what might they be? We are looking for any alternative sources of water that may be available to us? We typically need about 1.2 million gallons of water per day (on average) to operate so that water amount would also have to be sufficient to meet those requirements (if available).

Again, thanks for your time and for any information you can provide?

Scott

Scott Carroll • General Manager • The King Kamehameha Golf Club
Troon • o 808-866-5055 • m 808-870-2551 • sccarroll@troon.com
[Troon.com](#) • [Facebook](#) • [Twitter](#) • [Instagram](#) • [Blog](#)



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COMMISSION ON WATER RESOURCE MANAGEMENT
STATE OF HAWAII

Surface Water use Permit Applications,	)	Case No. <u>CCH-MA15-01</u>
Integration of Appurtenant Rights and	)	
Amendments to the Interim Instream Flow	)	CERTIFICATE OF SERVICE
Standards, Na Wai Eha Surface Water	)	
Management Areas of Waihee, Waiehu, Iao	)	
and Waikapu Streams, Maui	)	
	)	

CERTIFICATE OF SERVICE

On February 5, 2016, a copy of the foregoing document was served on the following parties by U.S. mail, postage prepaid, or electronic service, as set forth below:

SERVICE BY MAIL

Noelani & Alan Almeida
Gordon Almeida
P.O. Box 1005
Wailuku, HI 96793

Alan Birnie
175 W. Waiko Road
Wailuku, HI 96793

Cordell Chang
2315 Kahekili Highway
Wailuku, HI 96793

Joseph Alueta
P.O. Box 785
Wailuku, HI 96793

Gary & Evelyn Brito
2160A Puuohala Road
Wailuku, HI 96793

Joshua Chavez
P.O. Box 6240
Kahului, HI 96733

Michael Bailie
P.O. Box 1433
Wailuku, HI 96793

David & Anne Brown
2525 Kahekili Highway
Wailuku, HI 93793-9233

Winifred & Gordon Cockett
1159 Piihana Road
Wailuku, HI 96793

Vernon Bal
230 Koeli Street
Wailuku, HI 96793

Douglas Myers
1299 Malaihi Road
Wailuku, HI 96793

Pauline Kanegai Curry
P.O. Box 3172
Wailuku, HI 96793

Dorothy Bell
1419 Nuna Place
Waikapu, HI 96793

Regino Cabacungan
304 Hoomalu Place
Wailuku, HI 96793

Charles Dando, Sr. & Jr.
85 E. Kanamele Loop
Wailuku, HI 96793

Dwayne Betsill
Koolau Cattle Company, LLC
635 Kenolio Road
Kihei, HI 96753

Thomas Cerizo
1740 Kamamalu Place
Wailuku, HI 96793

Alfred & Patricia DeMello
El Ranchitos DeMello
P.O. Box 1394
Lockeford, CA 95237

James Dodd
P.O. Box 351
Wailuku, HI 96793

Steve Haller
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Haiku, HI 96708

Amanda Jones
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P.O. Box 97
Kihei, HI 96753

Michael Doherty
41 Waihee Valley Road
Wailuku, HI 96793

Robert Hanusa
895 Malaihi Road
Wailuku, HI 96793

Kaanapali Kai, Inc.
2145 Wells St., Ste. 3301
Wailuku, HI 96793

Richard Emoto
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Wailuku, HI 96793

Darrell Higa
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Kauai Kahalekai
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Patricia Federcell
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Kahului, HI 96732-3307

George & Yoneko Higa
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Kahului, HI 96732

Kenneth Kahalekai
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Wailuku, HI 96793

Rudy & Perlita Fernandez
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Paul & Jennifer Higashino
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Alfred Kailiehu, Sr.
Alfred Kailiehu, Jr.
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Wailuku, HI 96793

Roderick Fong
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495 Hukilike Street, Bay 4
Kahului, HI 96732

Hiolani Ranch LLC
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San Diego, CA 92163

Leinaala Kihm
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Wailuku, HI 96793

Dave Gomes
Hawaiian Cement – Maui
Concrete & Aggregate Div.
P.O. Box 488
Kahului, HI 96732

Greg Ibara
227 Kawaipuna Street
Wailuku, HI 96793

Sterling Kim
Hale Mua Properties, LLC
250 Alamaha St., Ste. N18
Kahului, HI 96732

Brian Ige
RCFC Kehalani, LLC
2005 Main Street
Wailuku, HI 96793

Clifford & Cristal Koki
P.O. Box 442
Wailuku, HI 96793

Russel Gushi
185 West Waiko Road
Wailuku, HI 96793

Ronald Jacintho
Pohakulepo Recycling, LLC
150 Pakana Street
Wailuku, HI 96790

Lawrence Koki
2585 Kahekili Highway
Wailuku, HI 96793

Valentine Haleakala
2160 Puuohala Road
Wailuku, HI 96793

Ronald Jacintho
ROJAC Trucking, Inc.
150 Pakana Street
Wailuku, HI 96793

Mary Jane Kramer
Na Mala o Waihee Private
Water Co. Inc.
c/o Commercial Properties of
Maui Management, Inc.
1962-B Wells Street
Wailuku, HI 96793

Anthony Manoukian
Anthony Aram & Downey
Rugtiv Manoukian Tr.
P.O. Box 1609
Waianae, HI 96792

David Nobriga
Nobriga's Ranch Inc.
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Wailuku, HI 96793

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San Francisco, CA 94104

Glenn McLean
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Wailuku, HI 96793

Kenneth Mendoza
2160 B Puuohala Road
Wailuku, HI 96793-0463

Nelson Okamura
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Landscaping Co. LLP
P.O. Box 1058
Puunene, HI 96784

Jonathon Kurtz
Living Waters Land
Foundation, LLC
P.O. Box 2327
Wailuku, HI 96793

Lawrence Miyahira
Jason Miyahira
P.O. Box 762
Wailuku, HI 96793

Francis Ornellas
340 Iao Valley Road
Wailuku, HI 96793

Jane Laimana
45-520 Alokahi Street
Kaneohe, HI 96744

Elsie Miyamoto
1455 Moloiki Street
Honolulu, HI 96825-3229

Ken & Saedene Ota
2261 Aupuni St., Ste. 101
Wailuku, HI 96793

Cindy Lee, Managing Agent
Waiolani Mauka Community
Association, Inc.
c/o Scott Nunokawa
P.O. Box 946
Wailuku, HI 96793

Jinsei Miyashiro Trust
P.O. Box 235
Wailuku, HI 96793

Kalani & Tera Paleka
P.O. Box 342
Wailuku, HI 96793

Glynnis Nakai
Maui National Wildlife
Refuge Complex, USFWS
P.O. Box 1042
Kihei, HI 96753

Robert Pinto
c/o Claire Pinto
130 Pilikana Place
Wailuku, HI 96793

David & Katherine Lengkeek
128 River Road
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A handwritten signature in black ink, appearing to be 'Jodi S. Yamamoto', written over a horizontal line.

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