Chapter 6 Irrigation System Design

Contents

Tables

Figures

Figures (continued)

Exhibits

652.0605 State Supplement

General

Irrigation design theory and practice are well described in NEH Part 623, including Chapter 4 "Surface", Chapter 7 "Microirrigation", and Chapter 11 "Sprinkler." This Supplement Chapter 6 “Irrigation System Design” provides layout and component illustrations, and applicable design equations. *Most sample designs and worksheets for irrigation systems shown in this chapter are from SCIG 1987, so use of these sample designs need to reflect current Conservation Practice Standards (CPS).* Where available, references are made to NRCS design criteria or applicable conservation practice standard. Figure SC6-26 shows an example NRCS microirrigation system layout map.

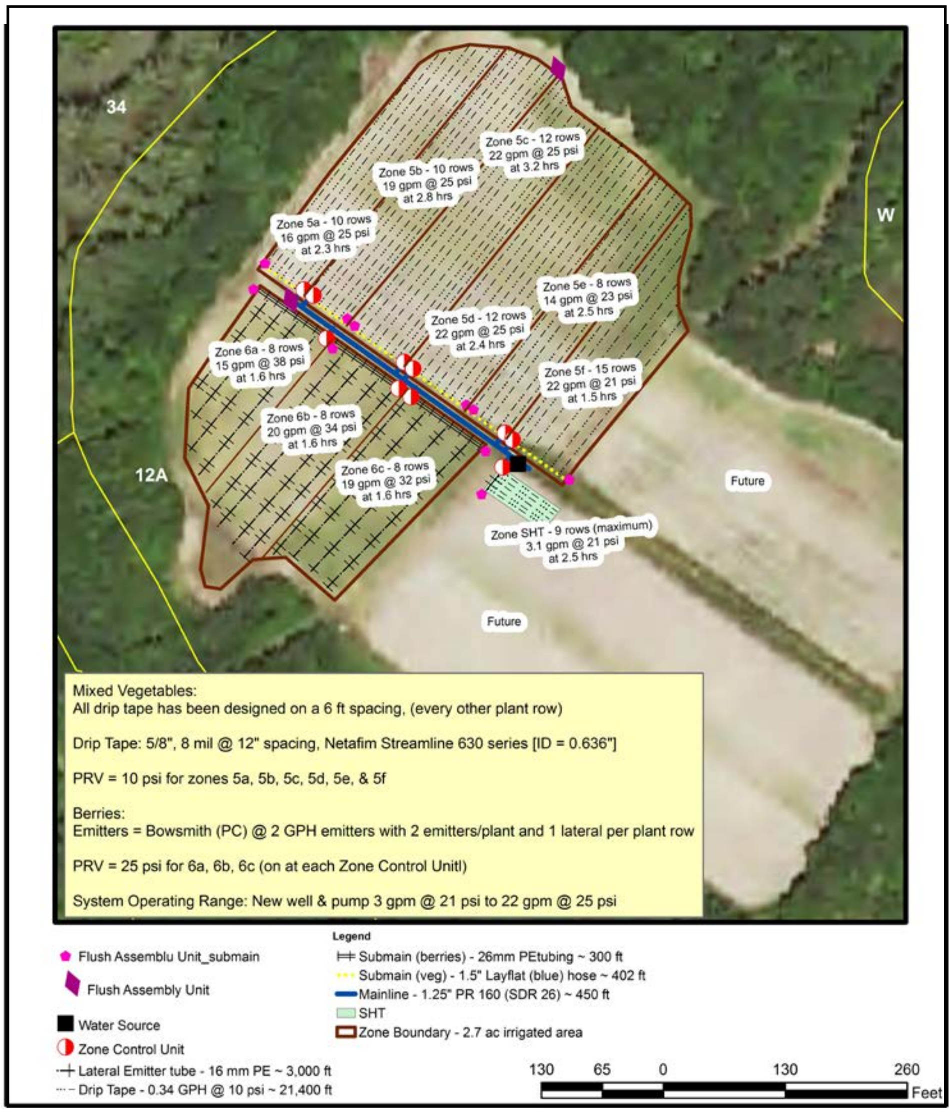


Figure SC6-26 NRCS typical microirrigation system layout with typical text and components

Today most irrigation system can be designed utilizing commercially available software or NRCS approved tools.

Whenever available these and other robust industry software are preferred over the step-by-step procedures shown in these examples. Generally speaking the advantages of the tested and approved software include mathematical accuracy, pre-entered constants, and built-in lookup tables with values normally associated with system components. The better software will also generate detailed design sheets, layout instructions, construction requirements, and approved signatory forms. They may also incorporate site specific aerial or topographic maps and imagery and engineering designs.

In the following sections procedures, equations, examples, and worksheets are provided for an understanding of what factors are involved in the design of various irrigation systems. They are also useful for creating designs when the desired irrigation systems do not fit conditions of the packaged software or when there is no applicable software. The example problems in this chapter are intended to illustrate procedures to follow in the design of typical micro and sprinkler irrigation systems. It is understood these few examples cannot illustrate all design situations or alternatives to consider when designing irrigation systems.

(a) Microirrigation Systems

General

Microirrigation is accomplished with drip and microspray watering devices. Microirrigation systems adapt to many special applications that scale from a few rows of plants to hundreds of acres of fruit, vegetables, nursery plants or orchards. The apparent simplicity and size of the components may lead some to assume that microirrigation systems can be designed, installed and operated with minimal experience. **In reality, the design and operation requires a higher level of skill than most other irrigation systems**.

The following figures (Fig. SC6-27 - 29) show typical micro flow devices available for use in microirrigation system design. Their operation and water delivery system make them unique to certain crop production methods.

Figure SC6-27 Drip tape with in-line emitters allows precise placement of water in the plant bed/ root zone, and it permits the use of plastic mulch for weed suppression

NRCS designers should be familiar with the principal equipment and component manufacturers and distributors operating within the state. As much as possible they should maintain catalogs and manufacturer design sheets for equipment and components typically available and used in South Carolina.

Figure SC6-28 Drip emitters suspended above ground punched into a Polyethylene (PE) tubing which allows for individual placement of emitters if variable plant spacing

Figure SC6-29 Microsprayers suspended above ground on a spike fed by a feeder tube and polyethylene tubing

This is particularly true for sprinkler and sprayer heads, nozzles, drip emitters and microsprays because these are used in the various sprinkler and microirrigation methods that dominate the State's agricultural irrigation systems. Similarly, designs of microirrigation systems will be most effective if the design considers what components are readily available to the farmer in the area.

Design Criteria

Design criteria for microirrigation systems are contained in the Conservation Practice Standard, Irrigation System, Microirrigation - Code 441. All microirrigation systems must be designed in accordance with the criteria contained in current Standard 441.

(1) Emitter Wetted Pattern

The wetted pattern of a microirrigation system is controlled by soil texture. In addition to soil type, the application rate will affect the shape of the wetted pattern. It is possible to alter the shape of the wetted zone by varying the application rate. For example, 10 gallons of water applied by a microsprayer to a soil in 1 hour will probably produce a wider, shallower wetted pattern than 10 gallons applied over a 10 hour period. This is because a higher application rate tends to produce a wider zone of saturation under the emitter, assisting horizontal movement.

For increased lateral movement, **light sandy soil layers** within the DMR require water application at higher rates and/or closer spaced emitters (8 - 12 inches), while **heavy clays and clay loams** within the DMR often benefit from a lower water application rate and/or wider spaced emitters (12 - 24 inches).

Lower rates avoid surface ponding or runoff and promote deeper water penetration. Table SC6-18a is a tabular representation of Figure SC6-30 and shows the general SDI wetted pattern for various South Carolina soil textures. The Vertical Wetted Pattern table shows Group 7 distribution because it represents the depth of moisture replacement (DMR) for most vegetable and row crops grown under microirrigation. This Supplement assumes the wetted pattern of SDI and surface tape will be similar enough to be represented by the SDI values below. Table SC6-18b recommends the number of emitters needed to meet the horizontal wetted pattern as a function of soil texture and plant spacing.

Table SC6-18a General Vertical and Horizontal Wetted Pattern for various South Carolina Soil Textures

	IRRIGATION CYCLE, based on Depth of Moisture Replacement (DMR) 1/			
	8"	12"	18"	24"
Time	30 min vert.	60 min vert.	90 min vert.	120 min vert.

	HORIZONTAL Wetted Pattern (ft) 1/			
Texture Group No.	30 min horiz.	60 min horiz.	90 min horiz.	120 min horiz.
Group 1, 2 & 3	1.5	1.7	1.8	2.0
Group 4, 5 & 6	1.7	2.5	2.7	2.8
Group 7	1.8	2.8	3.1	3.4

Table SC6-18b Recommended Number of Emitters to meet Horizontal Wetted Pattern

		Recommended Emitters needed to meet Horizontal Wetted Pattern 2/						
		In-row Plant Spacing						
Irrig. Cycle	Texture Group No.	< 6"	12"	18"	24"	36"	48"	60"
30 minute	Group 1, 2 & 3	1	1	1	2	2	3	4
	Group 4, 5 & 6	1	1	1	2	2	3	3
	Group 7	1	1	1	2	2	3	3
60 minute	Group 1, 2 & 3	1	1	1	2	2	3	3
	Group 4, 5 & 6	1	1	1	1	2	2	2
	Group 7	1	1	1	1	2	2	2
90 minute	Group 1, 2 & 3	1	1	1	2	2	3	3
	Group 4, 5 & 6	1	1	1	1	2	2	2
	Group 7	1	1	1	1	1	2	2
120 minute	Group 1, 2 & 3	1	1	1	1	2	2	3
	Group 4, 5 & 6	1	1	1	1	2	2	2
	Group 7	1	1	1	1	1	2	2

1/ values developed from Figure SC6-30
2/ based on drip tape with 12 " emitter spacing irrigating 100% of horizontal wetted pattern
Groups 1, 2 & 3 [1 - CS; 2 - S; FS, 3 - LS, LFS, LVFS]
Groups 4, 5 & 6 [4 - SL, FSL, VFSL; 5 - L, SIL; 6 - SCL, CL, SICL]
Group 7 SC, SIC, C

(2) Effect of Application Time on Wetting Pattern

The number of emitters needed to wet the crop's canopy area is critical to determining the effective wetted area of the irrigation system. Fig. SC6-30 shows the effect of application time on the SDI wetted pattern within different soil textures. On deep, coarse sandy soils, the water tends to percolate straight down resulting in a small wetted diameter. On finer textured soils (sandy clays, clays) there is more lateral movement of the water resulting in larger wetted diameters. A test should be run on the site to be irrigated to determine lateral movement.

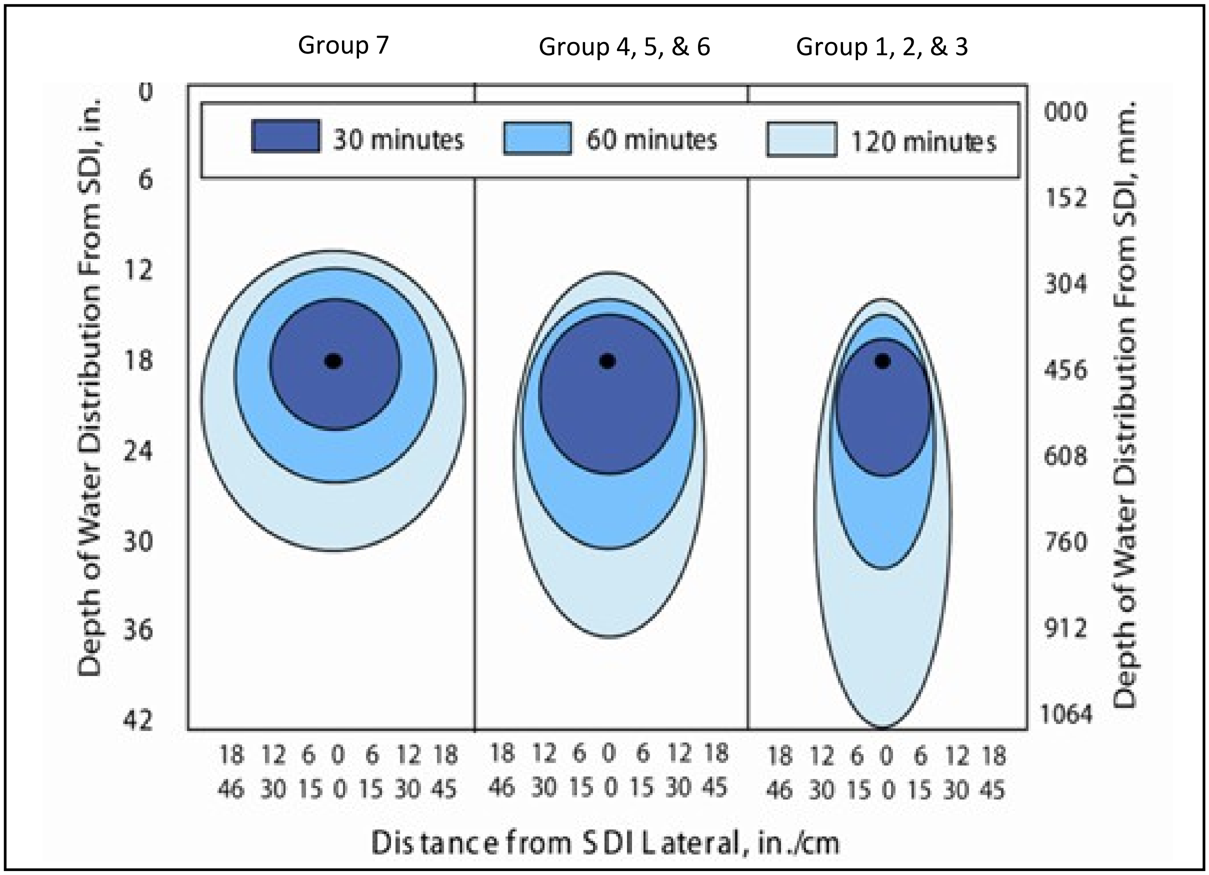


Figure SC6–30 Water distribution pattern from SDI system with some capillary movement towards soil suface

(3) System Components

(i) Zones –

Most microirrigation systems optimize use of pumps and mains by irrigating field areas called zones/ blocks. Within a zone/block, all of the emitters are discharging water at design rates for a period of time that is ideally based upon current crop evapotranspiration (ETc). Duration of irrigation may be limited by plant rooting volume and potential losses due to deep percolation (in sandy soils) or surface infiltration/ redistribution (in heavy soils). Intervals between irrigation may depend upon how much water is applied and stored in the root zone. For small plants, plants with limited rooting, and plants whose fruit is sensitive to fluctuating moisture, irrigation cycles may be less than a day. Each zone/block must incorporate a zone control unit, which is used to control the irrigation cycle at the field level. Figure SC6-31 shows a single zone control unit for a vegetable or row crop system.

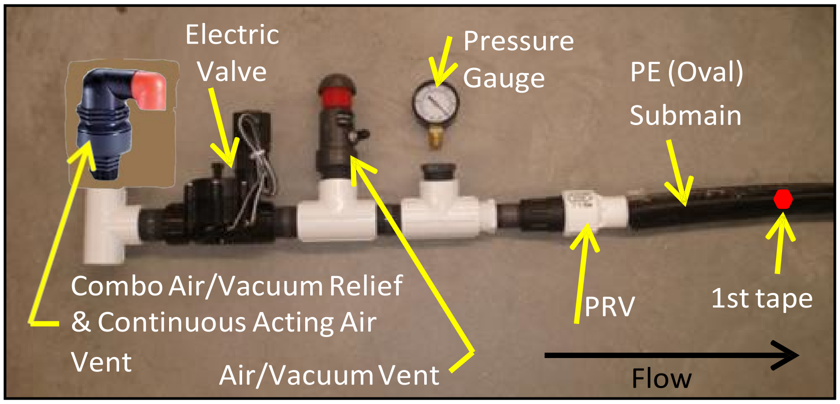


Figure SC6–31 Typical single zone control unit for microirrigation system

Ideally, a zone is matched to the pump's discharge rate and pressure. All of the capacity is used supplying the zone's emitters and maintaining the design pressure. After one zone is irrigated, the pump and distribution lines are available for irrigating other similarly sized zones. An irrigation cycle is established among zones with each zone running for its scheduled time and switching between zones, either automated or by manual control valves. Ideally duration of irrigation in a zone is set on a timer with an independent cutoff or sensor, which triggers if the full amount is not needed or if rain nullifies the need for irrigation.

(ii) Air Vents –

Type and location of air vents are vital to the longevity and proper functioning of any irrigation system. To clarify the difference between these vents, see Supplement Chapter 15,pg 15-130 for a description of general purpose, function and operational differences.

(iii) Isolation Valves –

A zone valve (Fig. SC6-32) controls the flow of water into the piping system to a specific zone/block. To clarify the difference between typical irrigation valves, see Supplement Chapter 15, pg 15-129 or Supplement Chapter 17, pg 17-30 for a description of general purpose, function and operation of commercially available valves.

Figure SC6–32 Electric solenoid valve (left) and manual ball valve (right)

(iv) Pressure Gauge –

Pressure gauges (Fig. SC6-33 & SC6-33a) are desirable to have in a system so that the operator can conduct a visual check of specific components and operate the system in accordance with the design. The system efficiency is often dependent upon operating pressures.

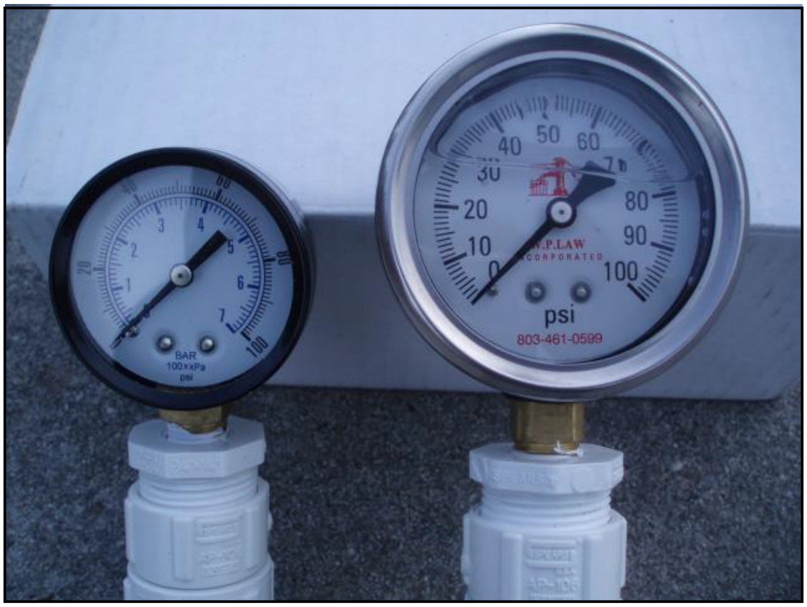


Figure SC6–33 Typical non-filled (left) and liquid filled pressure gauge (right)

Figure SC6–33a Non-filled pressure gauge showing 70 psi downstream of the zone control unit

(v) Pressure Regulating Valve (PRV) –

Location within the system is dependent on specific site conditions and operational requirements. These devices (Fig. SC6-34) are important because they maintain distribution uniformity by preventing pressure fluctuations and flow deviations caused by changes in system demand, water supply, elevation changes and/ or friction loss, which can cause an emitter's wetted pattern to change. <u>Observe caution during installation.</u>

Always install pressure regulators downstream from all shut-off valves.

Figure SC6–34 In-line PRV maintain constant "pre-set" outlet pressure and only function within its set flow range (middle)

PRV's should be installed in the proper direction, as indicated by an arrow on the housing, and as close as possible to the first micro flow device.

Note the following conditions that will by-pass the PRV and probably "pop" the submain:
1) if the submain flush value is closed and no drip tape is installed - no flow outlet - and the zone valve is "opened" or **2)** the PRV flow range (gpm) does NOT match the zone flow rate (too high or too low).

Figure SC6-34a shows what happens when the PRV flow range does not meet the designed zone flow rate (gpm). The 70 psi on the inlet side of the PRV will <u>not</u> be reduced and pressure within the PE (Oval) hose (rated @ 21 psi) will built up to 70 psi and burst.

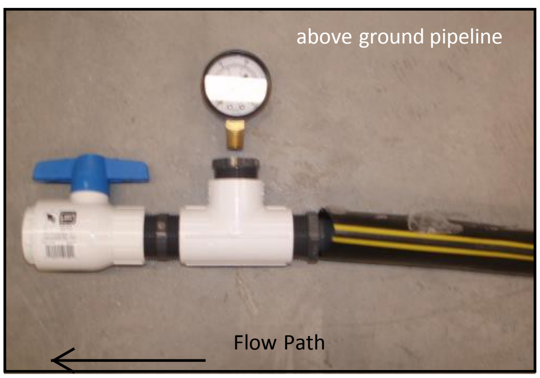
Figure SC6–34a 2 inch PE (Oval) hose "burst" due to PRV flow range outside of zone flow rate (gpm)

(vi) Submain (manifold) –

These pipes (Fig. SC6-35) are located downstream of the zone control unit and carry water to the irrigation zones/blocks. The pipe material typically consists of polyethylene (PE) oval hose with working pressures of 21 psi or 42 psi and PVC layflat with working pressures of 50-80 psi (related to hose diameter).

Figure SC6–35 “Paired” layflat (left) and PE (Oval) hose submain (right)

An important component for maintenance includes the ability to flush the submain and mainline pipes at scheduled intervals. Figure SC6-36 shows typical components of the flush assembly units.



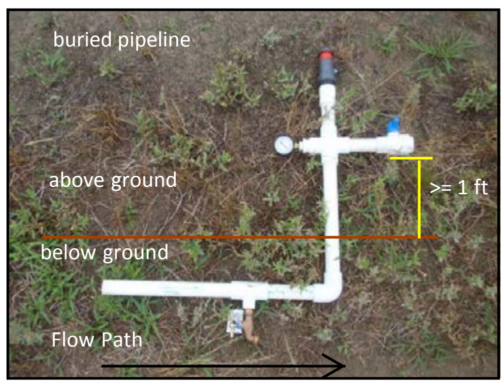


Figure SC6–36 Flush assembly unit for above ground submain (left) and for all buried pipe (right)

(vii) Lateral Lines –

Lateral lines are connected to the submain and normally are designed so that when operating at the design pressure, the discharge rate of any emitter served by the lateral will not exceed a variation of 10 percent of the design discharge rate. Design consideration should be given to lateral line spacing, which is based on plant spacing in the row, soil texture, Crop ETc, and the use of plastic mulch.

Lateral lines, normally installed above ground, supply water to micro flow devices. Polyethylene (PE) or similar material is used for both flexible tubing (orchards, vineyards, and shrubs) with the most common sizes being 16 mm (1/2 inch), 20 mm (3/4 inch), and 26 mm (1 inch) and drip tape (vegetables and row crops) with common sizes of 5/8 and 7/8 inch. Installation of below ground lateral lines should be considered where feasible. This will extend the life of the material and protect it from damage. It is important that all components be purchased from a reputable dealer that can supply the material specified in the design.

Drip tape can be used for either surface (4 to 13 mil) or subsurface (13 to 15 mil) installations. The thickness (mil) greatly influences the longevity of the surface tape when evaluating storage and structural damage caused by rodents or farming operations.

Slack is left in the above ground lateral line so that temperature variations will not pull the emitters away from their initial position.

An orchard system's lateral tubes are connected to the buried submain lines through risers, flexible tubing, or other acceptable means. To control individual line pressure and maintain uniformity a pressure regulating valve (PRV) should be installed on each lateral tube if 1) extreme elevation variations exist and/or 2) non-PC (pressure compensating) emitters are installed. Use of multiple PRVs will increase cost but provide uniformity through the lateral tubes. If using PC emitters, then one PRV can be installed downstream of the zone control valve as close to the first lateral tube as practical.

Lateral lines are closed at the outlet end by means of a screw cap or other device. This is removed periodically so the line can be flushed to remove sediment and other debris. On subsurface drip systems (SDI), flushing manifolds (Fig. SC6-40) are provided to facilitate the flushing process.

(viii) Emitters –
Emitter designs are numerous, most specific to manufacturers in an industry with many companies and patent holders. Emitters may be open capillary tubing, micro tubing with flow control devices at their ends, or tubing with small sprinklers (microsprayer) attached. But most agricultural row crop designs now use lateral lines that have regularly spaced flow control orifices built into the wall of tubing itself (Fig. SC6-37, left). Common spacing between in-line emitters is 12 to 36 inches and selection will be based upon plant type and spacing, potential lateral redistribution of water in the soil, and total discharge rate needed.

Figure SC6–37 Lateral (drip) tape (left), drip emitter (center) and microsprayer (right) device

Lateral (surface) lines may be placed on top of the ground or buried within 3 inches of the surface, while SDI laterals are commonly buried 8 - 12 inches below the surface. It may also be installed under plastic mulch as the field is set up before transplanting vegetable or other young plants.

The system and its performance are based on a specific discharge for each emitter at a design pressure. Therefore, companies providing emitters need to furnish performance curves that show gallon per hour flow rates versus pressure for each size of emitter to be used. Permissible flow rate is usually ±10 percent of the average flow rate, therefore, these performance curves are needed to determine the permissible pressure variation.

Emitters generally fall under two categories - those that apply water by the drip process at flow rates of 1 to 2 gallons per hour (Fig. SC6-37, middle) and those that apply water by spraying at flow rates of 8 to 50 gallons per hour (Fig. SC6-37, right).

(ix) Emitter clogging –
In-line drip emitters have micro pathways that use friction to reduce the flow of water as it moves from the interior (regulated) pressure to the atmospheric pressure in the soil. The small and tortuous pathways in the emitters are easily clogged. Unfiltered particles entering from the water source or which escape from installed filters can quickly and permanently clog emitters. Even clay particles can clog emitters if they settle and coalesce to form larger aggregates. Bacteria will grow on organic matter that may be in the water source, especially in surface water sources.

Some grow on interior walls of the tubing and, when they are broken loose, clumps of the cells will clog the emitters. Even without organic matter iron and sulfur reducing bacteria can survive on dissolved minerals in certain water sources and eventually grow to clog emitters. Besides bacterial slimes, chemical slimes can develop if the water is high in carbonates or oxidizable minerals. Chemicals added as fertilizers or pesticides may also react with the water or create precipitates.

Both chemicals and fertilizers should always be subjected to a 24 hour precipitate test with a sample of water prior to injection into the system. Fig. SC6-38 shows the results of a 24 hour "jar" test.

Figure SC6–38 Precipitate indicates reaction between fertilizer/chemical and water that will clog drip tape or emitters

A water quality test is an important part to the daily operation and longevity of any irrigation system. A list of typical clogging factors found in irrigation water and their concentration levels is provided in Chapter 15, pg 15-142.

Emitters can also clog from the exterior of the tubing. Roots and root hairs may enter through the emitter outlets. Emitter designs for buried tubing generally attempt to physically prevent or minimize this growth and emitters may be treated with a herbicide to further discourage roots seeking an easy water source.

Soil particles and soil organic matter may enter the emitter through back-siphoning. When the irrigation cycle ceases, water will largely drain from the tubing through the lowest elevation emitters thus causing higher elevation emitters to back siphon free water in the soil which may carry soil particles back into the emitter. While most will be pushed out with the next irrigation, some clay particles will enter the tubing settle and coalesce creating a later clogging hazard.

(4) SUBSURFACE DRIP IRRIGATION (SDI)

Description

Subsurface Drip Irrigation (SDI) is a drip application method that benefits from the use of Global Positioning System (GPS) for precise placement of lateral tubing with in-line emitters below or deeper than the topsoil. The installation is designed and managed to be permanent. It is commonly used with row crops, although in some instances producers of alfalfa or other valuable hay crops have put it to limited use. There is no clear distinction between subsurface placement of drip tubing in orchards or other perennial crops and the row crop variant. Design and management of the drip system itself is similar, and many consider both to be SDI.

Figure SC6–39 SDI submain with flexible feeder lines connected to the buried drip tape

System Component

Creating a durable drip system that may remain in the soil for 15 to 20 years requires attention to the two most common causes of drip failure – emitter clogging and physical damage to the tubing.

Longevity of SDI systems requires a regular schedule of emitter maintenance through lateral line flushing, chemical treatment, and chlorination. The first is accomplished most effectively if a flushing manifold with an air/vacuum vent, valve, and a recommended pressure gauge are installed (Fig. SC6-36, right or Fig. SC6-40). This increases the installation costs, but the alternative is having each lateral tube terminate at the surface where clamps or end caps must be opened. These exposed tubes are readily damaged by field operations and animals seeking water. Chemical treatment usually with acids, can dissolve precipitated carbonates and iron oxyhydroxides when they are present. Chlorination treatments kill bacteria and help break down organic matter of their slimes and in the water that sustains them.

Physical damage

Drip tubing rated for burial has heavier walls than tubing placed on or near the surface, as in seasonal vegetable operations. This is in part because underground installation usually exerts a stretching stress as the tubing is knifed in. Soil settling above and field traffic act to compress the tubing; so the lateral tubing walls must be strong enough to maintain an interior cross section adequate to sustain flow and pressure for all emitters. Collapsed or pinched tubing during installation or subsequent field operations will block sections of the irrigation system.

Leaks or failure occur when tubing is damaged by field operations or pests. In row crops, tillage operations and, in the case of peanuts, digging operations can snag and severely damage buried tubing. Fields that must be plowed will require tubing to be buried deeper than the plow depth or between 12 and 16 inches. If subsoiling is required regularly to loosen natural or tillage hard pans, SDI may not be the ideal irrigation choice. However some progress has been made in using precision guidance GPS to install tubing, keep subsoil shanks between the lateral tubing rows, and during the plant/harvest operation. Burial removes the tubing from reach of many rodents and other pests, but vigilance is needed to watch for leaks caused by burrowing animals including certain insects.

Tape spacing and depth

SDI installations commonly place thick walled tape in a non-traffic middle between two rows of plants. If plant rows are 36 inches apart, tape would be in alternate middles 72 inches apart. Each drip tape would supply two adjacent rows whose plants are 18 inches from the tape, within easy reach of many of the plants roots. Guidance provided by precision GPS can keep rows aligned with the buried tape. Most row crops have sufficient rooting systems to reach and exploit moist zones around tape located 72 inches apart, regardless of the alignment of tape and rows. However, if the tape falls under a wheel traffic row, rooting will be constrained by the compacted soil and the irrigation rendered less effective.

SDI lateral tape life expectancy is increased as placement depth is increased because it is largely out of harms way. However, deep placement is contrary to the crops needs, and water use efficiency can be significantly diminished by deep placement.

Upward movement of water from tape occurs due to capillary movement. This is strongly affected by soil texture with greater capillary movement in clayey and silty soil (~ 12 inches) than sand (~ 6 inches). But capillary (unsaturated) movement is a slow process. While water is slowly moving upward from the tape, water is moving downward by gravity in a saturated system. The downward movement occurs at a far greater rate. If roots have not reached the tape depth and beyond, much of the gravitational water could be lost. Water use efficiency will be far less than the typically expected 90 to 95 percent for drip irrigation. Attempts to wet the soil surface for germination and early seedling growth using SDI wastes most of the irrigation water.

An important component of maintenance includes the ability to flush the buried lateral tape (dripline) at scheduled intervals. Figure SC6-40 shows common installation of the SDI flush assembly unit.

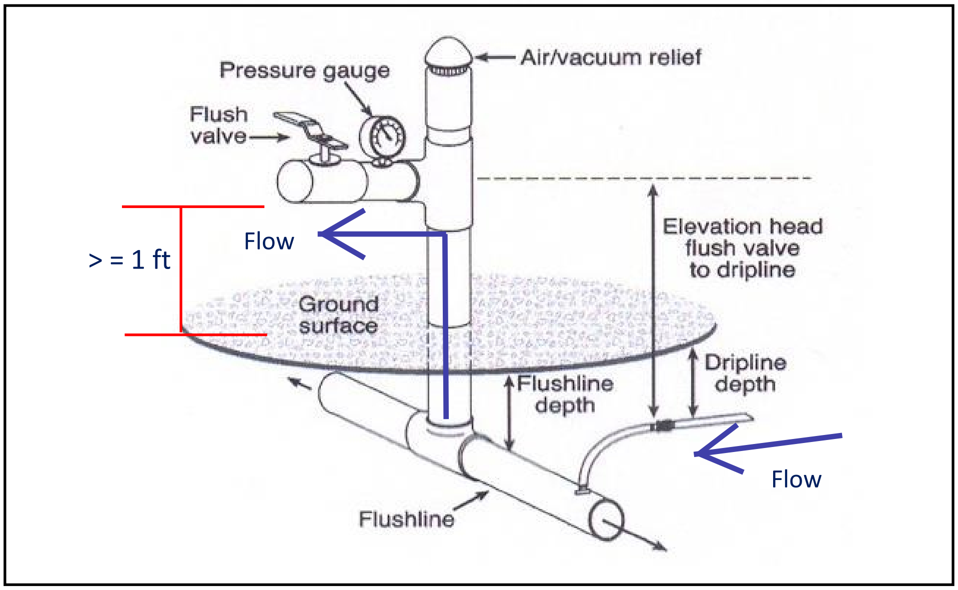


Figure SC6–40 Flush assembly unit for SDI system

Example Problem:

The following example (Exhibit SC6-2A) (from Brian Smith, Agricultural Engineer at Clemson University Extension; Personal communication) demonstrates one format when designing, calculating, and recording data for a microirrigation system. It is determined that based on soils, climate, and intended crops – grapes and vegetables – that 1 inch of water will be needed each week.The owner has requested a setup with fifteen 1 acre zones for the grapes, with enough capacity to expand and irrigate an additional seven acres of vegetables. The example works through the grape design (phase I) only. Phase I covered 9 zones with phase II covering the remaining 6 zones. No design is computed for the vegetable part of the system.

The example shows an iterative process for determining the total zones with the designer recommending 6 zones at 2.5 acres each. The operator decided on 15 total zones at 1.25 acres each. This example demonstrates the procedure for sizing the submain (manifold) in decreasing diameters for only 5 zones (see Exhibit SC6-2A, 3 of 6). The remaining 10 zones would utilize the same sizing procedure.

MICROIRRIGATION SYSTEM WORKSHEET 1

Exhibit SC6-2A, (1 of 6)

Cooperator: Frazier Sample Designed by: B. Smith Checked by: A. Eng

1. Flow Rate Requirement:

Grower requests:
15 acres of grapes plus 7 acres of vegetables.
Grapes are grown here with 12 feet between rows by 20 feet in row.
One acre zones for grapes.
Two 10.7 gph microsprayers used per plant.

Design for 95% application efficiency with a net I.0 inch/week application.

$$Gross\ application = \frac{1.0\ inch}{week} \times \frac{1}{0.95} = 1.05\ \frac{inches}{week}$$

For grape irrigation:

$$Plant\ population = \frac{43560\ sq.feet}{acre} \times \frac{1\ row}{12\ feet} \times \frac{1\ plant}{20\ feet} = 181.5\ \frac{plants}{acre}$$

tentatively,

$$Flow\ required = \frac{181.5\ plants}{acre} \times \frac{2\ microspray}{plant} \times \frac{10.7\ gph}{microspray} \times \frac{1\ gpm}{60\ gph} = 64.7\ \frac{gpm}{acre}$$

$$Flow\ required \approx 65\ gpm\ for\ the\ 1\ acre\ zones$$

2. Number and Size of Zones and Irrigation Time:

1 acre zones (requested), 15 acres total, so 15 zones of grapes.

$$Run\ time\ per\ zone = \frac{27154\ gallons}{acre\text{-}inch} \times \frac{1\ acre}{zone} \times \frac{1\ minute}{65\ gallons} \times \frac{1\ hour}{60\ minutes} = 7.31\ \frac{hours}{zone}$$

$$Run\ time\ per\ week = \frac{7.31\ hours}{zone} \times 15\ zones = 109.7\ \frac{hours}{week}$$

Using the growers requests will require 109.7 hours/week for grape irrigation.

Typically drip systems should be designed to operate for no more than 12 to 18 hours /day, 7 days per week, for a total of 84 to 126 hours per week. This leaves some "catch-up" time in case of mechanical failure.

Following this premise, we are left with 126 hours maximum/week minus 109.7 hours/week for 15 zones of grapes or only 16.3 hours/week for vegetable irrigation with this system. Not much time!

MICROIRRIGATION SYSTEM WORKSHEET 2

Exhibit SC6-2A, (2 of 6)

Cooperator: Frazier Sample Designed by: B. Smith Checked by: ______________

1. Flow Rate Requirement (alternatively):

A better approach would be to calculate the maximum flow rate possible that would still yield a gross application of 1.05 inches/week during the potential maximum of 126 hours of irrigation per week and include both grapes (15 acres) and vegetables (7 acres) in that calculation.

$$Flow\ required = \frac{22\ acres}{1} \times \frac{1.05\ inches}{week} \times \frac{27154\ gallons}{acre\text{-}inch} \times \frac{1\ week}{126\ hours} \times \frac{1\ hour}{60\ minute} = 82.97\ \frac{gpm}{acre}$$

$$Flow\ required \approx 83\ \frac{gpm}{acre}$$

2. Number and Size of Zones and Irrigation Time (alternatively):

For the grape system, again:

$$Flow\ required = \frac{181.5\ plants}{acre} \times \frac{2\ microspray}{plant} \times \frac{10.7\ gph}{microspray} \times \frac{1\ gpm}{60\ gph} = 64.7\ \frac{gpm}{acre}$$

At the higher flow rate, a larger zone could be irrigated:

$$Zone\ size = \frac{83\ gpm}{zone} \times \frac{1\ acre}{64.7\ gpm} = 1.28\ \frac{acres}{zone}$$

and:

$$Number\ of\ zones = 15\ acres \times \frac{1\ zone}{1.28\ acres} = 11.7\ zones$$

$$Number\ of\ zones \approx 12\ zones$$

$$Zone\ size = \frac{15\ acres}{12\ zones} = 1.25\ \frac{acres}{zone}$$

$$Run\ time\ per\ zone = \frac{27154\ gallons}{acre\text{-}inch} \times \frac{1.25\ acre}{zone} \times \frac{1.05\ inch}{week} \times \frac{1\ minute}{65\ gallons} \times \frac{1\ hour}{60\ minutes}$$
$$= 7.16\ \frac{hours}{zone\text{-}week}$$

$$Run\ time\ per\ week = \frac{7.16\ hours}{zone} \times 12\ zones = 85.9\ \frac{hours}{week}$$

This leaves 126 hours maximum/week minus 85.9 hours/week (used in the 12 zones of grapes) = 40.1 hours/week for vegetable irrigation with this system.

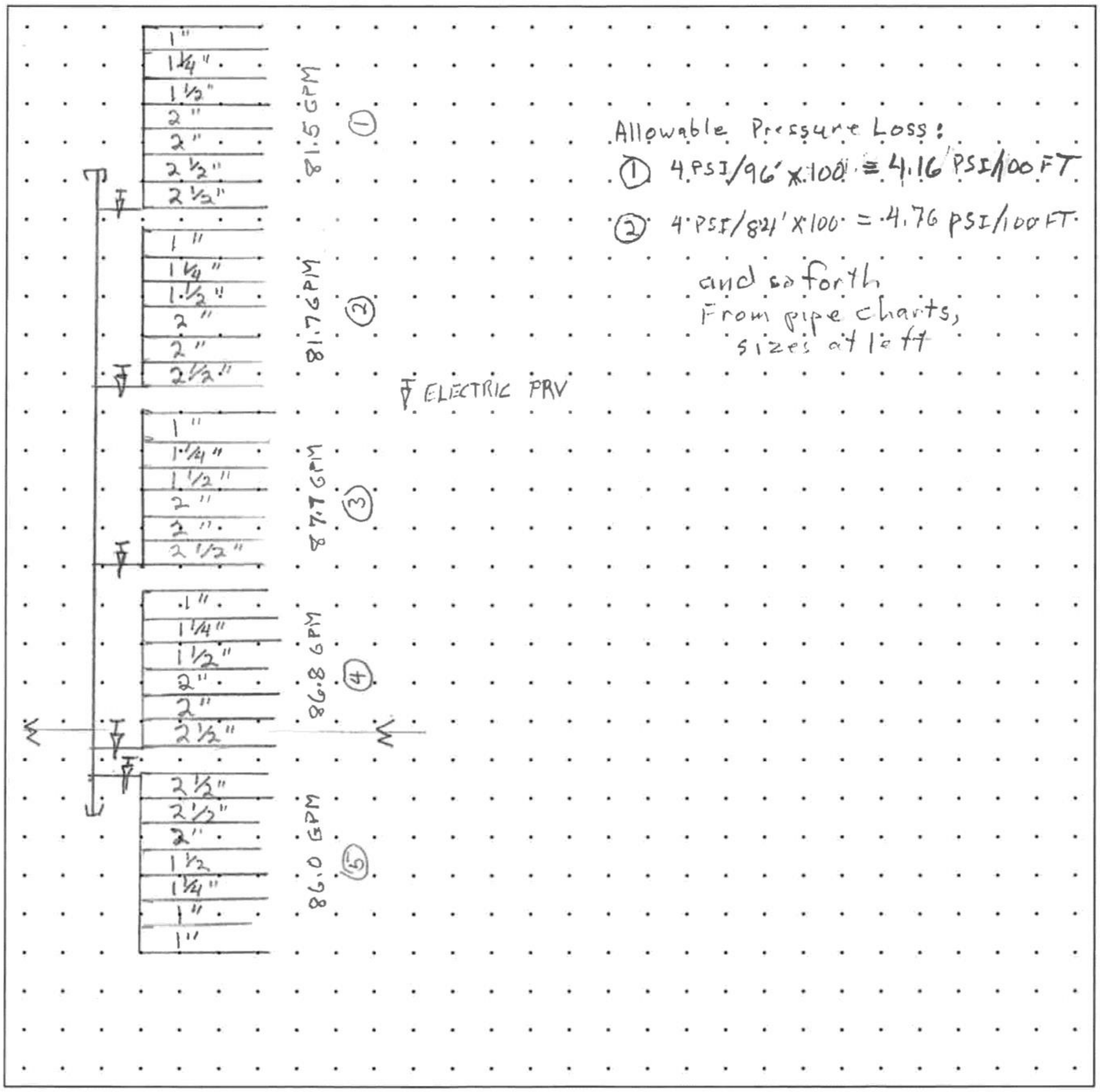
Brian Smith suggests designing this system using one microsprayer per plant (a 300 degree pattern instead of the 360 degree assumed above) and irrigating 6 zones of 2.5 acres each. This would require fewer components for automation, longer run times per zone, yet with the same application rate and net irrigation time.

Exhibit SC6-2A, (3 of 6)

IRRIGATION DATA LAYOUT

Cooperator: FRAZIER SAMPLE **Designed by:** B. Smith **Checked by:** A. Eng

5. Sketch map on grid or attach photo or overlay with drawing; Map of design area – Scale 1" = _____ feet.



Sketch map should show:

1. Source of water
2. Major elevation differences
c. Row direction
d. Sprinkler system layout
e. Plan of Operation
f. Field obstructions (gullies, ditches, roads, buildings, etc.)
g. North arrow

MICROIRRIGATION SYSTEM WORKSHEET 3

Exhibit SC6-2A, (4 of 6)

Cooperator: Frazier Sample Designed by: B. Smith Checked by: ______________

3. Physical system

Mainline:

763 feet to top of field.
340 feet to end of field edge
? feet to expansion.

Worst case rows: 248 feet to zone 1

Mainline Total: 1011 feet

Submain:

Worst case, 8 rows
8 rows X 12 feet/row = 96 feet

We will set the submain inlet pressure to 30 psi, and allow 4 psi loss in submain. Also hold to 5 feet/second flow velocity or less.

Submain pipe sizing added to drawing.

Pressure and mainline:

30 psi at submain, plus ~ 4 psi valve loss (2 inch valve);

Need ~ 34 psi at zone 1 valve.

Mainline length: 1011 feet

Elevation loss: 118 feet – 99 feet = 19 feet, or 8.2 psi

Largest zone flow rate is 88 gpm.

Use 3-inch PR 200 PVC, 0.65 psi/100 feet Loss @ 90 gpm
Friction loss: 0.65 X 10.11 = 6.57 psi;
Elevation: 8.20 psi
Velocity Head (3.66 feet/second): 0.09 psi
Total main loss: 14.86 psi

Pressure required at well head:

Main loss: 14.86 psi
Valve loss: 4.0 psi

Working pressure: 30.0 psi

48.86 psi at well head minimum required.

Exhibit SC6-2A, (5 of 6)

MICROIRRIGATION SYSTEM WORKSHEET 4

Cooperator: Frazier Sample Designed by: B. Smith Checked by: ________________

Pump Sizing:

Need: 49 psi at well head
88 gpm flow rate.

Estimate pumping level at 160 feet.

TDH required: **(49 psi x 2.31 ft/psi) + 160 ft = 273.2 ft TDH at 88 gpm**

Pump selected:

AERmotor GA 80-10, 8 stage, 6 inch submersible
320 feet TDH @ 90 gpm
70 HP motor, 3 inch NPT discharge.
Will require 6-inch or 8-inch well.

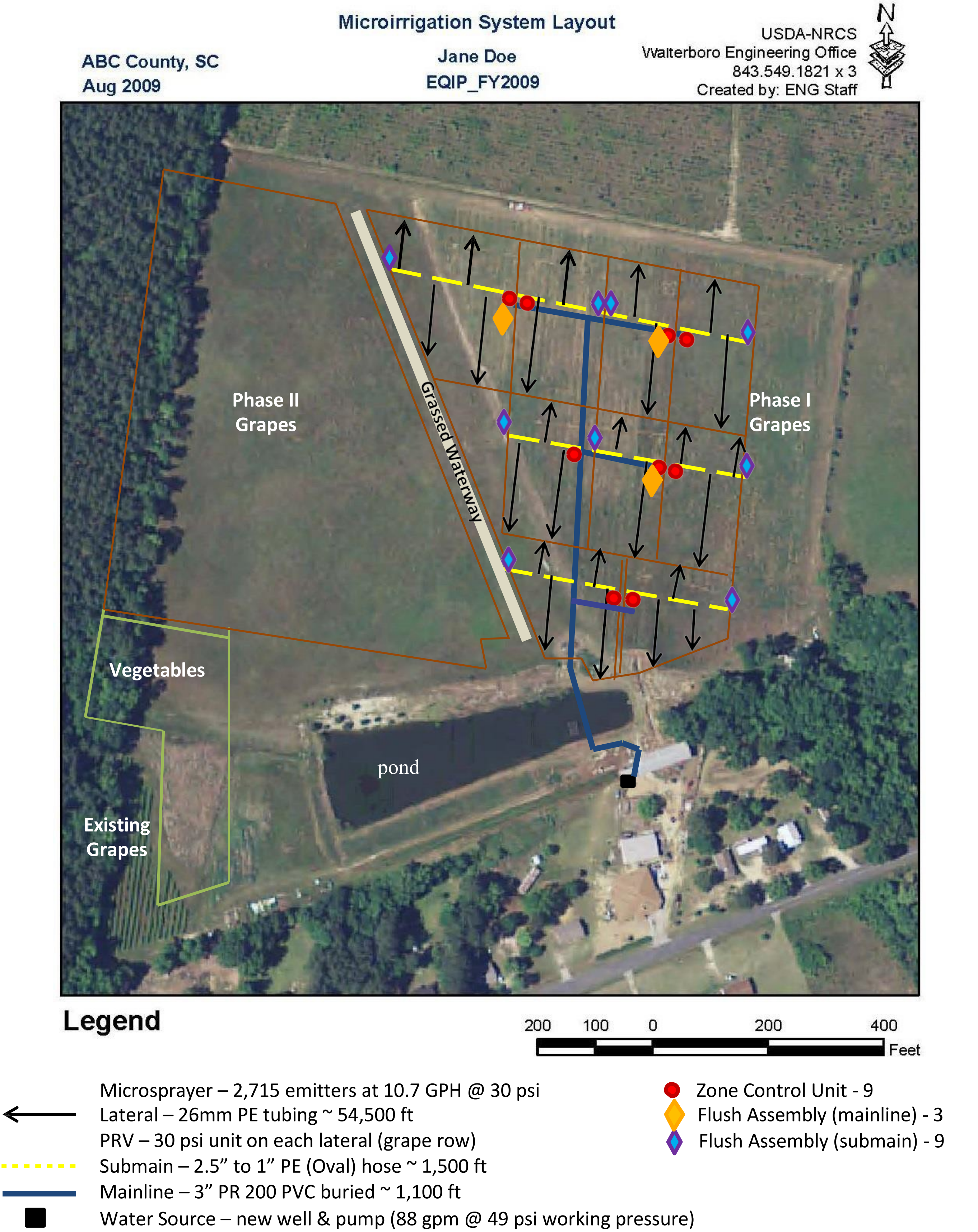
Lateral Sizing:

System SDR (gph/ft): 10.7 gph/10 feet = 1.07 gph/feet

Allowable loss:

Want a minimum of 20 psi (6 psi, or 13.8 feet)
Lateral sizing will change with length and elevation change. On average:
Long run: 720 feet, gains 17.5 feet due to elevation
Maximum allowable friction loss: 13.8 feet + 17.5 feet = 31.3 feet.
16 mm tubing will only allow a length of 330 feet.
20 mm tubing will only allow a length of 500 feet.
26 mm tubing will only allow a length of 750 feet.
Therefore, 26 mm tubing is the choice here.

Exhibit SC6-2A, (6 of 6)



MicroirrigationSystem:

Layout Considerations

Items that must be considered in the layout of a microirrigation system:

a. Soil texture is an important factor in row and emitter spacing.

b. Evaluate plant spacing and row direction so that the submain can be properly located.

c. Note the type and location of the water source.

d. Location of obstacles such as ponds, fences, overhead power lines and buried electrical and gas lines which are safety hazards.

e. Consider topography which may affect the layout of the system and valving arrangement so that each irrigation zone/block can be operated within the allowable pressure variation.

Construction Requirements

Construction items that must be checked to be assured of a quality installation are as follows:

a. The depth of cover over the buried mainline must be adequate for protection from vehicular traffic and the farming operation.

b. Thrust block dimensions, location and alignment to prevent pipe joint separation, if applicable.

c. Location and size of air vents and pressure regulating valve (PRV).

d. Flush Assembly units for both mainline and submain and one manual drain on the main pipeline.

e. Micro device model and flow rate.

f. Location and size of zone control valves which serve each irrigation zone/block.

g. Check components for proper flow direction (check valve, electronic valve, filter, injector unit, PRV)

h. Verify the pipe requirements such as SDR number, pressure rating, ASTM designation, PVC material, pipe diameter and if PIP or IPS pipe.

i. Backflow device installed downstream of well.

j. Verify pump, motor and well size. Then check pressure and variation within each irrigation zone/block using a pressure gauge.

i. Installation of Injector Unit on system.

(b) Subsurface Irrigation System

General

Subsurface (water table control) irrigation involves the application of water on level to gently sloping, slightly wet to wet soils to create an artificial or perched water table over some natural barrier that restricts deep percolation. Moisture reaches the plants through control of the water table and capillary movement.

Irrigation water can be introduced by either open ditches or underground conduits. The water table is maintained at some predetermined depth below the ground surface, usually 24 to 36 inches, depending on the rooting characteristics of the crop grown. The water table can be regulated by controlling the drainage scheme as it applies to subsurface water. Instead of removing subsurface water to make deeper rooting possible, drainage is curtailed and water is added to keep the water table high enough to provide adequate moisture to the root zone through capillary action within the soil. However, the drainage system is still responsible for removing excess surface water and maintaining control of subsurface water so that the water table does not remain in the root zone for a long enough period to cause crop damage.

The plan for drainage becomes more critical when the drainage facilities will be used for subsurface irrigation. A planner must consider a number of items, as follows:

- Ample water supply during dry season.
- Naturally high water table, or a very slowly permeable soil layer below the root zone on which an artificially elevated water table can be maintained without excessive losses through deep percolation.
- Rapidly permeable layer immediately below the topsoil that will allow comparatively free lateral movement of water.
- Uniform and nearly level topography permitting complete and even distribution of water.
- A well planned system of mains, laterals and structures, which will permit orderly movement of water to all parts of the area.
- Adequate outlet for drainage of the system.

There are many locations in the South Carolina Coastal Plain and Flatwoods where the subsurface irrigation method could be used. An understanding of drainage and water table control is needed in designing subsurface irrigation systems. For an in-depth discussion on drainage and water table control, refer to the following: National Engineering Handbook (NEH) Section 16, "Drainage of Agricultural Land", NEH Part 650, Chapter 14 "Water Management (Drainage)", and in particular NEH Part 624, Chapter 10 "Water Table Control", and conservation practice standard, Irrigation System, Surface and Subsurface – Code 443.

(1) Types of Subsurface irrigation

Systems can be managed through either open ditch systems or by an underground conduit.

(i) Open Ditch System –
The open “flow through” ditch system consists of water being supplied to the main supply ditch at the high point of the field. Irrigation water is conveyed by gravity through the entire field area with lateral ditches. Laterals are located to run from the main ditch on the contour or with less than about 1.0 foot vertical variation from end to end. Structures are used to restage the water at about 1.0 foot intervals or less so that water will back into the laterals and move laterally to raise the water table (Figs. SC6-41 and SC6-42).

Main ditches usually require control structures at or near 0.5 ft. vertical intervals, except on the steeper slopes where a structure is required at each lateral. The variation in depth to water table can then be controlled by one structure to stay within the 0.5 ft. permissible variation. A greater variation than this will usually result in part of the area being under irrigated and part being too wet for shallow rooted crops.

Figure SC6-41 A main ditch with a water table control structure to adjust depth of the water table in the field

Figure SC6-42 Parallel field ditches for the purpose of raising water table for subsurface irrigation (Picture of vegetable field in Florida)

(ii) Underground Conduit –
The function of underground conduits (drain tubing) for irrigation is basically the same as the open ditch method. Lateral ditches are replaced by lateral pipelines, which are usually perforated corrugated plastic tubing. Water is supplied through the drain tubing, regulating the water table.

As in the open ditch method, structures are needed to control the water table at its desired elevation. Structures, whether in an open ditch main or in a conduit mainline, are designed to be adjustable so water can be released during excessive rainfall and water can be contained at the desired elevation during irrigation pumping. Underground conduits do not take up surface area, can be installed closer together and deeper than ditches, and maintenance is very low. Normally the cropping pattern is not affected by the orientation of the buried drain tubing. However installation of drain tubing cost more that construction of ditches.

Example Problem:
See NRCS, Florida Irrigation Guide, Supplement FL652.0605e & 0605f for open “flow through” ditch and “underground outlet” design examples.

(c) Permanent Solid-Set System

General

The South Carolina example problem here illustrates the procedures used in the design of a permanent solid-set irrigation system as typically installed in the State. NEH Part 623 and Section 15, Chapter 11 "Sprinkler Irrigation" should provide sufficient information for alternative designs. It details variations for design of components – sprinklers, laterals, mainlines, etc. – that together make up the farmer's sprinkler irrigation system. Additionally NEH Part 652.0602 (b) and (c) discusses and provides a design example for a periodic move system using procedures similar to those for solid-set systems.

At one time solid-set systems were the entry level irrigation system. Often portable pipe was used in layout, and irrigation was set up and moved as weather and crop stage dictated. Today, most are used in irrigating relatively small fields or orchards (Fig SC6-43 to SC6-45). These usually contain high value crops that justify the often expensive, though relatively permanent installation. Auxiliary irrigation for frost protection, crop cooling, and waste disposal also commonly involve solid-set sprinkler systems.

Figure SC6-43 Solid-Set (portable) sprinkle system

Figure SC6-44 Solid-Set system with impact sprinklers

Figure SC6-45 Low level solid-set (permanent/portable) sprinkle system with misters

Design Criteria

Design criteria for permanent solid-set irrigation systems are contained in the NRCS Conservation Practice Standard, Sprinkler System – Code 442, for South Carolina. Distributions patterns and spacing must meet standards for uniformity (CU or DU) as related to the crop value and purpose of the irrigation.

Example Problem:

The following example problem (Exhibit SC6-3) is intended to cover the basic design steps to follow in the design of permanent solid-set sprinkler irrigation systems. The standard form (Exhibit SC6-3A) is used as a tool in designing, calculating, and recording data.

Exhibit SC6-3 Design example for a solid set sprinkler irrigation system, in South Carolina.

Given
Location: Aiken, South Carolina.
Field Shape: 1320 feet east to west by 660 feet north to south (20 acres).
Soil: Dothan loamy sand on 4 percent slopes with soil texture of Loamy Sand; DMR for lettuce = 0 - 11 inch
Crop: Small vegetables – lettuce, tomatoes, peppers, beans, greens, cole crops (collards, broccoli, cauliflower)
Row direction and spacing: Rows run north to south 30 inches apart.
Plant spacing along row: Varies.
Well information: 12 inch well without pump. Power unit planned is electric, 3 phase. Static water level is at 75 feet below ground surface. At a 400 GPM pumping rate, water level is at 125 feet. Pump centerline is at 140 feet.
Other: Owner would like to operate system about 8 - 10 hours per day using manual shut off valves. All pipe to be buried a minimum of 30 inches below the ground surface.

Solution

All ***Item*** numbers mentioned in the step by step solution refer to the items on “Irrigation Data Sheet” Exhibit 6-3D.

Step 1. Complete *Item* 1. Soils and field area.

a. Available water capacity (AWC) values can be obtained in the **Web Soil Survey Physical Properties Report** for this county and soil: 0 - 11 inch layer – 0.88 to 1.26 inches; 11 - 31 inch layer – 1.60 to 2.22 inches. With no site specific soil data, a reasonable average AWC is 0.08 inch/inch over the entire depth for this soil.

Complete *Item* 2. Crops.

b. From the farmer’s suggestions, several crops will be grown in rotation or in mixtures within the area. Dates provided suggest double cropping. Water use would be computed for each crop and the crop that presents the greatest demands will ultimately be used to complete the design.

Complete *Items 3 & 4*. Water supply and pump. These items provide an inventory of pertinent data.

c. If existing water supply and pumps exists, describe them here. They may limit choices and designs. Otherwise design the pumping plant and water supply after the irrigation system.

Step 2. Complete *Item* 5. Make a drawing to scale of the field locating buildings, trees, well and other features.

Step 3. Complete *Item* 6, except for acreage to be grown. That will be discussed later.

a. Guidance in selecting the depth to moisture replacement (**Table SC3-9**) and the daily peak ETc (**ETc Tool**) can be found in this guide**.** Of the planned crops, tomatoes or lima beans would have the deepest rooting. Rooting depths suggest that a depth of moisture replacement of 18 inches be used for the tomatoes/lima beans while 12 inches will be used for the lettuce. The maximum irrigation rate will need to be 0.26 in/day for peak use periods for the tomato, while lettuce would only need 0.13 in/day to meet peak needs. The weighted (AWC) is computed using average data from *Item 1*.

Step 4. Complete the following parts of *Item* 7.

a. AWC within the depth of moisture replacement (DMR) is the product of DMR (*Item* 6 - Depth) times the water holding capacity of the soil for the layers to that depth (*Item* 6 – Weighted AWC). For the beans, DMR = 18 inches and layer AWC = 0.08 inches/inch, therefore, AWC = (18 inches) × (0.08 inches/inch) = 1.44 inches

b. The management allowable depletion (MAD) for this group of water sensitive vegetables is 30 or 40 percent during critical times (**Table SC3-8**). For beans, use 40 percent; for lettuce or tomato, use 30%.

c. The maximum net application depth needed per irrigation (inches) is the product of the highest percent depletion allowed (highest MAD) prior to irrigation times the water available within the DMR zone. For beans, maximum = (0.40) × (1.44 inches) = 0.58 inches; for lettuce, 0.38 inches.

d. The net water to be applied and the rate of that application must be less than or equal to the maximum allowed for the soil and slope to prevent runoff. For this loamy sand surface on a 4 percent slope, up to 1.0 inches can be applied at application rates of 1.5 inches per hour (**Table 2-19**). With less than 0.70 inch application anticipated, runoff should not be an issue. Keep net application amount (d) = 0.60 inches

e. Maximum application rate = 1.5 inches per hour.

f. The system efficiency is assumed to be 70 percent.

g. The gross water applied per irrigation (***dg*** in inches) is found by dividing the net water applied per irrigation by the system efficiency. In this case we see the lima beans will require the greatest gross water required.

$\boldsymbol{d_g}$ = 0.58 inches / 0.70 = 0.83 inches for beans and $\boldsymbol{d_g}$ = 0.38 inches / 0.70 = 0.54 inches for lettuce

h. The peak irrigation interval (***f*** in days) is determined by dividing the net water applied per irrigation by the peak ETc. Here the shortest interval 1.7 days is for tomatoes during critical period. A full irrigation cycle must be completed within that time. Designing for the higher gross application needed for beans will assure that the tomatoes will have enough water, if the water can be applied over the entire field within 2 days.

$\boldsymbol{f}$ = 0.83 inches / 0.18 inches/day = 3.2 days for beans; $\boldsymbol{f}$ = 0.61 inches / 0.26 inches/day = 1.7 days for tomatoes; $\boldsymbol{f}$ = 0.54 inches / 0.13 inches/day = 2.9 days for lettuce.

i. Normally, the irrigation period (***T*** in days) to be used in the formula for determining the system discharge required for each zone ($\boldsymbol{Q_R}$ in gallons/minute/day) is the irrigation interval (***f*** = 2.9 days, for lettuce) determined above. However, in this example the field was broken up into four irrigation zones of 5 acres each, which resulted in two zones being irrigated each day (10 acres/day). Therefore, one (1) day was entered in each column for the irrigation cycle and 5 acres per irrigation zone in *Item* 6. The advantage of dividing the field into four zones/blocks is that a smaller pump can be used and smaller well capacity is required.

$\boldsymbol{f}$ = 1 day; $\boldsymbol{A}$ = 5 acres

j. Four (4) hours operating per day per zone was requested by the owner; however, do not enter this value yet.

Step 5. Tentatively determine the discharge or quantity of water required Q_{Rt} for each irrigation zone. Use the formula:

$$Q_{Rt} = \frac{453 \times A \times d}{f \times T}$$

where:
Q_{Rt} = required minimum discharge capacity (gpm)
A = design area (acres)
d_g = gross application depth (inches)
f = irrigation interval or frequency (days)
T = actual operating time per day (hours/day)

In this example:

Q_{Rt} = (453 x 5 acres x 0.54 inches bean gross application) / (4 hours operating per day x 1 day per irrigation) Q_R = 306 gpm for lettuce, and 470 gpm for beans with gross application of 0.83 inches.

Note that the Q_{Rt} should not exceed the well capacity. The rate calculated for the lettuce is well within this, so the irrigation can be completed within the time desired, but the lima beans would require a well pumping rate higher than available to stay within 4 hours per day. In situations where the well capacity is exceeded then the irrigation zone acreage would need to be decreased or the operating hours per day increased or a well of higher capacity would have to be installed. Assume a design based on lettuce or tomatoes, then extend the hours of irrigation for the limas.

Step 6. Select a sprinkler spacing that is compatible with farming operations. Some alternatives would be 40 ft × 60 ft or 60 ft × 60 ft

A 40 ft × 60 ft arrangement in a rectangular pattern was tentatively selected.

Step 7. Check the sprinkler spacing requirement in the Practice Design Standard, Code 442. Irrigation will be done under average wind conditions (less than 5 mi/hour). The sprinkler spacing should be no greater than 50 percent of the sprinkler wetted diameter and the lateral spacing should be no greater than 65 percent of the soil wetted pattern.

Step 8. Select a sprinkler. There are two requirements for which the sprinkler selection is to be based:

a. The sprinkler wetted diameter must be at least 92.3 feet. This is computed by dividing the lateral spacing of 60 feet by the required maximum spacing of 65 percent of the soil wetted pattern:

Sprinkler Wetted diameter = (60 feet / 0.65 = 92.3 feet);

b. The minimum required discharge of the sprinkler (q_{SPK}). The following formula is used to determine the discharge per sprinkler:

$$d_t = \frac{(q_{SPK} \times 96.3)}{S \times L}$$

where:
d_t = tentative application rate (inches/hour)
q_{SPK} = individual sprinkler discharge (gallons/minUTE)
S = spacing of sprinklers along lateral (feet)
L = spacing between laterals (feet)

For a tentative application rate ***dt*** divide the gross application of 0.54 inches for lettuce by the hours operating per day (4 hours) which results in 0.135 inches per hour. Now solve the formula for q_{SPK}:

$$q_{SPK} = (0.135 \text{ inches/hr} \times 40 \text{ ft} \times 60 \text{ ft}) / 96.3$$
$$= 3.36 \text{ gallons/minute/sprinkler}$$

With the two sprinkler requirements of 5.01 gpm and 92.3 feet wetted diameter, refer to the sprinkler manufacturer's charts. The chart shown below shows a typical manufacturer's sprinkler data and was used to select the sprinkler. The sprinkler selected has a capability of 3.84 gpm @ 45 psi with a wetted diameter of 94 feet which meets the criteria. The nozzle size is 9/64 inches. This data was entered in *Item* 9.

Typical sprinkler manufacturers data used for design and selection of solid set sprinkler application. Highest point of the stream above the nozzle is 7 feet. 1/

Nozzle Pressure	Nozzle 7/64”		Nozzle 1/8”		Nozzle 9/64”		Nozzle 5/32”		Nozzle 11/64”	
	diam.	flow	diam.	flow	diam.	flow	diam.	flow	diam.	flow
psi	ft	gpm	ft	gpm	ft	gpm	ft	gpm	ft	gpm
25	78	1.73	82	2.25	85	2.90	88	3.52	90	4.24
30	79	1.89	84	2.47	87	3.16	90	3.85	92	4.64
35	80	2.05	85	2.68	89	3.40	92	4.16	94	5.02
40	81	2.20	86	2.87	91	3.63	94	4.45	96	5.37
45	82	2.32	87	3.05	92	3.84	96	4.72	98	5.70
50	83	2.44	88	3.22	93	4.04	98	4.98	100	6.01
55	84	2.56	89	3.39	94	4.22	100	5.22	102	6.30
60	85	2.69	90	3.55	95	4.28	101	5.54	103	6.56

1/ Shown for standard nozzle at normal operating pressure. Area below the dotted line in the table is the recommended working pressure for best distribution.

Step 9. Complete *Item* 8.

a. Application rate ***d*** is recomputed as above for the tentative application rate:

$$d = (q_{SPK} \text{ x } 96.3) / (S \text{ x } L)$$
$$= (3.84 \times 96.3) / (40 \times 60)$$
$$= 0.15 \text{ inches/hour}$$

b. Time per lateral or zone set in hours is computed by dividing the gross application d_g of 0.54 inches by the application rate d of 0.15 inch/hour.

Time per zone = 0.54 inches / 0.15 inch/hour = 3.6 hour

c. Determine the number of sprinklers per zone. Divide the field using the drawing prepared in Step 2 into 4 as nearly equal zones as possible. Place the sprinklers, pipe layout and valves on the plan. Label each zone and place it on the drawing. Count the number of sprinklers per zone and enter in *Item* 8:

sprinklers per zone = 88

d. Determine the actual maximum discharge of the zone (**QA** gallons/minute/zone). Multiply the number of sprinklers per zones times the q_{SPK} to determine gpm/zone:

Q_A = 88 sprinklers × 3.84 gpm/sprinkler
= 338 gallons/minute [design mainline pipe for this flow rate]

Step 10. Complete the last entry of *Item* 7. Enter the actual hours operating per day, 3.6 hours, as calculated in Step 9b. The required minimum discharge capacity (Q_R) is obtained by the formula:

$$Q_{Rt} = \frac{453 \times A \times d}{f \times T}$$

where:
Q_{Rt} = required minimum discharge capacity (gpm)
A = design area (acres)
d_g = gross application depth (inches)
f = irrigation interval or frequency (days)
T = actual operating time per day (hours/day)

In this example:

Q_R = (453 × 5 ac × 0.54 inches) / (1 day × 3.6 hr/day)
≈ 340 gpm

Note that as a check, the Q_A should be approximately equal to Q_R.

Step 11. Determine Total Dynamic Head. Refer to *Item* 10, as each of the following points is discussed:

a. Size the lateral and submain to determine its head loss. Usually the longest lateral is used to determine the head loss within the irrigation zone. However, ground elevation changes may sometimes cause the maximum head loss to occur elsewhere. This will be discussed later in this example. First, the gpm for the lateral and submain was listed in a cumulative manner beginning with the last sprinkler. The length of pipe carrying the corresponding gpm was then listed.

b. Then using Supplement Chapter 16 the pipe was sized and corresponding friction head loss (HL_f in feet/100 feet) was listed on the data sheet. The pipe is sized so that the velocity of water flow through the pipe is less than or equal to 5 feet per second. The total friction head loss is determined by multiplying the HL_f (feet/100 feet) times the pipe length (feet) and summing the results. The elevation differences are then totaled and added to the total friction head loss to obtain the total head loss in the lateral.

The summation of 6.38 feet was calculated in this design example.

Elevation difference of natural ground between the risers and within an irrigation zone must be evaluated for each design as it can affect the layout of the irrigation zone and the pipe sizing. It affects the layout because the nozzle pressure must be maintained within certain limits in each irrigation zone/block. These limits are discussed in Step 13.

The effect that elevation difference has on pipe sizing can best be explained using an example. For instance, if a lateral is to be installed downhill from the mainline, a smaller pipe with higher friction head loss may be used. The elevation difference is downhill (increase in pressure) which offsets the decrease in pressure due to friction head loss. An increasing elevation plays a reverse role often resulting in a larger diameter pipe.

c. The head loss for the irrigation zone is then modified so that the theoretical *mid-system* sprinkler is operating at the design nozzle pressure. This provides for a more balanced system in that the sprinkler closer to the pump operates at a pressure a little higher than the design nozzle pressure and the farthest sprinkler a little lower in pressure. The head loss can be modified by multiplying the summation of HL by 0.5.

Note: The factor 0.75 would be used if this was a single pipe size lateral because approximately 75 percent of the pressure loss in a single pipe size lateral with uniformly decreasing discharge has already occurred at the midpoint of the lateral.

Assume the sprinklers within an irrigation zone are desired to operate at a pressure within +/- 10 percent of the design operating pressure. In this case, with the design operating pressure at 45 psi, the allowable variation in sprinkler operating pressure is + 0.10 x 45 psi = + 4.5 psi. Therefore, 45 psi + 4.5 psi = 40.5 psi and 49.5 psi for the minimum and maximum sprinkler operating pressure.

d. Size the mainline and determine the head loss. *Item* 10 could have been used for sizing and determining the mainline head loss since no elevation changes were involved, but the pipe sizing data sheet was used for the mainline also.

The 6 inch main with flow of 338 gpm has a friction head loss of 0.69 ft/100 feet. Total head loss is equal to 0.69 ft/100 feet × 495 feet = 3.43 feet. The 3.43 feet total head loss is equal to 1.48 psi.

e. Determine the recommended maximum working pressure. This is the class of pipe (160 psi) multiplied by 0.72 = 115 psi since it is assumed special surge and water hammer control is not to be provided. Do not compute actual working pressure until later in the design.

f. Design sprinkler nozzle pressure. The 45 psi sprinkler operating pressure was determined in *Item* 9. Remember that this is the operating pressure of the theoretical mid-sprinkler of the irrigation zone.

g. Miscellaneous and fitting friction losses ("local losses") can be computed using the formula:

$$h_{f\text{-}local} = K_r \times \frac{V^2}{2g}$$

where:

$h_{f\text{-}local}$ = local head loss (feet)

$V^2/2g$ = velocity head (feet) found in Table 11-24 of NEH Part 623 or Supplement Chapter 16 for various pipe inside diameters and flow rates.

K_r = dimensionless constant found in Supplement Chapter 16, Exhibit SC16-6 for various fittings.

Local friction loss is usually estimated to be within a range of 3 to 8 feet or 1.3 psi to 3.5 psi depending on the complexity of the system. This example was estimated to have about 1.3 psi head loss for miscellaneous and fitting losses.

h. The riser height head loss is the height required to get the sprinkler above the vegetation to prevent distortion of the sprinkler pattern. In this case, 3 feet (1.3 psi) is required.

i. Calculate the pump discharge pressure (at the entrance to the main pipe line). This is the pressure the pump must produce so that the theoretical mid-sprinkler of the irrigation zone is operating at its design operating pressure of 45 psi. To obtain the pump discharge pressure, the preceding items were totaled as follows:

Lateral & submain friction losses	1.38 psi
Mainline friction losses	1.48 psi
Nozzle pressure	45.00 psi
Local fittings friction losses	1.30 psi
Riser height	1.30 psi
Pump discharge pressure	50.50 psi

j. Maximum pipe working pressure in main. This is the same as the pump discharge pressure just determined (50.5 psi). From step 11d, the maximum recommended working pressure for the 6 inch class 160 pipe is 115 psi, thus the pipe strength is adequate throughout.

k. Pumping lift is discussed in NEH Part 652, Chapter 7 or Supplement Chapter 7. It is the vertical distance the pump must lift the water in the well to reach the ground level (main inlet) or in the case of a centrifugal pump the vertical distance plus losses (suction lift) from the water elevation at maximum drawdown to the pump discharge. The pump drawdown is considered in determining the pumping lift. This example has the static water level at 75 feet with 50 feet of drawdown when pumping.

Therefore the pumping lift is 75 feet + 50 feet = 125 feet or 54.1 psi because 2.31 ft = 1 psi.

l. Total dynamic head (TDH). This is the total head loss that the pump must operate against in order for it to perform the required work. The pump discharge pressure (50.5) psi + pumping lift (54.1 psi) = 104.6 psi TDH. This is usually expressed in feet which would be 241.6 feet TDH. (use 242 feet).

m. Net positive suction head available (NPSHA) can be represented in terms of pressure or elevation. This represents the energy available to move the water into the eye of the impeller. More information can be found in NEH Part 652, Chapter 7 or Supplement Chapter 7.

$$NSPH_A = \frac{2.31 \text{ x } (P_A - P_V)}{\text{Sp. Gravity}} + (H_E - H_F) \quad \textbf{OR} \quad NSPH_A = 144 \text{ x } \frac{(P_A - P_V)}{w} - h_f + z$$

where:
$NPSH_A$ = Net positive suction head available (feet). See Supplement Chapter 7, Exhibit 7-23 for schematic.
P_A = pressure, psia, on a free water surface, atmospheric.
P_V = "saturated" vapor pressure, psia, of the water, based on the actual "feels like" air temperature.
(http://www.srh.noaa.gov/epz/?n=wxcalc_vaporpressure)
H_F or h_f = head loss (feet) due to friction loss in inlet (suction) line to impeller entrance (use 3 feet as average value in most situations). Include all components between intake and pump entrance.
H_E or z = elevation difference, feet (suction lift) between pump centerline and the water surface (assume 20' for this example). If the suction water surface is below the pump centerline, z is negative.
Sp. Gravity = specific gravity of a liquid being pumped at a given temperature (typically water @ 70F).
w = unit weight of water, pounds/cubic foot.

[The minimum probable value for the term $144 (P_A - P_V) / w$ at 70°F at sea level ≈ 144 (13.57 - 0.37) / 62.3 = 30.49 ft, use 31 feet. This value (31 feet) may be used throughout the Piedmont (up to 1000 feet about sea level) and lower lying areas of South Carolina for acceptable accuracy. For higher lying areas (up to about 4000 feet above sea level) the value should be reduced about one foot for each 1000 feet rise in elevation.]

In this example: $NPSH_A = 31 - 3.0 + 20.0 = 48$ feet

Step 12. Complete *Item* 11, the Pump Requirement. This is the maximum output (gpm) the pump must produce at a given TDH and minimum net positive suction head. From *Item* 8, the maximum Q_A for an irrigation zones is 338 gpm. The TDH from the preceding section is 242 feet. The NPSH required must be less than 48 feet. Therefore, the pump requirement would be expressed as 338 gpm at 242 feet TDH with NPSH less than 48 feet.

Step 13. Complete *Item* 12, the Power Unit Requirement. This is the brake horsepower (BHP) needed at the output from the power unit to supply power to the pump. The pump efficiency would be obtained from the characteristics curve for the particular pump to be used. A value of 70 percent would be a reasonable value for some pumps, therefore use 0.7. The drive efficiency for a direct connected electric motor is approximately 100 percent, so use 1.00. Finally, compute BHP using gpm and TDH from the preceding step.

$$\text{BHP} \geq \frac{338 \text{ gpm x } 242 \text{ ft TDH}}{3{,}960 \text{ x } 0.7 \text{ x } 1.0} = 29.5$$

Step 14. Complete *Item* 13. Check the sprinkler pressure variation within the system (Irrigation Zones) against the allowable variation. This was discussed earlier under Step 11b. The actual is found by using sheet 4 of 5 of Exhibit SC6-3A, *Item 13*. The actual nozzle pressure of the closer sprinkler is the pump discharge pressure (50.5 psi) minus the mainline losses (1.48 psi) minus miscellaneous and fitting friction losses (1.30 psi) minus the riser height loss (1.30 psi) = 46.4 psi.

The actual nozzle pressure of the farthest nozzle is the pump discharge pressure (50.5 psi) minus the mainline loss (1.48 psi) minus miscellaneous and fitting friction losses (1.30 psi) minus the riser height loss (1.30 psi) minus actual total lateral and submain losses (2.8 psi) = 43.6 psi.

The allowable nozzle pressure as taken from Step 11b. is 40.5 psi (minimum) and 49.5 psi (maximum). The actual nozzle pressures of 43.6 psi and 46.4 psi are within this range.

EXHIBIT 6-3A, Sheets 1- 5 follow.

Exhibit SC6-3A, (1 of 5)

IRRIGATION DATA SYSTEM

System type (circle): Center Pivot, Traveling Gun, Permanent Solid Set, Other ____

Conservation District: Aiken Field Office: Aiken

Cooperator: John Doe Location: Aiken Co

Irr. System No.: System No 1 Field No.: 2 – Old Jenson Place

1. Design area 20 acres (area actually irrigated)

   Soil series Dothan ls

   Design Soil Series: Dothan Predominate maximum slope 4 percent

Soil Depth (in.)	Texture (USDA)	Average AWC (in./in.)
0 – 11	ls	(0.88 – 1.26 in) 0.08 – 0.11
11 – 31	SL	(1.60 – 2.22 in) 0.08 – 0.11
		Use 0.08 in/in

2. Crops:

Crop	Area (acres)	Planting Date	Maturity Date
Lettuce (Various)	0 – 20	20 Feb	18 Apr
Tomatoes	0 – 20	20 Apr	20 Aug
Lima Beans	0 – 20	20 Apr	20 Aug
Total (acres)			

3. Water Supply:

   Source of Supply: (stream, well, farm pond, etc.; description) 12 in. dia

   Stream: Measured flow (season of peak use) ____ gpm

   Farm Pond: Storage ____ acre feet; Available for irrigation ____ acre feet.

   Stream or Reservoir: Maximum drawdown available or elevation at low flow ____ feet;
   Maximum elevation lift on intake side of pump ____ feet.

   Well: Static water level 75 feet.
   Measured capacity 400 gpm at 50 foot drawdown.
   Design pumping lift 125 feet (to ground level – main pipeline inlet.)
   Pump impeller level 140 feet.

   Distance supply source (main pipeline inlet) to field 0 feet.

   Quality of water (evidence of suitability): No Apparent Problems

4. Other Data:

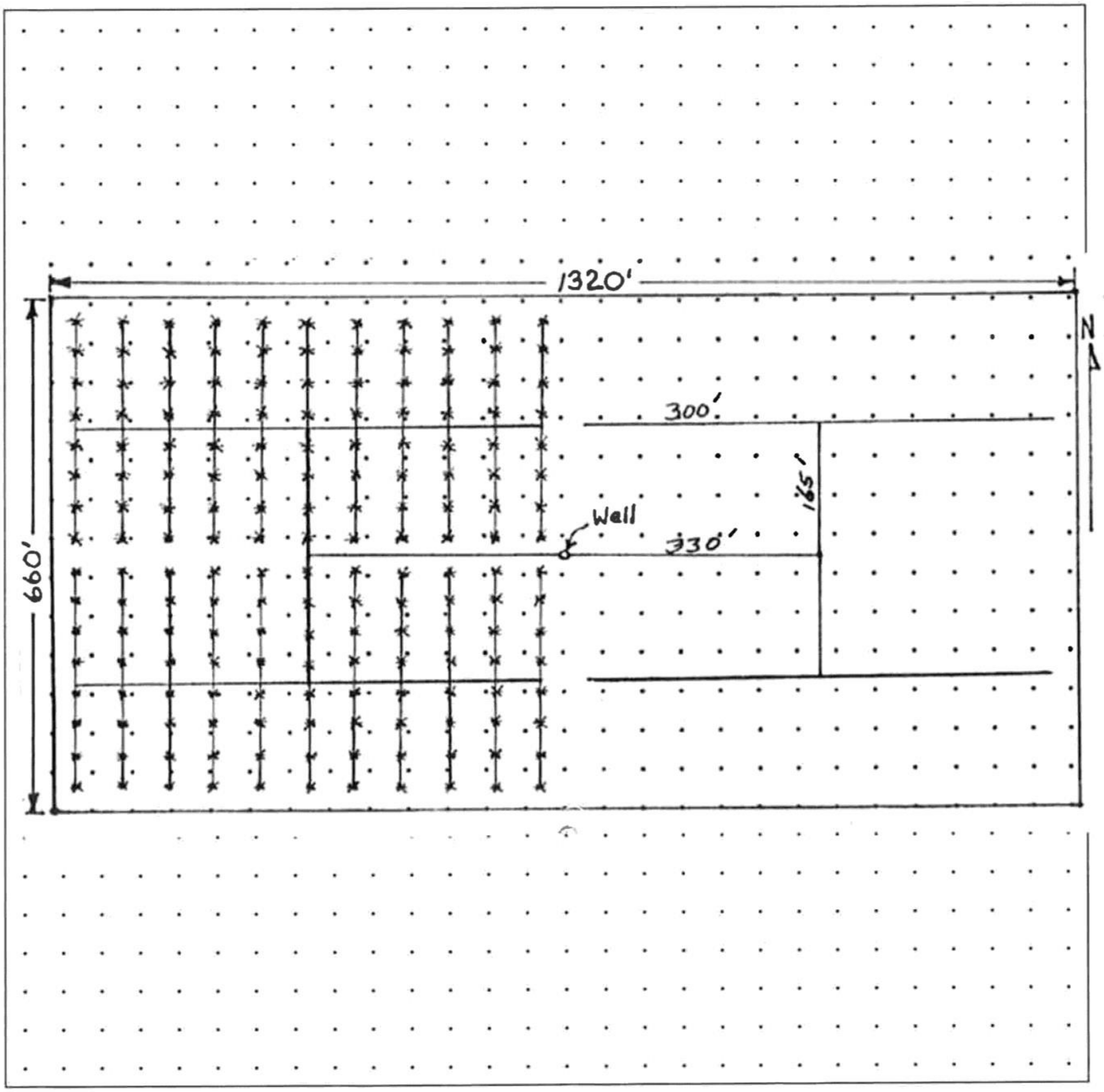
   Type of power unit and pump to be used: Electric – 3 phase

Exhibit SC6-3A, (2 of 5)

IRRIGATION DATA LAYOUT

Cooperator: John Doe Designed by: Tom Jones Checked by: A. Engineer

5. Sketch map on grid or attach photo or overlay with drawing; Map of design area – Scale 1" = 200 feet.



Sketch map should show:

1. Source of water
2. Major elevation differences
c. Row direction
d. Sprinkler system layout
e. Plan of Operation
f. Field obstructions (gullies, ditches, roads, buildings, etc.)
g. North arrow

Exhibit SC6-3A, (3 of 5)

PERMANENT SOLID SET SPRINKLER SYSTEM DATA 1

Cooperator: John Doe Designed by: Tom Jones Checked by: A. Engineer

		Irrigation unit Number			
6.	Crop Information	1	2	3	4
	Kind of crop	Tomato	Limas	Lettuce	
	Acreage to be irrigated at one time (acres) [1]	5	5	5	
	Depth of soil water control zone (inches) **(DMR)**	18	18	12	
	Peak use rate (Inches/day)	0.26	0.18	0.13	
	Weighted AWC for water control zone (inches/inch)	0.08	0.08	0.08	

7.	Design Procedure	1	2	3	4
	a. AWC within water control zone (inches)	1.44	1.44	0.96	
	b. Management Allowable Depletion (percent)	30	40	30	
	c. Maximum Net Water Allowed per Irrigation (inches)	0.43	0.58	0.38	
	d. Net Water Needed per Irrigation (inches)	0.43	0.58	0.38	
	e. Maximum Recommended Application Rate (inches/hour)	No Limits			
	f. Irrigation System Efficiency (percent)	70	70	70	
	g. Gross application per irrigation (inches) [1]	0.61	0.83	0.54	
	h. Peak irrigation interval (days)	1.7	3.2	2.9	
	i. Irrigation Period (days per irrigation)	1	1	1	
	j. Daily operating time per day (hours)	4	4	4	
	Q_R = Quantity of water required (gpm) [1]	345	470	306	

8.	Irrigation Unit Design	1	2	3	4
	Application Rate (inches/hour) [2]			0.15	
	Actual time per lateral or unit set (hours) $time = \frac{gross\ application}{application\ rate}$	4.1	5.5	3.6	
	Number of sprinklers per unit			88	
	Maximum unit application rate (Q_A – gpm/unit) $QA = Number\ of\ sprinklers\ per\ unit \times gpm/sprinkler$			338	

9. Sprinkler Specifications

a. Sprinkler spacing 40 feet, lateral spacing 60 feet.

b. Nozzle size 9/64 in. X – ; Wetted diameter 92 feet.

c. Capacity 3.84 gpm @ 45 psi or 104 feet.

Notes:

1. $$Q_R = \frac{453 \times (5)\text{ acres} \times (0.54)\text{ inches gross application}}{(4.0)\text{ hours operating/day} \times (1)\text{ days/irrigation}} = (306)\text{ gpm}$$

2. Application Rate $\left(\frac{\text{inches}}{\text{hour}}\right) = \frac{\frac{\text{gpm}}{\text{sprinkler}} \times 96.3}{S \times L}$ Must be ≤ Maximum Recommended Rate

   Where: S = Spacing of sprinkler along lateral (in feet)

   L = Spacing between laterals (in feet)

3. Q_A = Maximum unit gpm: Must be approximately equal to Q_R

Exhibit SC6-3A, (4 of 5)

PERMANENT SOLID SET SPRINKLER SYSTEM DATA 2

Cooperator: John Doe Designed by: Tom Jones Checked by: A. Engineer

10. Determining Total Dynamic Head [4]

Kind of Pipe			Design Capacity	IPS PIP other Diameter	Length	Friction Head Loss [5]	Total Head Loss	Total Head Loss, HL		Working Pressure	
										Recommend Max. [6]	Actual Max.
Main	Sub-main	Lateral	(gpm)	(inches)	(feet)	(ft/100ft)	Feet	(feet)	(psi)	(psi)	(psi)
	/	/	See attached sheet				6.38				
				for pipe calculations							
								(7)			
							6.38	3.19	1.38		
✓								3.43	1.48	115.	50.5

	(feet)	(psi)
Design Sprinkler Nozzle Pressure	104.0	45.0
Miscellaneous and Fitting Losses (usually 3 psi +)	3.0	1.3
Riser Height	3.0	1.3
Pump Discharge Pressure (at main pipeline inlet)	116.6	50.5
Pumping Lift (including losses)	125.0	54.1
Total Dynamic Head, TDH	241.6	104.6
Estimated Net Positive Suction Head Available, NPSHA	48	—

11. Pump Requirements: (338) gpm @ (104.6) psi or (242) feet of head and NPSH less than (48) feet.

12. Power Unit Requirement:

$$\text{BHP} \geq \frac{(\ 338\ )\text{ gpm} \times (\ 242\ )\text{ feet} \times \text{Total Dynamic Head}}{3960 \times (\ 0.7\ )\text{ pump efficiency} \times (\ 1.0\ )\text{ drive efficiency}} = (\ 29.5\ )\text{ gpm}$$

13. Check pressure variation the system (irrigating unit).
    - Allowable = ± (10) percent of nozzle operating pressure = ± (4.5) psi.
    - Allowable = (40.5) psi to (49.5) psi.
    - Actual [8] = (43.6) psi to (46.4) psi.

Notes:

4. Use pipe sizing data sheets where elevation differences are present and/or additional data lines are needed.
5. Keep velocity ≤ 5 fps unless means to control surge and water hammer are otherwise adequate.
6. For plastic pipe, pressure rating divided by 0.72 unless means to control surge and water hammer are otherwise adequate.
7. Sets optimal nozzle pressure at a theoretical mid-system sprinkler.
8. Consider elevations and location. Adjust Optimal Nozzle Pressure if possible to stay within allowed variation. If not, the system must be redesigned.

Design Approved: Ann Engineer Date: Jan 13, 2013

Sheet 5 of 5

Cooperator John Doe
Field Office Aiken

PIPE SIZING WORK SHEET

Designed by Tom Jones
Checked by A. Engineer

Irrigation Unit No. ____			Pipe Sizing Calculations								Pipe Material: PVC☐ SDR☐ IPS☑ PIP☐ Other ____
Main	Sub-Main	Lateral	Design Capacity	Pipe Diam.	Length	HL_f	Multiple Outlet Factor	Total HL_f	Elevation Difference HL_e	Total HL $HL_f + HL_e$	Remarks
			(gpm)	(inches)	(feet)	(ft/100ft)		(feet)	(feet)	(feet)	
		✓	3.84	1	40	0.49		0.20	0.20	0.40	All pipe is PVC
		✓	7.68	1	40	1.79		0.72	0.10	0.82	type 1120 material
		✓	11.52	1 1/4	40	1.16		0.47	0.10	0.57	
		✓	15.36	1 1/4	40	1.94		0.39	0.20	0.59	
	✓		30.72	2	60	1.21		0.73	-0.20	0.53	
	✓		61.44	2 1/2	60	1.72		1.03	-0.10	0.93	
	✓		92.16	3	60	1.41		0.85	0	0.85	
	✓		122.88	3 1/2	60	1.25		0.75	0.10	0.85	
	✓		153.60	4	60	1.06		0.64	0.20	0.84	
							Σ	5.78	0.60	6.38	1/2 total HL = 6.38/2 = 3.19 ①
✓			337.92	6	495	0.69		3.43	0	3.43	class 160 pipe
		①	Modification to provide theoretical mid-system sprinkler								
			to be at optimum pressure used for design								

Exhibit SC6-3A, (5 of 5)

Permanent Solid-Set Irrigation System:

Layout Considerations

Items that must be considered in the layout of a permanent solid-set irrigation system area as follows:

a. Soil limitations which may affect the ease of installation such as cut banks caving, depth to rocks and wetness.

b. Plant spacing and row direction so that riser can be properly located.

c. Maximum height of plants for determining riser height.

d. Location of obstacles such as ponds, fences, overhead power lines and buried electrical and gas lines which are safety hazards.

e. Topography which may affect the layout of the system and valving arrangement so that each irrigation zone can be operated within the allowable pressure variation.

Construction Requirements

Construction items that must be checked to be assured of a quality installation are as follows:

a. The depth of cover over the buried main line must be adequate for protection from vehicular traffic and the farming operation.

b. Thrust block dimensions, location and alignment to prevent pipe joint separation.

c. Location and size of air vents and pressure relief valve. Risers function as air vents but others may be required if a pipeline has a summit with no riser.

d. Riser material, diameter, height and spacing.

e. Sprinkler model and size nozzle. Location of part circle sprinklers if planned.

f. Location and size of valves which serve each irrigation zone.

g. Verify the pipe requirements such as SDR number, pressure rating, ASTM designation, PVC material, pipe diameter and if PIP or IPS pipe.

h. Check valve installed at pump discharge.

i. Verify pump, motor and well size. Then check the nozzle pressure and variation within each irrigation zone using a pressure gauge with a pitot tube.

(d) Traveler Irrigation System

General

NEH Part 623 and Section 15, Chapter 11 "Sprinkler Irrigation" provides a detailed explanation of design procedures and a partial design example. That material along with our example can be used as a design guide.

The South Carolina example problem illustrates the procedures used in the design of a typical traveling gun irrigation system as installed in the State. Although somewhat more limited in capabilities than other irrigation methods, with careful field layout and proper design of water supply, travelers can provide effective irrigation for field crops. It is understood that one example cannot explain all design situations or alternatives to consider.

Figure SC6-46 Typical traveler spray application in a crop (tobacco) field.

Design Criteria

Design criteria for traveling gun sprinkler irrigation system are contained in Conservation Practice Standard, Irrigation System, Sprinkler - Code 442, for South Carolina. All traveling gun sprinkler irrigation system must be designed in accordance with the criteria contained in the most current Code 442. NEH, Section 15, Chapter 11, Table 11-31 provides recommended towpath spacing. This table is duplicated in this example section for convenience and is shown as Table SC6-19.

This criterion relates to water losses tied to wind speed. To provide acceptably uniform coverage for the crop, closer towpath spacing is needed when wind speed increases. Overlap may reach 50 percent in higher wind speeds. Figures SC6-47 and SC6-48 show common spray coverage of traveler systems.

Figure SC6-47 Typical wetted pattern of one application run with a traveler (big gun) system

Figure SC6-48 Ideally, fields used with traveler systems are rectangular with a water supply main and row of riser connections through the center providing application overlap. Odd shaped fields can also be irrigated effectively with modifications for travel run times and a little tolerance for overlap.

Example Problem

The following example problem (Exhibit SC6-4) is intended to cover the basic traveling gun design steps. A standard form (Exhibit SC6-4A) is a useful tool in designing and recording data.

Exhibit SC6-4 Design example for a traveler sprinkler irrigation system in South Carolina.

Given

Field dimensions: The total length of the field is 1,800 feet and width is 1660 feet, approximately 68 acres.
Crop & Acres: 40 acres soybeans, 28 acres peanuts
Soil: Fuquay Sand with soil texture of sand (S) for 0 - 24 inch DMR
Location: Orangeburg, South Carolina
Crop Rows: North and South
Slope: Maximum 6 percent
Available equipment: Existing Nelson 200 gun, 27 degree trajectory, 1 3/4" Ring Nozzle, 270 degree angle of operation. Hose length is 660 feet.
Existing pump: Pump capability (existing): 500 gpm @ 320 feet TDH; 600 gpm @ 350 feet TDH; 700 gpm @ 400 feet TDH.

Solution:

All ***Item*** numbers mentioned in the step by step solution refer to the items on "Irrigation Data Sheet" Exhibit 6-4A.
Step 1. Complete *Item* 1. Soils and field area.

a. AWC values can be obtained in the **Web Soil Survey Physical Properties Report** for this county and soil: 0-24 inch layer – 0.03 to 0.07 inches/inch. With no site specific soil data, a reasonable average AWC is 0.05 inch/inch over the entire depth for this soil.

   Complete *Item* 2. Crops.

b. From the farmers suggestions, several crops will be grown in rotation or in mixtures within the area. Water use would be computed for each and the crop that presents the greatest demands will ultimately be used to finalize the design.

   Complete *Items 3 & 4*. Water supply and pump. These items provide an inventory of pertinent data.

c. If existing water supply and pumps exists, describe them here. They may limit choices and designs. Otherwise design the pumping plant and water supply after the irrigation system.

Step 2. Complete *Item* 5. Make a drawing to scale of the field locating buildings, trees, well and other features.

Step 3. Complete *Item* 6. Guidance in selecting the depth to moisture replacement (**Table SC3-9**) and the daily peak ETc (**ETc Tool**) can be found in this guide**.** The weighted AWC is computed using data from *Item* 1.

Step 4. Complete the following parts of *Item* 7 (the figures used in the following steps will be specifically oriented to the soybeans, the crop with the larger peak consumptive use).

a. Available water capacity (AWC) within the water control (root) zone is the product of the root zone water extraction depth (24 inches) times the water holding capacity of the soil (0.05 inches/in.) for soybeans.

b. The Management Allowable Depletion (MAD) prior to irrigation is selected to be 50 percent for soybeans (**Table SC3-8**).

c. The maximum net water applied per irrigation (inches) is the product of the MAD percent (50 percent) times the water available within the root zone (1.2 inches). Thus, the maximum net water applied per irrigation is = 0.50 x 1.2 inches = 0.60 inches.

d. Maximum application rate from **Table SC2-18**. Use 0.8 inch per hour or less.

e. The net water to be applied should be less than or equal to the maximum allowed. Use the maximum for this example - 0.60 inches.

f. The water application efficiency is selected to be 70 percent (average for day and night irrigation).

g. The gross water applied per irrigation (inches) is the net water applied (0.60 inches) divided by the system efficiency (70 percent). Gross water applied = 0.60 inches / 0.7 = 0.86 inches.

h. The peak irrigation interval (days) is the net water applied (0.60 inches) divided by the design peak use rate (0.30 inch/day). Peak irrigation interval = 0.60 inch / 0.30 inch/day = 2.0 days.

i. The irrigation period to be used in the formula for determining the Q_R is the irrigation interval, 2.0 days.

j. The hours operating per day were discussed with the owner who advised that he irrigated continuously until completed. Therefore, the 20 hours were agreed upon providing another 4 hours for moving the equipment.

k. Now determine the quantity of water required (gpm) using the formula as follows (See Step 5 of solid-set example for explanation of the formula.):

$$\boldsymbol{Q_R} = \frac{\boldsymbol{453 \times A \times d}}{\boldsymbol{f \times T}}$$

$$\boldsymbol{Q_R} = \frac{453 \times 68\ acre\ \times 0.86\ inches\ \text{gross applicaton}}{20\ hr\ day \times 2.0\ days\ per\ irrigation} = 662\ gpm$$

Step 5. Complete *Item* 8, the Irrigation Zone

a. Keeping in mind the capability of the pump (see Exhibit 6-4A, Sheet 1) and the minimum discharge (***Q*** - gpm) required – 662 gpm, determine the nozzle size, sprinkler discharge (gpm), and nozzle pressure (psi).

b. Using the Volume Gun Performance Tables (Supplement Chapter 16) with a ring nozzle size of 1 7/8 inches, a capacity of 675 gpm at 80 psi was selected giving a wetted diameter of 470 feet.

c. Assuming a wind speed of 5 to 10 mph, requiring approximately 60 - 65 percent of the wetted diameter of the sprinkler (**Table SC6-19**, below), determine the lane spacing. A spacing of 290 feet between risers (lanes) was tentatively selected. That is 62 percent of the wetted diameter.

d. Now, in order to properly irrigate the ends of the field parallel to the travel lanes, the riser needs to be approximately 75 percent of the wetted radius away from the field boundary, in this example, 0.75 x 235 ft = 176 feet. Determine the distance actually available by dividing the field length 1,800 feet by the lane spacing 290 feet = 6.21 spaces. Take 1.21 spaces x 290 feet/space = 350 feet and place half of this (175 feet) distance at each end of the field between the riser (lane) and field boundary. The 175 feet is adequate.

e. The application rate is computed using the following formula:

$$\textbf{\textit{App. Rate}} \cong \frac{96.3 \text{ x } \textbf{\textit{q sprinkler}}}{0.81 \text{ x } 3.14 \text{ x } \textbf{\textit{r}}^{2}} \text{ x } \frac{360}{\textbf{\textit{w}}}$$

where:
App. Rate = Application rate (inches/hour);
q sprinkler = sprinkler discharge rate (gpm);
r = wetted diameter/2 (feet);
w = portion of circle receiving water (degrees)

In this example:

$$\boldsymbol{App.Rate} \cong \frac{96.3 \times 675gpm}{0.81 \times 3.14 \times 235ft^2} \times \frac{360}{270} = 0.62\ inches/hour$$

f. The travel speed is computed by the following formula:

$$\boldsymbol{v} = \frac{1.605 \text{ x } \textbf{\textit{q sprinkler}}}{\textbf{\textit{lane spacing}} \text{ x } \textbf{\textit{gross appl.}}}$$

where:
v = Travel speed (feet/minute);
q sprinkler = sprinkler discharge rate (gpm);
lane space = spacing of risers/lanes (feet);
gross appl. = is the gross application per irrigation event for the crop (inches)

In this example, for soybean:

$$\text{Travel speed } (\boldsymbol{v}) = \frac{\textbf{\textit{1.605}} \text{ x } \textbf{\textit{675 gpm}}}{\textbf{\textit{209 ft}} \text{ x } \textbf{\textit{0.86 in.}}} = 4.34 \text{ feet/minute}$$

g. Time per 660 feet run (hours) = (660 feet)/(4.34 feet/min) x 1 hour/60 min = 2.53 hours

Table SC6–19 Recommended tow-path spacing for traveling sprinklers with ring (lower) and tapered (higher percentage) nozzles. 1/

Sprinkler wetted diameter	Percent of Wetted Diameter						
	50	55	60	65	70	75	80
	Wind over 10 mph		Wind up to 10 mph		Wind up to 5 mph		No wind
ft	ft	ft	ft	ft	ft	ft	ft
200	100	110	120	130	140	150	160
250	125	137	150	162	175	187	200
300	150	165	180	195	210	225	240
350	175	192	210	227	245	262	280
400	200	220	240	260	280	300	320
450	225	248	270	292	315	338	360
500	250	275	300	325	350	375	400
550	275	302	330	358	385	412	440
600	300	330	360	390	420	-	-

1/ Source NEH Section 15, Chapter 11, Table 11-31.

Step 6. Complete *Item* 9, the Sprinkler Specification.

Step 7. Make a scaled plan layout of the system. Pipe sizes etc., will be added later.

Step 8. Complete *Item* 10. Size the mainline and determine the Total Dynamic Head (TDH) required for the pump:

a. Using 8 inch diameter PVC, SDR 26, class 160 IPS pipe and a length of 1,725 feet. determined from the layout, the friction head loss is 0.69 feet/100 feet (Supplement Chapter 16). The total head loss for the 8 inch PVC is 0.69 feet/100 feet x 1,725 feet = 11.9 feet. The recommended maximum working pressure in the pipe is 0.72 x 160 psi (class rating) = 115 psi, since it is assumed special means to control surge and water hammer will not be provided. Do not enter the actual working pressure yet.

b. Flexible hose diameter, 5 inches, was known since the equipment was on hand, but for a new system it could be determined from **Table SC6-20**, below.

c. Using 660 feet of 5 inch flexible hose, the friction loss taken from Supplement Chapter 16 is 2.0 psi/100 feet or 4.62 feet/100 feet. Total head loss for the hose is 660 feet x 4.62 feet / 100 feet = 30.5 feet.

d. Enter the sprinkler pressure at the nozzle, miscellaneous losses and elevation differences between the main pipeline inlet and the nozzle when located on the high point in the field.

e. The sum of a, c, and d gives a pump discharge pressure at the main pipeline inlet required of 249.1 feet of head or 107.84 psi. Enter this value also as the actual maximum working pressure in the main.

f. The pumping lift (suction lift in this example) is the sum of the static suction lift and friction losses in suction pipe and miscellaneous inlet fittings. The static suction lift is 15.0 feet from *Item* 3. The friction loss in a 6 inch inflow line (30 linear feet, 5 inch PVC SDR 26) is 5.9 feet/100 feet x 30 feet = 1.77 feet. The losses in the inlet fittings may be calculated using appropriate head loss coefficient k from Supplement Chapter 16, Exhibit SC16-6. Usually these losses are < 2 feet; use 2 feet. The total pumping lift is approximately 15.0 + 1.77 + 2.0 = 18.77 feet. Use 19 feet.

g. The total dynamic head is the pumping lift plus the pump discharge pressure, 19.0 feet + 249.1 feet = 268.1 feet or 116.06 psi because 2.31 ft = 1 psi.

h. The minimum net positive suction head available (NPSHA) is approximately equal to 31.0 - suction lift = 31.0 - 19.0 = 12.0 feet (see page 6-105h or Supplement Chapter 7 for more information).

Table SC6 – 20 Flexible hose selection (for this example only.
(See Supplement Chapter 16 for friction loss)

Flow Range (gpm)	Hose Diameter (inches)
50 – 150	2.5
150 - 200	3.0
200 - 300	3.5
250 - 600	4.0
400 - 750	4.5
500 - 1000	5.0

Step 9. Complete *Item* 11. The pump requirement of 675 gpm at 268 feet of head (TDH) is within the capability of the pump. Although not given for this pump, the NPSH required must be less than about 12.0 feet or cavitation is likely.

Step 10. Complete *Item* 12, the Power Unit Requirement. This is the brake horsepower (BHP) needed at the output from the power unit to supply power to the pump. The pump efficiency would be obtained from the characteristics curve for the particular pump to be used. A value of 0.70 would be a reasonable value for some pumps; use 0.7. The drive efficiency for a direct connected electric motor is approximately 100 percent; use 1.00. Therefore, compute BHP using gpm and TDH from the preceding step.

$$\text{BHP} \approx (675 \text{ gpm x } 268 \text{ feet TDH}) / (3{,}960 \text{ x } 0.7 \text{ x } 1.0) = 65.3$$

Step 11. Complete the plans. The specifications, location of the pipe, check valve, air vents, pressure relief valve, risers, thrust blocks, etc., should be shown on the plans. See sheet 2 of 4 of Exhibit 6-4A.

EXHIBIT 6-4A, Sheets 1- 4 follow.

Exhibit SC6-4A, (1 of 4)

IRRIGATION SYSTEM DATA

System type (circle): Center Pivot, Traveling Gun, Permanent Solid Set, Other

Conservation District: Orangeburg Field Office: Orangeburg

Cooperator: John Farmer Location: Orangeburg Co.

Irr. System No.: System No. 3 Field No.: 3 North

1. Design area 68 acres (area actually irrigated)

   Soil series Fuquay

   Design Soil Series: Fuquay Predominate maximum slope 4 percent

Soil Depth (in.)	Texture (USDA)	Average AWC (in./in.)
SDM 0-24	Sand	(0.03 - 0.07 in/in) 0.05 avr
		Use 0.05 in/in

2. Crops:

Crop	Area (acres)	Planting Date	Maturity Date	DMR
Peanut	28	4/15	9/30	12"
Soybean	40 - 68ac	5/1	9/10	18"
Total (acres)	68			

3. Water Supply:

   Source of Supply: (stream, well, farm pond, etc.; description) Stream

   Stream: Measured flow (season of peak use) 1000+ gpm

   Farm Pond: Storage - acre feet; Available for irrigation - acre feet.

   Stream or Reservoir: Maximum drawdown available or elevation at low flow 4 feet;

   Maximum elevation lift on intake side of pump 15 feet.

   Well: Static water level - feet.

   Measured capacity - gpm at - foot drawdown.

   Design pumping lift - feet (to ground level – main pipeline inlet.)

   Pump impeller level - feet.

   Distance supply source (main pipeline inlet) to field 1000 feet.

   Quality of water (evidence of suitability): Good

4. Other Data:

   Type of power unit and pump to be used: Diesel

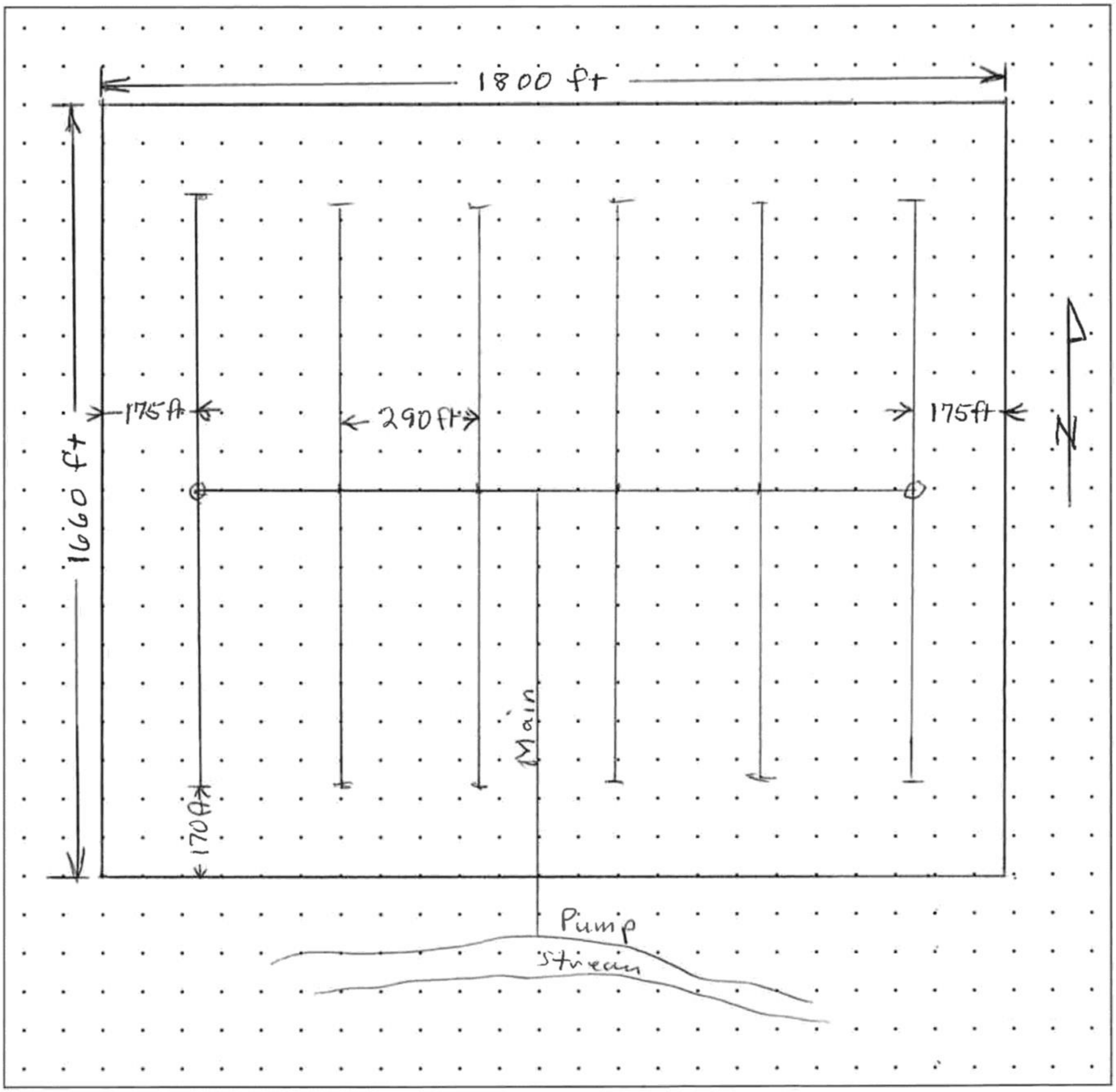
Exhibit SC6-4A, (2 of 4)

IRRIGATION SYSTEM LAYOUT

Cooperator: J. Farmer Designed by: W. Jones Checked by: A. Engineer

5. Map of design area – Scale 1" = 300 feet

Sketch map on grid or attach photo or overlay with drawing.



Sketch map should show:

a. Source of water
b. Major elevation differences
c. Row direction
d. Sprinkler system layout
e. Plan of Operation
f. Field obstructions (gullies, ditches, roads, buildings, etc.)
g. North arrow

Exhibit SC6-4A, (3 of 4)

TRAVELING GUN SPRINKLER SYSTEM DATA 1

Cooperator: J. Farmer Designed by: W. Jones Checked by: A. Engineer

6. Crop Information	Irrigation unit Number 1	2	3	4
Kind of crop	Peanut	Soybean	Soybean	
Acreage to be irrigated (acres) [1]	28	40	68	
Depth of soil water control zone (inches)	18	24	24	
Peak use rate (Inches/day)	0.28	0.30	0.30	
Weighted AWC for water control zone (inches/inch)	0.05	0.05	0.05	

7. Design Procedure	1	2	3	4
a. AWC within water control zone (inches)	0.9	1.2	1.2	
b. Management Allowable Depletion (MAD - percent)	50	50	50	
c. Maximum Net Water Allowed per Irrigation (inches)	0.45	0.60	0.60	
d. Net Water Applied per Irrigation (inches)	0.45	0.60	0.60	
e. Maximum Recommended Application Rate (inches/hour)	0.8	0.8	0.8	
f. Irrigation System Efficiency (percent)	70	70	70	
g. Gross application per irrigation (inches) [1]	0.64	0.86	0.86	
h. Peak irrigation interval (days)	1.6	2.0	2.0	
i. Irrigation Period (days per irrigation)	1.6	2.0	2.0	
j. Daily operating time per day (hours)	20	20	20	
k. Q_R = Quantity of water required (gpm) [1]	253	390	662	

8. Irrigation unit design		1	2	3	4
Q_A[2] = Quantity of water actual (gpm)				675	
Application Rate (inches/hour)[3]				0.62	
Travel Speed (feet/minute) [4]	Lane Spacing, 290 feet			4.34	
	Lane Spacing, _______ feet				
Time per 660 foot run (hours)	Lane Spacing, 290 feet			2.53	
	Lane Spacing, _______ feet				

9. Sprinkler Specifications

a. Lane spacing 290 feet.

b. Nozzle size 1 7/8 inch ring or taper (circle); Wetted diameter 470 feet;
Capacity 675 gpm @ 80 psi; Trajectory angle 27 degrees; Degrees of coverage 270.

c. Number of sprinklers operating simultaneously 1

d. Total design capacity of all sprinklers 662 gpm.

Notes:

1. $$Q_R = \frac{453 \times (68)\text{ acres} \times (0.86)\text{ inches gross application}}{(20)\text{ hours operating/day} \times (2)\text{ days/irrigation}} = (662)\text{ gpm}$$

2. Q_A must be $\geq Q_R$

3. $$\text{Application Rate}\left(\frac{\text{inches}}{\text{hour}}\right) = \frac{96.3 \times \text{sprinkler discharge (gpm)}}{0.81 \times \pi \times (Radius\ of\ wetted\ circle)^2} \times \frac{360}{(Degree\ of\ Coverage)}$$

4. $$Travel\ Speed\ \left(\frac{feet}{minute}\right) = \frac{1.605 \times sprinkler\ discharge\ (gpm)}{Lane\ spacing\ (feet) \times Gross\ water\ applied\ (inches)}$$

Exhibit SC6-4A, (4 of 4)

TRAVELING GUN SPRINKLER SYSTEM DATA 2

Cooperator: J. Farmer Designed by: W. Jones Checked by: A. Engineer

10. Determining Total Dynamic Head Total Main Line Length ______ feet.

Kind of Pipe & SDR, Sch, Class, etc	Pipe Size	Design Capacity	IPS ☑ or PIP ☐ Pipe Sizing		Hose Sizing [6]		Total Head Loss, HL		Working Pressure	
			Length	Friction Head Loss [5]	Length	Friction Head Loss [5]			Recom-mend Max. [6]	Actual Max.
	(inch)	(gpm)	(feet)	(ft/100ft)	(feet)	(ft/100ft)	(feet)	(psi)	(psi)	(psi)
PVC, Sch 26 Class 160	8	675	1725	0.69	–	–	11.9	27.5	115	108
LayFlat Hose	5	675	–	–	660	4.62	30.5	13.30		
Hose Inlet Pressure [8] or Sprinkle Pressure at nozzle (circle)							184.8	80.0		
Miscellaneous and Fitting Losses (usually 3 psi +) [9]							6.9	3.0		
Elevation Difference [10]							15.0	6.49		
Pump Discharge Pressure (at main pipeline inlet)							249.1	107.84		
Pumping Lift (including losses)							19	8.23		
Total Dynamic Head, TDH							268	116		
Estimated Net Positive Suction Head Available, NPSHA							12.0	–		

11. Pump Requirements: Capacity (675) gpm @ (116) psi or (268) feet of head and NPSH less than (12) feet.

12. Power Unit Requirement:

$$\text{BHP} \geq \frac{(675)\text{ gpm} \times (268)\text{ feet} \times \text{Total Dynamic Head}}{3960 \times (0.7)\text{ pump efficiency} \times (1.0)\text{ drive efficiency}} = (65.3)$$

Notes:

5. Keep velocity ≤ 5 fps unless means to control surge and water hammer are otherwise adequate.
6. Omit this section if required inlet pressure is known and is used in TDH calculation.
7. For plastic pipe, pressure rating divided by 0.72 unless means to control surge and water hammer are otherwise adequate.
8. Manufacturer recommended pressure plus one-half the elevation difference (plus of minus) from hose inlet to highest point in the field along the lanes.
9. Traveler turbine losses (approximately 10 psi) would need to be added as applicable.
10. Difference in elevation either from well or pump discharge and the elevation of the highest hose inlet or nozzle (plus or minus) in the field along travel lanes.

Design Approved By: Ann Engineer Date 1/20/2013

Traveler Systems:

Layout Considerations

Items that must be considered for layout of traveler systems are as follows:

a. Plant spacing and/or row direction so that travel lanes can be located properly.

b. Location of obstacles and safety hazards.

c. Whenever possible, place the risers a full hose length away from the edge of the field. This greatly facilitates laying out the hose and reeling it back up.

d. Soil limitations such as surface texture may necessitate a part circle volume gun so that the area is not irrigated in front of the gun as it moves, providing a dry footing.

e. Topography may dictate the lane direction to prevent misalignment of the traveler while in operation.

Construction Requirements

The following is a list of construction items that should be checked to be assured of a quality installation:

a. The depth of cover over the buried mainline must be adequate for protection from vehicular traffic and the farming operation.

b. Thrust block dimensions and location to prevent pipe joint separation.

c. Location and size of air vents and pressure relief valve.

d. Size and proper flow direction of installed check valve, electric valves, PRV, chemigation unit and filters.

e. Riser material, size, number and location.

f. Verify the pipe requirements such as SDR number, pressure rating, ASTM designation, PVC material, pipe diameter and if PIP or IPS size.

g. Verify pump, motor and well size. Check nozzle pressure.

h. Sprinkler model and nozzles size.

(e) Center Pivot Systems

General

The example design in this chapter is intended to illustrate a typical design procedure. It is understood that an example cannot show all design situations or all alternatives to be considered when designing a center pivot irrigation system. Center pivot irrigation systems are most commonly designed by the manufacturer and evaluated by the NRCS engineer.

Center pivot and the related linear move designs are discussed thoroughly in NEH Part 623 and Section 15, Chapter 11 "Sprinkler Irrigation." Although sample designs are not provided, pivots are examined component by component, and appropriate design equations are provided to allow computation of their design and limiting conditions. Sections in NEH Part 652, Chapter 11 also thoroughly discuss problems with infiltration near the end sections of the pivot lateral as related to intensity of water application on those end sections.

Center pivot systems (Figures SC6-49 and SC6-50) are best suited and most economical in fields allowing a full circle operation. Many fields in South Carolina bear irregularities and field obstructions that limit full circle operation. The field in Figure SC6-50 would benefit from a zone control VRI system, which would "shut-off" the nozzles when the pivot traveled over the pond.

Figure SC6-49 Center pivots have complex and proprietary superstructures and features that are usually designed as a unit by their manufacturers.

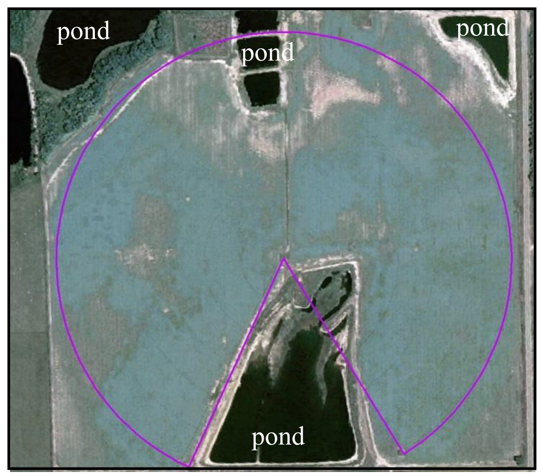


Figure SC6-50 Although ideally suited and operate most efficiently in circular or rectangular fields, they can be fitted to complex field situations, espcially if fitted with a VRI system.

Design Criteria

Design criteria for center pivot irrigation systems are contained in the Conservation Practice Standard, Sprinkler System - Code 442, for South Carolina. All center pivot systems must be designed in accordance with applicable requirements contained in current Code 442.

Example Problem

The following example (Exhibit SC6-5) illustrates a typical problem. Since center pivots are designed by the manufacturer using computers, this example could apply to many situations in which NRCS only would be providing soils and other data or only would be evaluating a system design. NRCS could provide partially completed data sheets to the landowner. The landowner then could have an irrigation company provide pertinent design data on the forms and return them to NRCS. An NRCS employee then could complete the data sheets as a permanent record for future reference and provide a copy to the land-owner. A standard form (Exhibit SC6-5A) is a useful tool in designing and recording data.

Exhibit SC6–5 Design example for a center pivot sprinkler irrigation system in South Carolina.

Given:

Field size, configuration: Rectangular, 2,840 feet largest diameter possible.
Crop & acres: 185 acres corn.
Soil: Fuquay Sand with soil texture of Sand for 0 - 24 inch DMR
Location: Orangeburg, South Carolina
Well: 16 inch.
Slope: 0-6 percent.
Other: No existing pump. Power unit will be diesel. End gun will not be used for this system.

Solution:

All ***Item*** numbers mentioned in the step by step solution refer to the items on the “Irrigation Data Sheet” in Exhibit SC 6-5A.

Step 1. Complete *Items* 1-4. These *Items* provide pertinent data of the site. See traveling gun example for more details.

Step 2. Complete *Item* 5. Make a drawing to scale of the field locating trees, buildings, well, and other features.

Step 3. Complete *Item* 6. Guidance in selecting the depth to moisture replacement (**Table SC3-9**) and the daily peak ETc (ETc Tool) can be found in this guide. The weighted AWC is computed using data from *Item* 1.

Step 4. Complete the following parts of *Item* 7.

a. Available water capacity (AWC) within the water control (root) zone is the product of the root zone water extraction depth (24 inches) times the AWC of the soil (0.05 inches/inch).

   AWC = 24 inches x 0.05 inches/inch. = 1.20 inches

b. The Management Allowable Depletion (MAD) is selected to be 50 percent for corn (**Table 3-8**).

c. The maximum net water allowed per irrigation is the product of MAD (50 percent) times the available water within the root zone (1.20 inches). Maximum net water allowed = 0.50 × 1.20 inches = 0.60 inches

d. The net water to be applied should be less than or equal to the maximum allowed. Use the maximum for this example - 0.6 inches.

e. Maximum application rate from **Table SC2-19** for sand, 0.6" water applied, & 5 percent predominate maximum slope = (No limit).

f. The system efficiency in this example is assumed to be 70 percent. (Note: modern pivots are much more efficient, i.e., 85% or greater)

g. Gross water applied per irrigation is the net water applied (0.60 inches) divided by the system efficiency (0.70). Gross water applied = 0.60 inches / 0.70 = 0.86 inches

h. The peak irrigation interval is the net water applied (0.60 inches) divided by the design peak use rate (0.30 inches/day) = 2.0 days.

i. The irrigation period to be used in the formula for determining Q_R is the irrigation interval (***f***) 2.0 days.

j. The hours operating per day (***T***) is 22 hours.

k. As with other sprinkler irrigation systems, total capacity requirements are based on known application depth, area and time of application:

$$\boldsymbol{Q_R} = \frac{\boldsymbol{453 \times A \times d}}{\boldsymbol{f \times T}}$$

where:
$\boldsymbol{Q_R}$ = Total system discharge capacity (gpm);
A = design area to receive water (acres);
$\boldsymbol{d_g}$ = gross application depth (inches);
f = irrigation interval or frequency (days);
T = actual daily operating time (hours/day).

In this case:

$$\boldsymbol{Q_R} = \frac{(453 \text{ x } 145 \text{ acres x } 0.86 \text{ inches})}{(2.0 \text{ days/irr. x } 22 \text{ hours/day})} = 1{,}283 \text{ gpm}$$

The manufacturer used 1,300 gpm for the design of this system.

Step 5. The manufacturer provides the data for *Item* 8. This must meet the criteria previously discussed.

a. Pivot length = 1,360 feet (outside tower = 1,330 feet);

b. pivot inlet pressure = 65 psi.

c. Impact sprinklers.

d. Gross application per revolution is 0.86 inches per 44 hours.

e. Nozzle gpm and pressure along last 100 feet of span is 10.1 gpm at 45 psi on spacing of 6.4 feet. Note: The recent trend in center pivot is the use of low-pressure impact or mostly spray type sprinklers at 25 to 45 psi range for energy efficiency as compared to the mid-pressure system here at 45 psi and higher.

f. Nozzle wetted diameter is 102 feet.

g. Gun coverage = ___________feet, __________ gpm @ ________ psi (Not applicable to this problem)

Step 6. Check the maximum application rate, *Item* 9.

a. Time per revolution to apply gross application = 44 hours (from manufacturer).

b. Velocity of outside tower:

$$\boldsymbol{v} \text{ (ft/hour)} = \frac{\text{outside circumference (ft)}}{\text{revolution time (hour)}}$$

In this case:

$$v = \frac{(2 \text{ x } 3.14 \text{ x } 1{,}330 \text{ feet})}{44 \text{ hours}} = 190 \text{ feet/hour}$$

c. Determine time of application (i .e. time it takes the sprinkler to move past one point), average, and maximum application rates using the formulas provided in *Item* 9.

Step 7. Complete *Item* 10. for sizing the mainline, determining total dynamic head and the net positive suction head required for the pump.

a. The mainline is 30 feet of 10 inch diameter PVC pipe (SDR 21). The friction head loss is 0.88 feet/100 feet and is taken from Supplement Chapter 16. The total head loss in the mainline is 0.88 feet/100 feet x 30 feet = 0.3 feet. The recommended maximum working pressure in the pipe is 0.72 x 200 psi (class rating) = 144 psi, since it is assumed special means to control surge and water hammer will not be provided. The actual working pressure will be computed later in the problem.

b. The pressure at the pivot was given by the manufacturer and is 65 psi. The elevation increase from pivot inlet to the highest sprinkler at the high point along the lateral = 15 feet or 6.5 psi. Therefore, the recommended pressure at pivot inlet = 65 + 6.5 / 2 = 68.2 psi.

c. The miscellaneous and fitting losses were estimated to be 3.0 psi.

d. The elevation difference from well to the pivot inlet was measured to be 12.0 feet.

e. The sum of a., b., c. and d. gives a pump discharge pressure at the main inlet pipe required of 176.7 feet or 76.5 psi. Enter this value also as the actual maximum working pressure in the main. The working pressure is less than the recommended maximum thus the pipe should be adequate.

f. The elevation pumping lift (from *Item* 3) is 150 feet. Total lift including pump column and other losses would be slightly more. Use 150 feet as an approximation for lift plus losses.

g. The total dynamic head, TDH, is the pumping lift plus the pump discharge pressure, 150.0 feet + 176.7 feet = 326.7 feet or 141.4 psi.

h. The minimum net positive suction head available (NPSHA) is approximately equal to 31.0 - h_f + z. (see page 6-105h or Chapter 7 of this guide for more information. For h_f use 3 feet for loss at impeller, and in the well pipe z = 180 ft-150 ft = 30 feet Therefore:

$$\text{NPSHA} \approx 31.0 - 3.0 + 30. = 58.0 \text{ feet}$$

Step 8. Complete *Item* 11, Pump Requirement. This is the maximum discharge (gpm) the pump must produce at a given TDH. From *Item* 7, the actual Q_R for the irrigation zone is 1,300 gpm. The TDH from the preceding section is 141 psi or 327 feet The NPSH required must be less than 58.0 feet (usually this value is most critical for centrifugal pumps).

Step 9. Complete *Item* 12, Power Requirement, using:

$$\text{BHP} \geq \frac{(1{,}300 \text{ gpm x } 327 \text{ ft } TDH)}{(3{,}960 \text{ x } 0.7 \text{ x } 1.0)} = 153.4$$

Step 10. Complete the plans. The specifications, location of the pipe, check valve, air vents, pressure relief valves, etc., should be shown on the plans.

EXHIBIT 6-5A, Sheets 1- 5 follow.

Exhibit SC6-5A, (1 of 5)

IRRIGATION SYSTEM DATA

System type (circle): Center Pivot, Traveling Gun, Permanent Solid Set, Other ____

Conservation District: Orangeburg Field Office: Orangeburg

Cooperator: Bill Jones Location: Orangeburg Co

Irr. System No.: System 1 Field No.: Field 3 South

1. Design area 145 acres (area actually irrigated)

Soil series Fuquay

Design Soil Series: Fuquay Predominate maximum slope 5 percent

Soil Depth	Texture	Average AWC
(in.)	(USDA)	(in./in.)
0 - 24	Sand	(0.03 to 0.07) 0.05
		use 0.05

2. Crops:

Crop	Area (acres)	Planting Date	Maturity Date
Corn	145	3/20	7/10
Total (acres)	145		

3. Water Supply:

Source of Supply: (stream, well, farm pond, etc.; description) 16 inch dia.

Stream: Measured flow (season of peak use) ____ gpm

Farm Pond: Storage ____ acre feet; Available for irrigation ____ acre feet.

Stream or Reservoir: Maximum drawdown available or elevation at low flow ____ feet;

Maximum elevation lift on intake side of pump ____ feet.

Well: Static water level 140 feet.

Measured capacity 1450 gpm at 10 foot drawdown.

Design pumping lift 150 feet (to ground level – main pipeline inlet.)

Pump impeller level 180 feet.

Distance supply source (main pipeline inlet) to field 0 feet.

Quality of water (evidence of suitability): No apparent problems

4. Other Data:

Type of power unit and pump to be used: Diesel

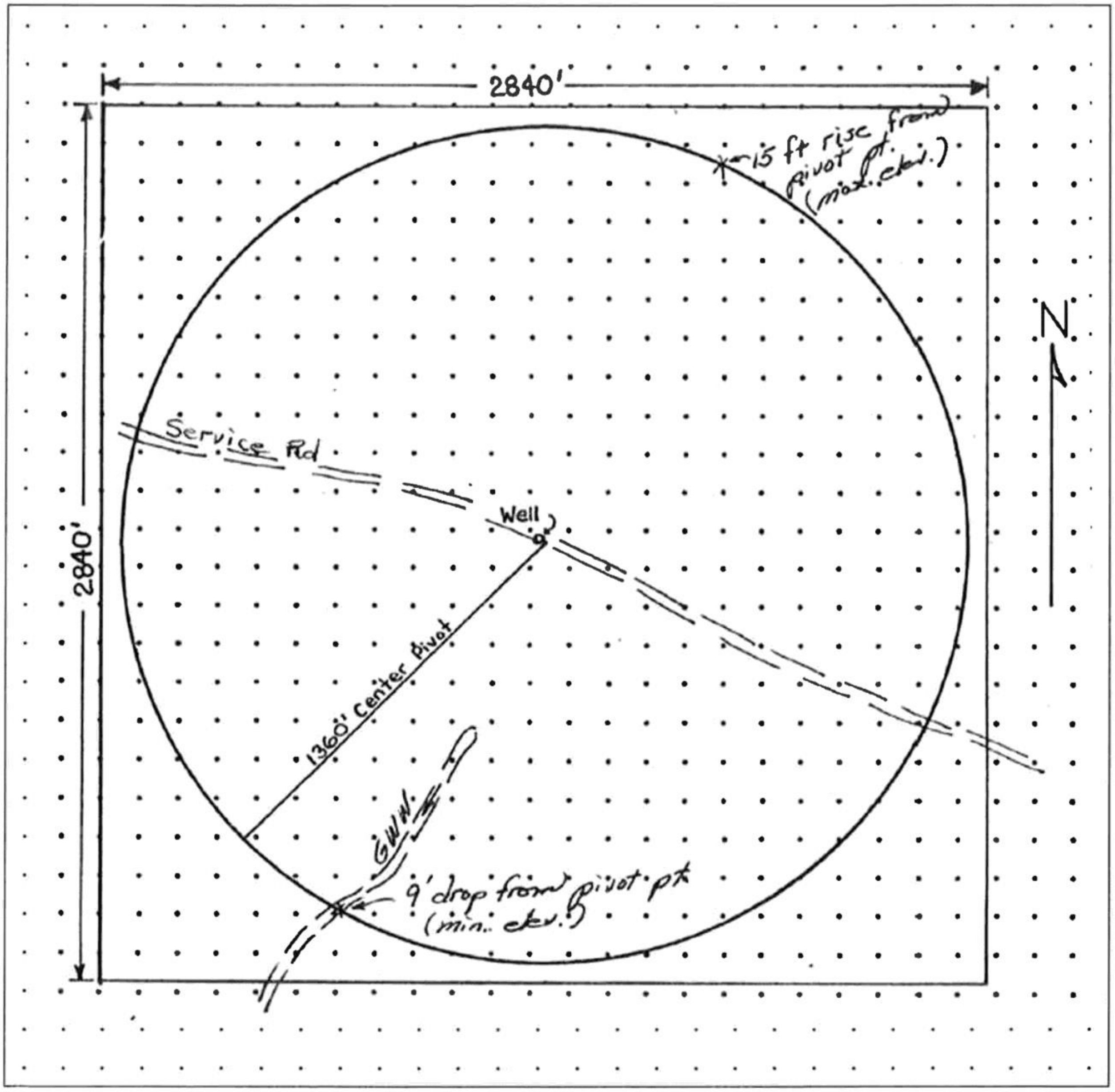
Exhibit SC6-5A, (2 of 5)

IRRIGATION SYSTEM LAYOUT

Cooperator: Bill Jones Designed by: Bob Smith Checked by: A. Engineer

5. Map of design area – Scale 1" = 500 feet

Sketch map on grid or attach photo or overlay with drawing.



Sketch map should show:

a. Source of water
b. Major elevation differences
c. Row direction
d. Sprinkler system layout
e. Plan of Operation
f. Field obstructions (gullies, ditches, roads, buildings, etc.)
g. North arrow

Exhibit SC6-5A, (3 of 5)

CENTER PIVOT SPRINKLER SYSTEM DATA 1

Cooperator: Bill Jones Designed by: Bob Smith Checked by: A. Engineer

6. Crop Information

	Crop Number			
	1	2	3	4
Kind of crop	Corn			
Acreage to be irrigated (acres) [1]	145			
Depth of soil water control zone (inches)	24			
Peak use rate (Inches/day)	0.30			
Weighted AWC for water control zone (inches/inch)	0.05			

7. Design Procedure

Design Procedure	1	2	3	4
a. AWC within water control zone (inches)	1.2			
b. Management Allowable Depletion (MAD - percent)	50			
c. Maximum Net Water Allowed per Irrigation (inches)	0.6			
d. Net Water Applied per Irrigation (inches)	0.6			
e. Maximum Recommended Application Rate (inches/hour)	No Limit			
f. Irrigation System Efficiency (percent)	70			
g. Gross application per irrigation (inches) [1]	0.86			
h. Peak irrigation interval (days)	2.0			
i. Irrigation Period (days per irrigation)	2.0			
j. Daily operating time per day (hours)	22			
k. Q_R = Quantity of water required (gpm) [1]	1284			
l. Q_A = Quantity of water actual (gpm) [2]	1300			

8. Pivot Specifications [3]

a. Pivot total span length 1360 feet; (Outside tower at 1330 feet);
Pivot inlet pressure 65 psi (Nominal pressure, assuming level topography).

b. Impact Sprinkler ☒; Rotator/spray nozzle - On top ☐ ; On drops ☐ ; MESA ☐ ; LESA ☐ ; LEPA ☐ .

c. Gross application per revolution 0.86 inches in 44 hours.

d. Nozzle discharge rate along last 100 feet of span 10.1 gpm @ 45 psi on spacing of 6.4 feet.

e. Nozzle wetted diameter 102 feet; For impacts , trajectory low ☐ ; medium ☑ ; high ☐ ;

f. End gun wetted diameter NA feet; ______ gpm; ______ psi; Nozzle size ______ inch;
Nozzle type- ring ☐ or taper ☐ ; trajectory low ☐ ; medium ☐ ; high ☐ ; ______ degrees

Notes:

1. $$Q_R = \frac{453 \times (145) \text{ acres} \times (0.86) \text{ inches gross application}}{(22) \text{ hours operating/day} \times (2) \text{ days/irrigation}} = (1284) \text{ gpm}$$

2. Q_A must be $\geq Q_R$

3. Final specifications to be provided by manufacturer.

Exhibit SC6-5A, (4 of 5)

CENTER PIVOT SPRINKLER SYSTEM DATA 2

Cooperator: Bill Jones Designed by: Bob Smith Checked by: A. Engineer

9. Determine Time of Application, Application Rate and Gross Application Depth:

a. Time (hours) per revolution to apply gross application = 44 hours

b.
$$Velocity\ (v) at\ end\ tower = \frac{Outside\ Circumference}{time\ per\ revolution}$$

$$v = \frac{2 \times \pi \times 1330\ feet}{44\ \ hours\ per\ rev.} = 190\ \text{feet/hour}$$

c.
$$Time\ of\ application\ (hours) = \frac{Wetted\ diameter}{Velocity\ of\ end\ tower}$$

$$Time\ of\ application\ (hours) = \frac{102\ (feet)}{190\ \ (feet/hour)} = 0.54\ hours$$

d. The application rate from the center pivot system can be calculated from the equation:

$$\boldsymbol{I} = \frac{96.3 \text{ x } \boldsymbol{Q_S}}{\boldsymbol{S_B} \text{ x } \boldsymbol{D}}$$

where:
$\boldsymbol{I}$ = Average application rate (inches/hour);
$\boldsymbol{Q_S}$ = Individual sprinkler discharge (gpm);
$\boldsymbol{D}$ = Wetted diameter of sprinkler nozzle (feet);
$\boldsymbol{S_B}$ = Spacing of nozzles along the boom (feet);
96.3 = Units conversion constant
= (12 inches/feet) × (60 min/hour) / (7.48 gallons/cubic foot).

e. Gross application depth from individual sprinklers on a center pivot can be calculated:

$$\boldsymbol{d} = \frac{\boldsymbol{Q_S}}{0.62 \text{ x } \boldsymbol{S_B} \text{ x } \boldsymbol{v}}$$

where:
$\boldsymbol{d}$ = Application depth in inches (gross);
$\boldsymbol{v}$ = Velocity of rotational speed of individual sprinkler around the pivot (feet/minute);
0.62 = Units conversion constant
= 7.48 gallons/cubic foot divided by 12 inches/foot

Exhibit SC6-5A, (5 of 5)

CENTER PIVOT SPRINKLER SYSTEM DATA 3

Cooperator: Bill Jones Designed by: Bob Smith Checked by:

10. Determining Total Dynamic Head Total Main Line Length ______ feet.

Kind of Pipe & SDR, Sch, Class, etc	Pipe Size	Design Capacity	IPS ☐ or PIP ☐ Pipe Sizing		Total Head Loss, HL		Working Pressure	
			Length	Friction Head Loss [5]			Recom-mend Max. [6]	Actual Max.
	(inch)	(gpm)	(feet)	(ft/100ft)	(feet)	(psi)	(psi)	(psi)
PVC, SDR21 Class 200	10	1300	30	0.88	0.3	0.1	144	76.5
Pivot inlet Pressure [6]					157.5	68.2		
Miscellaneous and Fitting Losses (usually 3 psi +)					6.9	3.0		
Elevation Difference [7]					12.0	5.2		
Pump Discharge Pressure (at main pipeline inlet)					176.7	76.5		
Pumping Lift (including losses)					150.0	64.9		
Total Dynamic Head, TDH					326.7	141.4		
Estimated Net Positive Suction Head Available, NPSHA					58	—		

11. Pump Requirements: Capacity (1300) gpm @ (141) psi or (327) feet of head and NPSH less than (58) feet.

12. Power Unit Requirement:

$$BHP \geq \frac{(1300)\text{ gpm} \times (327)\text{ feet} \times \text{Total Dynamic Head}}{3960 \times (0.7)\text{ pump efficiency} \times (1.0)\text{ drive efficiency}} = (153\text{ hp})$$

Notes:

4. Keep velocity ≤ 5 fps unless means to control surge and water hammer are otherwise adequate.
5. For plastic pipe, pressure rating divided by 0.72 unless means to control surge and water hammer are otherwise adequate.
6. Manufacturer recommended pressure plus one-half the elevation difference (plus of minus) from hose inlet to highest point in the field along the lanes.
7. Difference in elevation either from well or pump discharge and the elevation of the highest hose inlet or nozzle (plus or minus) in the field along travel lanes.

Design Approved By: Ann Engineer Date Jan 13, 2013

Additional Formulas for Center Pivot Systems and End Gun Discharge

a. The application rate from the center pivot system can be calculated from the equation:

$$AAR_{cp} = \frac{96.3 \text{ x } Q_s}{S_B \text{ x } D}$$

where:
AAR_{cp} = average application rate (inches/hour);
Q_s = individual sprinkler discharge (gpm);
D = wetted diameter of sprinkler nozzle (feet);
S_B = spacing of nozzles along the boom (feet);
96.3 = units conversion constant
= (12 inches/feet) × (60 min/hour) / (7.48 gallons/cubic foot).

b. Gross application depth from individual sprinklers on a center pivot can be calculated:

$$d = \frac{Q_s}{0.62 \text{ x } S_B \text{ x } v}$$

where:
d = application depth in inches (gross);
v = velocity of rotational speed of individual sprinkler around the pivot (feet/minute); and
0.62 = units conversion constant
= 7.48 gallons/cubic foot divided by 12 inches/foot

c. Speed can be calculated knowing the rotation time of the center pivot and the distance r:

$$Speed_r = \frac{2 \text{ x } 3.14 \text{ x } r}{60 \text{ x } t_{rotation}}$$

where:
$Speed_r$ = rotational speed (feet/minute);
r = radius from center pivot to point r (feet or meters);
$t_{rotation}$ = time required for one rotation of the center pivot system (hours).

d. Also the end gun discharge, q_g, can be calculated:

$$q_g = Q_R \text{ x } (1 - \left(\frac{L^2}{R^2}\right))$$

where:
q_g = the length of the lateral pipe (feet);
R = L plus 90 percent of the radius wetted by the end gun (feet);
Q_R = total system discharge capacity (gpm).

Design problem: Determining Center Pivot Sprinkler timer chart

Develop a table that relates the dial setting of the center pivot timer to the gross water (in inches) applied. The table may be used by the irrigator to adjust the system speed to obtain a desired gross application. The procedure described applies to electric system timers which read from 0 to 100 percent. However, the procedure can be adapted to other timers (see Exhibit SC6-5B, page 6-112k).

Procedure:

1. Determine Speed of End Tower. Select a reference mark on a wheel on the end tower. Set a stake by this mark. Start timing when the wheel starts moving forward. Continue timing until the wheel has moved 20 to 30 feet or until after the can catch is made. Mark distance traveled by placing a second stake by reference mark on wheel and stop timing just as the wheel starts to move forward. Read time and measure distance between the two stakes.

   Speed of end tower (feet/hour) = (Distance traveled (feet) × 60)/Time (min).

2. Determine Time per Revolution. Once speed is determined, compute time of travel for one revolution at the percent setting on the timer.

   Time per revolution (hours) at that percent setting on timer =
   (Distance traveled by end tower (feet) × 60/ Time (min).

   Distance traveled by end tower (feet) = 2 × 3.14 × Distance from pivot to end tower (feet).

3. Determine Hours Per Revolution for 100 percent Dial Setting. The time (hours) per revolution at 100 percent = (Hours per revolution) × (Dial Setting)/100. Note: Use the dial setting on the control panel at the time the speed was determined and hours per revolution corresponding to this setting.

4. Determine Hours Per Revolution For Each Dial Setting: Time (hours) per revolution at X percent = 100 × (Time (hours) per revolution at 100 percent) / (X percent).

Exhibit SC6-5B Design example: Determining Center Pivot Sprinkler timer chart.

Example:

The center pivot timer was set on 35 percent and end tower traveled 60.2 feet in 19 minutes. Distance from pivot to end tower is 1,330 feet. System applies 1,300 gpm on 145 acres.

End tower speed = (60.2 × 60) / 19 = 190 feet per hour

Time per revolution at 35 percent = (2 × 3.14 x 1,330) / 190 = 44 hours

Hours per revolution at 100 percent = 44 × (35 / 100) = 15.4 hours

Hours per revolution for each of the other dial settings:

For 90 percent = (15.4 × 100) / 90 = 17.1 hours
For 80 percent = (15.4 × 100) / 80 = 19.2 hours
For 70 percent = (15.4 × 100) / 70 = 22.0 hours
For 60 percent = (15.4 × 100) / 60 = 25.7 hours
For 50 percent = (15.4 × 100) / 50 = 30.8 hours
For 40 percent = (15.4 × 100) / 40 = 38.5 hours
For 30 percent = (15.4 × 100) / 30 = 51.3 hours
For 20 percent = (15.4 × 100) / 20 = 77.0 hours
For 10 percent = (15.4 × 100) / 10 = 154.0 hours

Gross application for each dial setting:

For 100 percent = (15.4 × 1,300) / (453 × 145) = 0.30 inches
For 90 percent = (17.1 × 1,300) / (453 × 145) = 0.34 inches
For 80 percent = (19.2 × 1,300) / (453 × 145) = 0.38 inches
For 70 percent = (22.0 × 1,300) / (453 × 145) = 0.44 inches
For 60 percent = (25.7 × 1,300) / (453 × 145) = 0.51 inches
For 50 percent = (30.8 × 1,300) / (453 × 145) = 0.61 inches
For 40 percent = (38.5 × 1,300) / (453 × 145) = 0.76 inches
For 30 percent = (51.3 × 1,300) / (453 × 145) = 1.02 inches
For 20 percent = (77.0 × 1,300) / (453 × 145) = 1.52 inches
For 10 percent = (154.0 × 1,300) / (453 × 145) = 3.05 inches

Center Pivot System:

Layout Considerations

During planning and layout of a center pivot there are many things to be considered. Items to be considered are the soil limitations, obstacles such as fences, ponds, ditches and trees, topography of the field, the farming operation and safety hazards such as electrical and buried gas lines.

a. The soil limitations might affect the pivot's ability to traverse the field and/or the runoff erosion potential from high application rates.

b. Obstacles, if not considered, could result in severe damage to the pivot. Bridges or culvert crossings may be needed to cross wet areas or ditches. Electrical lines and buried cable or gas lines must be located prior to burying the pipe or locating the pivot, not only to facilitate installation, but to prevent a real safety hazard.

c. Topography must be considered because center pivots are limited as to the slope on which they can function properly.

d. The greater the land slope the greater the erosion potential. Therefore, the application rate must be compatible with the slope to prevent erosion from center pivot systems.

Construction Requirements

Once a system is designed it must be installed as planned in order for it to function properly. The following is a list of key points that should be checked during construction to be assured of a quality installation:

a. Depth of cover over the buried mainline is important for protection from vehicular traffic and farming operation.

b. Thrust block dimension and location to prevent pipe joint separation.

c. Location and size of air vents and pressure relief valve.

d. Size and proper direction of installed check valve.

e. Riser material and dimension as well as location for pivots.

f. Length and quality of pipe, diameter, location, appropriate ASTM designation, size, pressure rating and SDR as measured or found written on the pipe.

g. Determine if IPS or PIP pipe is used which will have an effect on the total head loss of the system.

h. Verify length of the center pivot lateral and if spray or impact type sprinklers.

i. Check sprinkler brand, model, nozzle size and orifice plate number.