KS652.0605 State supplement - irrigation system design

(a) General information

This part contains additional technical information required for the design of the various types of irrigation systems. Section KS652.0605(b) addresses gravity irrigation systems. Section KS652.0605(c) addresses sprinkle irrigation systems. Section KS652.0605(d) addresses micro (drip) irrigation systems.

Table KS6-1 is provided for guidance in determining the recommended irrigation efficiency to use in the various system designs. The efficiencies shown are for the system efficiency. System efficiency considers all water losses beginning at the water source and ending at the soil surface or point of application. These values are appropriate for use in irrigation scheduling programs, which are addressed in Chapter 9, Irrigation Water Management. It does not consider impacts of irrigation management alternatives. Those issues are discussed in KS652.0505.

Table KS6-1 Typical Efficiency for Irrigation Systems

Irrigation System Type	Efficiency (%)
Surface Irrigation - Basic (Earthen conveyance ditch and siphon tubes or cutouts)	50
Surface Irrigation - Basic (Earthen conveyance ditch, siphon tubes or cutouts, land leveled)	60
Surface Irrigation - Basic (Earthen conveyance ditch, gated pipe, land leveled, tailwater reuse)	70
Surface Irrigation - Improved (Delivery pipeline, gated pipe)	70
Surface Irrigation - Improved (Delivery pipeline, gated pipe, land leveled)	75
Surface Irrigation - Improved (Tailwater reuse, land leveled, delivery pipeline, gated pipe)	80
Center Pivot [1/ 2/] and Linear Move - Sprinklers on top of pipe	80
Center Pivot [1/ 2/] and Linear Move - Nozzles below lateral but > 6 feet height above ground	85
Center Pivot [1/ 2/] and Linear Move - Nozzles near ground (in canopy)	87
Center Pivot and Linear Move - Low Energy Precision Application (LEPA)	92
Sprinkler - Solid set	75
Sprinkler Irrigation - Side roll	70
Subsurface Drip Irrigation (SDI)	92

[1/] When the center pivot system includes an end gun, reduce the efficiency by 5%.
[2/] When the center pivot system includes a corner system (sometimes referred to as a trailer section), reduce the efficiency by 3%.

The efficiency values are efficiencies that one could realistically obtain for the system without concern for irrigation management decisions. The values agree with Natural Resources Conservation Service (NRCS) field tests, Kansas State University (KSU) Biological and Agricultural Engineering staff and engineers at the Northwest and Southwest KSU Research Center.

For sprinkler and microirrigation systems, the following assumptions are made so as to be able to attain the efficiency shown on the table:

- The water is conveyed to the field through a pipeline and there are no water losses between the point where water is extracted from the well or other extraction point.
- The water applied is less than or equal to the soil water moisture deficit at the time of irrigation and there is no water lost to deep percolation.
- The only resulting inefficiency to water being applied equally to all points in the field is due to variations in the distribution and uniformity caused by emitter and sprinkler nozzle spray patterns, flow variation due to pressure variation, and overlap.

(b) Gravity irrigation

(1) SRFR - Surface Irrigation Model

In Section 652.0601 Surface Irrigation, the Surface Irrigation Model, SRFR is referenced so that "SRFR methodology will be used as the basis for future surface irrigation designs in NRCS." (Part 652 page 6-3) Below is guidance for accessing the program and an introduction to its use.

SRFR is CCE-certified and is available for WinNT machines. It is available on the Internet at:

http://servicecenter.usda.gov/release/#Certified
Under Software name, locate SRFR
Description: SRFR Surface Irrigation Simulation Model
Date available: 3/9/2000
Location available: Download/3.6MB

Click on Download/3.6MB and store it in a directory. An administrator is required to open the srfr inst.exe package. Once opened, the executable file will extract the SRFR program and supporting data.

For non-CCE WinNT computers, the program can be accessed from the Web site:
ftp://ftp.wcc.nrcs.usda.gov/water_mgt/SRFR/

Click on USWCL-SRFR-Package.exe and save file in a directory.

The README File, shown below, provides direction for use of this program. For additional assistance, contact the engineer on the Kansas Natural Resources Conservation Service (NRCS) state office staff with irrigation and water management responsibilities. This person has received training in the use of this program.

SRFR -- A Surface Irrigation Simulation Model
Version 4.06 QUICK START

This file is distributed both as part of the installation software and as a stand-alone ASCII text file.

1. SRFR is a DOS program that can be run out of a WINDOWS environment. Once installation is complete, clicking on Start -- Programs -- US Water Conservation Lab (assuming the default folder was selected for the installation) -- SRFR (shortcut) will execute the program.

2. The main control window, which comes up (following a default help screen) when SRFR is called, contains a default simulation, with sufficient data to execute. Clicking on the traffic-light button in the tool bar performs the simulation.

3. Some user control is available in the animation screen by clicking on the buttons in the tool bar. Pressing the F1 function key on the keyboard interrupts the animation and brings up a help screen from the on-line manual to explain the meaning of the various tool-bar buttons. Closing the help window resumes the simulation.

4. In general, pressing F1, or clicking on a ?Help button brings up explanatory information pertinent to the current display. This can be printed to an on-line printer for hard copy: press the Printer button, or <Shift+F7>. In addition, general help information can be found through the help index (<Alt+F1>) under the titles “SRFR --“. In particular, SRFR -- Overview and SRFR -- General Instructions constitute good introductions to the software.

5. By default, the ultimate results of the simulated irrigation are shown in a window displaying the longitudinal distribution of infiltrated water and a series of performance parameters. Alternate graphical displays are available from the tool bar or as described in Item 11 below.

The graphs can be printed to an on-line HP laser printer by clicking on the printer button in the tool bar. Alternately, when operating from the DOS prompt in WINDOWS 95 or NT, pressing <Print Scrn> captures the screen contents onto the clipboard as a bitmap.

Pressing <Alt+Enter> or <Alt+Tab> freezes SRFR and allows the image on the clipboard to be brought into a graphics program (Paint, CorelDraw, etc.) with a "Paste" and printed. To capture a frame of the animation, pause the computer first by pressing <Pause> on the keyboard. After export of the screen contents, pressing <Alt+Enter> or <Alt+Tab> restores control to SRFR.

6. The hydraulic properties of the field, the physical design of the system, and parameters defining the operation of the system for the desired irrigation simulation can be modified in the menus that drop down from the tool bar. SETUP allows the selection of units (English, metric, etc.).

7. The CONFIGURE menus allow specification of the system and inflow configurations. Grayed-out options are unavailable to the standard user (user level is selectable in the SETUP menu).

8. The DATA menus allow entry of numerical values for the input data. Many simple simulations can be described entirely by editing the data in the data-SUMMARY window. More complex conditions can be entered through the detailed windows specifying system geometry, field conditions, and inflow.

9. Cumulative-infiltration depths are based on furrow spacing (by default), except in the case of the NRCS families. In that case, infiltration depth is related to volume infiltrated per unit length of furrow by the NRCS empirical wetted-perimeter

formula. Other choices are available in the Configure menus.

10. The EXECUTE menus allow specification of the numerical-solution conditions. GO starts the simulation.

11. The graphics button in the tool bar enables display of the graph type selected from the list available at its right. The user is returned to the main control window by clicking on the X-button at the far left of the tool bar. Alternately, F3 or <Alt>+F4 removes the window.

12. Data files can be saved, or saved files can be opened using the FILE menus. Some file operations can be performed by clicking on a file name in the main control window.

13. Simulation IDs (simulation names) can be edited by clicking on the current simulation ID. Deleting, moving, or copying can be accomplished by pressing the appropriate file-operation buttons. (See associated help screen.)

14. The SRFR.BAT program is designed to restart the executable SRFR program after a run-time error (aborted run). If the program none-the-less crashes and freezes the computer, run ScanDisk or CHKDSK after reboot to collect any loose clusters into files for deleting.

15. Selection of a printer port other than the default, LPT-1, is achieved in the PCL-tabbed menu that comes up when the Print option is selected. Do not attempt to print if no printer is connected to the selected port--this leads to a freeze, requiring a reboot.

16. If you have any pre-existing data files from earlier versions of SRFR, not recognized by the current version, run DATCNVRT in the directory in which they reside. In most cases, this operation should be unnecessary because SRFR itself calls DATCNVRT when it encounters a file in an out-of-date format.

17. If the entire screen or any part of it goes blank during operation, it can be refreshed by pressing the F5 function key.

18. Several sample data files are included in the install package, illustrating features of certain types of surface irrigation. They can be of interest in terms of both data entry and simulation:

The file, TOMSHOPS, contains data suggested by Tom Spofford (NRCS), drawn from experience in the Pacific Northwest. It simulates a 36-hour irrigation of hops on a 7 percent slope. This is run as a kinematic wave. The more moderate case runs with either a zero-inertia solution or as a kinematic wave.

Note: For slopes that are so steep that the flow depths are but a small fraction of the total elevation change from upstream to downstream, the default Display option, Plot Elevations, does not allow viewing the behavior of the irrigation stream. Selecting the Depth option, instead, deals with that problem. The button just to the right of the printer button toggles animated depth and surface-elevation profiles, as does 'y' or 'Y' from the keyboard.

OPENHOUS illustrates gains in efficiency possible with cutback irrigation; superimpose output plots from the two cases for the comparison.

The SCS CUTBACK case illustrates the reduction in stream length that can physically occur when the inflow is reduced.

The first of the SURGES simulations cuts off at the quarter points in the field, with cutback when the end is reached; the second is an arbitrary control by time and with various stream sizes. Differences between left-side sets (left side out) and right-side sets are illustrated. The last simulation, Overtaking, illustrates with an exaggerated case the assumptions made by SRFR to allow the simulation to proceed without actually modeling the physical merging of overtaken surges, absent in the current release.

DUNKLIN illustrates the hard-pan-underlain soils experienced by Keith Admire (NRCS) in southern Missouri. The data entry specifies the early infiltration with either the NRCS families or a modified Kostiakov formula. In addition, a limiting depth is specified--the accumulated infiltration when the soil is saturated and won't take any more. It is assumed that this doesn't happen until the entire space between furrows is full. With no further infiltration, the computational stream after cutoff gets ever shallower and slower, until it dissolves in computational imprecision. To avoid this, recession is assumed to occur when the stream depth drops below a selectable value. Three selections are compared--0.5 mm, 1 mm, and 2 mm--to illustrate the effect on the recession curve. (See Hydraulic Summary graphs.)

The BORDER simulations show variations in inflow-cutoff control beyond simply setting the cutoff time. The first two control cutoff by location of the advancing stream front; the third involves a prediction of lag time, designed to achieve the target depth of infiltration at the upstream end of the border strip just as recession starts there.

DRAINBAK illustrates a method of surface irrigation, which is starting to appear in Arizona and in the new irrigation works in the lower Mississippi Valley. A series of large level basins (10 acres) are benched on the prevailing field slope, so that each successive basin is a little lower. Each is supplied with water from a broad earth ditch running along the inlet side, with its bottom a foot or two below field elevation.

Gates between successive reaches of the ditch are initially closed, damming water introduced at the upstream end. When the water level in the first ditch section rises above field level, the irrigation begins. Cutoff is effected by opening the gate to the next basin. This causes the water level in the first reach to drop below field level, and flow starts from the basin, draining back into the supply ditch for the next basin.

Besides providing protection to the crop in case of unexpected rain, the method allows applying small depths efficiently.

CABLGATN allows comparison of furrows supplied by cablegation and by a constant inflow.

SRGVALVS illustrates some of the capabilities of the Waterman LVC-6 commercial surge controller. The Inflow Management data entry screen is of particular interest. Other choices are the P&R STAR controller and the Waterman LVC-5.

OVERFLOW illustrates the messages appearing if the maximum furrow depth is exceeded, or border berms are overtopped.

The files, TWIN and LUMPY, show the effect of slope changes on an irrigation.

EGYLVL illustrates the effect of land leveling on the performance of an irrigation. In each simulation, cutoff is timed by completion of advance.

The FILTER data, suggested by Gary Conaway of the NRCS Water and Climate Center, illustrates a hydrologic application rather than an irrigation. A simulated runoff hydrograph is introduced to a buffer filter strip to investigate the possibilities of filtering runoff prior to discharge into a waterway.

(2) Design criteria and design guide sheets from Kansas Irrigation Guide
The irrigation design group is shown on the upper right-hand portion of each sheet.

Irrigation design groups are composed of soils that most nearly fit into a given soil intake family as shown in the following chart.

Chart KS6-1

Soils in Design Group No.	Soil Intake Family of Nearest Fit 0.1	0.3	0.5	1.0	1.5	2.0	3.0
1 and 2	x						
3 and 4		x					
5 and 6			x				
7 and 8				x			
9 and 10					x		
11						x	
12							x

Column 1 - Crops
This column shows the major crops that are irrigated. No attempt has been made to justify the irrigation of crops from an economic cost-return standpoint. The guide considers soils, crops, and irrigation methods only.

Column 2 - Normal Irrigation Depth
This is the normal irrigation depth to maintain an adequate moisture supply for the maturing crop grown under proper irrigation on the specific soil. Preplanting irrigations will normally fill the plant root zone, and normal irrigations will replenish the moisture subsequently used. This is for the normal irrigation application only.

Column 3 - Net Moisture to be Replaced Each Irrigation
This column shows the net amount of water to be replaced for each crop during a normal irrigation. This value was obtained by determining the available water capacity in the root zone for the irrigated depth specified in Column 2 then selecting either double the amount of available water-holding capacity (AWC) in the top one-fourth of the root zone or one-half the amount of AWC in the full root zone whichever is greater. This value has been rounded to the nearest 0.5 inch, except in the case of 60-inch furrow irrigation spacing, where the alternate row being irrigated will receive 0.5 inch additional net moisture. However, the alternate dry row will be partially irrigated so the overall net application is usually an odd value--somewhat less than the uniform specified net irrigation for 40-inch rows.

Column 4 - *Irrigation* Methods
Corrugations - Corrugations are shown for the irrigation of close-growing crops such as alfalfa and small grain on design slopes of 0.7 percent to 1.5 percent and for pasture grasses on design slopes of 0.7 percent to 3.0 percent. In addition, corrugations are to be used where specified on flatter slopes where mechanical means are needed to obtain uniform spreading of water on border systems. Corrugation maximum stream size is 8 gallons per minute (gpm.)

Furrows - Furrows are shown for the irrigation of row crops including corn, sorghum, sugar beets, field beans, and soybeans. Criteria is given for slopes up to 1.0 percent on all soils that are suitable for furrow irrigation.

C - Cutback Irrigation - Water is applied at a faster (initial) rate at the beginning of the irrigation period and then reduced or cut back to a lesser rate, usually one-half the initial rate.

R - Re-use Irrigation - This method of irrigation utilizes a tailwater recovery system for storing and re-using the excess water. Water is applied to the rows at the initial rate for the entire irrigation interval. Excess water may be reapplied to the same or to another field.

Contour Furrows - These may be used for row crops, particularly with terraces, using a furrow with relatively large water-carrying capacity on field slopes of 0.60 percent to 6.0 percent. The furrows are run across the slope on a designed grade, usually 0.4 percent.

Sprinklers - The adaptability of sprinkler irrigation for the crops, soils, and slopes listed and the net irrigation application are given. Because of the numerous sprinkler irrigation types and their varied application techniques, specific design criteria are not given. The narrative section on sprinkler irrigation and appropriate tables will aid the user in giving technical assistance for the various methods of sprinkler irrigation [Section KS652.0605(c)].

Column 5 – Maximum Size Stream for Furrows or Corrugations

Information in this column applies to furrows and corrugations only. The maximum stream is calculated based on three limitations: (1) soil intake, (2) maximum non-erosive stream, and (3) furrow or corrugation capacity. The stream shown is the most limiting of the above 3 maximum streams.

The values used for each of these items are as follows:

Irrigation Design Group	Max. Stream (gpm)	Design Slope Group	Max. Non-Erosive Stream (gpm)	Furrow or Corrugation Spacing (In.)	Max. Stream (gpm)
1 and 2	30	0.1&0.2	50	20	8 Corrug.
				20	15 Furrow
3 and 4	40	0.4	30	22	20
5 to 12	50	0.7	17	30	30
		1.5	8	36	40
		3.0	4	40	50
				60	40

Where field experience dictates that a larger stream than the maximum shown can be safely used, the maximum furrow length can be increased proportionally.

Column 6 - Unit Streams

Furrows or Corrugations - The stream size is the stream needed in gpm per 100 feet to apply the planned gross application efficiently. It is determined by multiplying the average furrow intake rate for the planned net application by a factor of 1.5 to give proper travel time to the advancing furrow stream.

The furrow intake was determined using the following formula:

$$F_a = (gat^b)\left(W_1 + 1.33\,\frac{dt^{0.5}}{y}\right) \leq gat^b$$

(See Tables KS6-3 & KS6-4)

$$I_a = \frac{60\,F_a}{t}$$

(See Tables KS6-3 & KS6-4)

Where: F_a = average intake in inches
- g = variable factor depending on intake family, tillage, and crop residue
- a & b = intake values from intake family formula
- t = opportunity time in minutes
- W_1 = top width of furrow stream
- d = variable depending on intake family
- y = inches per inch - water holding capacity of soil at time of irrigation
- W_2 = furrow spacing in inches
- I_a = average furrow intake in inches per hour

Example for use of furrow tables:

Intake family 0.5
Net application 3.0 inches
g = .65 s = .002
Field length = 1300 feet

Solve for: 30-inch, 40-inch, and 60-inch spacing

From Table KS6-3:
T_o = 7.0 I_a = .43 LS = 22

Determine "q" from formula $q = .13W_2I_a$ (or use Table KS6-4)
Where: W_2 = furrow spacing in inches
Then: q = 1.68 for 30" spacing
q = 2.24 for 40" spacing
q = 3.35 for 60" spacing

Q = 13 x 1.68 = 22 gpm for 30" spacing
Q = 13 x 2.24 = 29 gpm for 40" spacing
Q =13 x 3.35 = 44 gpm for 60" spacing

From Table KS6-2 (parabolic furrows) for .002 grade:

W_l = 14" for 22 gpm
W_l = 16" for 29 gpm
W_l = 17" for 44 gpm

For 30-inch spacing:

Furrow wetted width = LS + W_1 = 22 + 14 = 36 inches (exceeds needed 30 inches)

Therefore, design for 30 inches is T_o = 7.0 hours and furrow stream = 22 gpm

For 40-inch spacing: 22 + 16 = 38 inches (Furrow is slightly wider than the wetted irrigation width.)

Therefore, design time = 40 / 38 x 7.0 = 7.4 hours

Furrow stream = 38 / 40 x 29 = 28 gpm

For 60-inch spacing: 22 + 17 = 39 inches

Design time would be 60 / 39 x 7.0 = 10.8 hours, which exceeds 35 percent of T_o

Therefore, increase T_o by 35 percent = 7.0 x 1.35 = 9.5 hours (Reference Column 7

From Table KS6-3, vertical intake for 9.5 hours by interpolation = 3.8 inches and LS = 25.
25 + 16 = 41" (adjusted wetted width)

(Note that W_1, used here is 16 not 17 because "Q" will be approximately 35 percent less than 44 gpm)

Average intake is: 41 / 60 x 3.8 = 2.6”
2.6 inches in 9.5 hours = 0.27 inch/hour

q = (.13)(60)(.27) = 2.1 gpm/100 feet

Q = 2.1 x 13 = 27 gpm

Column 7 - Normal Furrow Spacing or Corrugation Spacing
The furrow spacing shown is what is customarily used. To account for alternate row irrigation or the "bed" with furrow method of row shaping, the 60” furrow spacing is included. Irrigation in 60” furrow spacings usually does not give lateral spread to the whole 60” furrow space. The amount of spread is computed to be the water surface width in the row (from Table KS6-2)
plus lateral spread (LS column in Table KS6-3). This total subtracted from the row spacing is the dry width or unirrigated part of the furrow.

Dry width / row spacing = % dry

If “% dry" is less than 35 percent of the row spacing, then opportunity time (T_O) is increased by the “% dry" amount and unit stream (q) is decreased by the “% dry" amount. If “% dry" is over 35 percent then opportunity time (T_O) is increased by 35 percent and unit stream is computed accordingly (see sample calculation before *Column 7*).

For corrugations, computations were made for 20-inch spacing.

Column 8 - Maximum Length of Run - Furrows and Corrugations
Length of run is computed from the relationship of water intake characteristics of the soil, stream size, and net irrigation application. This column value is found by dividing Column 5 by Column 6 and multiplying by 100. When this procedure produced a length in excess of 2600 feet, the maximum furrow stream in Column 5 was reduced to provide a furrow stream needed for 2600 feet length.

Column 9 - Estimated Field Efficiencies
The field efficiencies shown are those considered realistic for the method of irrigation when good management practices are followed. Efficiency may be defined as the ratio of the quantity of water effectively put into the crop root zone and utilized by growing crops to the quantity delivered to the field. It is expressed as a percentage. It takes into consideration items such as evaporation, losses due to deep percolation, unequal distribution, and direct runoff. These efficiencies have been rounded to the nearest “5" (i.e., 60, 65, 70, etc.)

1. Furrows - Re-use Method - When runoff water is recovered and pumped back into the system, an overall efficiency of approximately 80 to 85 percent is obtained. The lesser efficiency is associated with 0.1 intake family soils, with shallow application and with the steeper irrigation grades.

2. Furrows - Cutback Method - An efficiency of approximately 65 to 70 percent has been used for this method of application. The lesser efficiency is associated with shallow application or the steeper irrigation grades.

3. Corrugations - Efficiency shown is that expected--if proper size stream is applied according to soil intake rate. Sixty percent is shown, except for 0.1 intake family where 55 percent was used.

Column 10 - Gross Water Used
The total amount of water to be used per irrigation is found by dividing Column 3 by Column 9 (i.e., net application divided by estimated field efficiency).

Column 11 - Estimated Time Required
1. Furrows - This figure is the needed opportunity time (T_o) or time required for the net application to enter the soil. To determine opportunity time, first change unit furrow stream shown in Column 6 to average intake rate by dividing by 1.5. Then change this to inches per hour for appropriate furrow spacing by use of Table KS6-5. Next, divide the net irrigation in Column 3 by this value to obtain the needed intake opportunity time (T_o).

2. Corrugations - Estimated time required is computed by changing gpm per 100 feet in Column 6 to inches per hour as described for furrows. Then, divide the gross application by this value.

Limitations and Adaptations
Relationships and limitations are accounted for in the irrigation design sheets for the 12 irrigation groups.

Judgment must be exercised in their use and should be used to fit local conditions. For example, the design guide sheets show forward grades of 0.1 and 0.2 percent on 0.1 intake family soils also level, and 0.1 percent grade on 0.3 intake family soils. This is reasonable in the western part of the state; but in the eastern part, forward grade preferably should be 0.3 percent or greater on clayey soils to avoid field wetness and poor farmability.

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam or silty clay loam surface layers and very slowly permiable subsoils.

GROUP NO. 1

(Intake Family 0.1)

Sheet 1 of 1
Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Irrigation not recommended										
SLOPE GROUP 0.5 TO 0.25% (DESIGN SLOPES 0.1% AND 0.2%)										
Corn, Sorghum or Beans	2.5	2.5	Furrow	12	0.45	30	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	40	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	60	2600	60	4.2	36.0
	2.0	2.0	Furrow	13	0.48	30	2600	60	3.3	18.0
		2.0	Furrow	17	0.63	40	2600	60	3.3	18.0
		2.0	Furrow	19	0.72	60	2600	60	3.3	24.0
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Corn, Sorghum or Beans	2.5	2.5	Furrow	12	0.45	30	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	40	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	60	2600	60	4.2	36.0
	2.0	2.0	Furrow	13	0.48	30	2600	60	3.3	18.0
		2.0	Furrow	17	0.63	40	2600	60	3.3	18.0
		2.0	Furrow	19	0.72	60	2600	60	3.3	24.0
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa, Grass	2.5	2.5	Corrugation	8	0.33	20	2400	55	4.5	24
or Small Grain	2.0	2.0	Corrugation		0.35	20	2300	55	3.6	18
Corn, Sorghum or Beans	2.5	2.5	Furrow	12	0.45	30	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	40	2600	60	4.2	24.0
		2.5	Furrow	16	0.60	60	2600	60	4.2	36.0
	2.0	2.0	Furrow	13	0.48	30	2600	60	3.3	18.0
		2.0	Furrow	17	0.65	40	2600	60	3.3	18.0
		2.0	Furrow	17	0.65	60	2600	60	3.3	24.0
SLOPE GROUP 1.1 % (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	2.0	2.0	Corrugations	8	0.35	20	2300	55	3.6	18
SLOPE GROUP OVER 2 %										
Irrigation not recommended										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silty clay or clay textures throughout.

GROUP NO. 2

(Intake Family 0.1) Sheet 1 of 1
Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Irrigation not recommended										
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.25% (DESIGN SLOPES 0.1% AND 0.2%)										
Corn, Sorghum or Beans	3.0	2.5	Furrow	16	0.60	30	2600	60	4.2	18.0
		2.5	Furrow	21	0.80	40	2600	60	4.2	18.0
		2.5	Furrow	24	0.92	60	2600	60	4.2	24.0
	2.5	2.0	Furrow	19	0.71	30	2600	60	3.3	12.0
		2.0	Furrow	24	0.92	40	2600	60	3.3	12.0
		2.0	Furrow	26	0.98	60	2600	60	3.3	18.0
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa, Grass	3.0	2.5	Corrugation	8	0.45	20	1800	55	4.6	18.0
or Small Grain	2.5	2.0	Corrugation	8	0.52	20	1500	55	3.6	12.0
Corn, Sorghum or Beans	3.0	2.5	Furrow	16	0.60	30	2600	60	4.2	18.0
		2.5	Furrow	21	0.80	40	2600	60	4.2	18.0
		2.5	Furrow	24	0.92	60	2600	60	4.2	24.0
	2.5	2.0	Furrow	19	0.71	30	2600	60	3.3	12.0
		2.0	Furrow	24	0.92	40	2600	60	3.3	12.0
		2.0	Furrow	26	0.98	60	2600	60	3.3	18.0
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa, Grass	3.0	2.5	Corrugation	8	0.45	20	1800	55	4.6	18
or Small Grain	2.5	2.0	Corrugation	8	0.52	20	1500	55	3.6	12
Corn, Sorghum or Beans	3.0	2.5	Furrow	16	0.60	30	2600	60	4.2	18.0
		2.5	Furrow	17	0.65	40	2600	60	4.2	20.0
		2.5	Furrow	17	0.65	60	2600	60	4.2	30.0
	2.5	2.0	Furrow	17	0.65	30	2600	60	3.3	12.0
		2.0	Furrow	17	0.65	40	2600	60	3.3	16.0
		2.0	Furrow	17	0.65	60	2600	60	3.3	24.0
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 1.1 % To 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	2.5	2.0	Corrugation	8	0.52	20	1500	55	3.6	12
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP OVER 2 %										
Irrigation not recommended										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow to moderately slow permeability.

(Intake Family 0.3)

GROUP NO. 3

Sheet 1 of 3

Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa, or Grass			Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa, or Grass			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
		3.3	Furrow-R	39	1.5	60	2600	85	3.9	20.0
		3.3	Furrow-C	39	1.5	60	2600	70	4.7	17.0
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	18	0.7	22	2600	85	4.1	16.3
		3.5	Furrow-C	18	0.7	22	2600	70	5.0	13.8
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow -C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow -R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow- C	34	1.3	40	2600	70	5	13.8
			Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa, or Grass			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
		3.3	Furrow-R	39	1.5	60	2600	85	3.9	20.3
		3.3	Furrow-C	39	1.5	60	2600	70	4.7	17.2
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	18	0.7	22	2600	85	4.1	16.3
			Furrow-C	18	0.7	22	2600	70	5.0	13.8
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	34	1.3	40	2600	85	4.1	16.3
		3.5	Furrow-C	34	1.3	40	2600	70	5.0	13.8
			Sprinkler							
* * * * * * * * * *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow to moderately slow permeability.

GROUP NO. 3

Sheet 2 of 3

(Intake Family 0.3) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa, or Grass			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5	13.8
		3.5	Furrow-R	30	1.3	40	2300	85	4.1	16.3
		3.5	Furrow-C	30	1.3	40	2300	70	5.0	13.8
		3.3	Furrow-R	30	1.4	60	2150	85	3.9	20.9
		3.3	Furrow-C	30	1.4	60	2150	70	4.7	17.7
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	18	0.7	22	2600	85	4.1	16.3
		3.5	Furrow-C	18	0.7	22	2600	70	5.0	13.8
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	26	1.0	30	2600	85	4.1	16.3
		3.5	Furrow-C	26	1.0	30	2600	70	5.0	13.8
		3.5	Furrow-R	30	1.3	40	2300	85	4.1	16.3
		3.5	Furrow-C	30	1.3	40	2300	70	5	13.8
			Sprinkler							
* *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa, or Grass	3.0	3.5	Corrugation	8	0.65	20	1230	60	5.8	13.8
			Sprinkler							
Corn Sorghum or Beans	3.0	3.5	Furrow-R	17	1.0	30	1700	80	4.0	16.3
		3.5	Furrow-C	17	1.0	30	1700	65	5.4	13.8
		3.5	Furrow-R	17	1.3	40	1300	80	4.4	16.3
		3.5	Furrow-C	17	1.3	40	1300	65	5.4	13.8
		3.1	Furrow-R	17	1.3	60	1310	80	3.9	21.9
		3.1	Furrow-C	17	1.3	60	1310	65	4.8	18.6
			Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	17	0.7	22	2400	80	4.0	16.3
		3.5	Furrow-C	17	0.7	22	2400	65	5.4	13.8
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	17	1.0	30	1700	80	4.4	16.3
		3.5	Furrow-C	17	1.0	30	1700	65	5.4	13.8
		3.5	Furrow-R	17	1.3	40	1300	80	4.4	16.3
		3.5	Furrow-C	17	1.3	40	1300	65	5.4	13.8
		3.5	Corrugation	8	0.65	20	1230	60	5.8	13.8
			Sprinkler							
* *										

R = Reuse   C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow to moderately slow permeability.

GROUP NO. 3

Sheet 3 of 3

(Intake Family 0.3) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	3.0	3.5	Corrugation	8	0.65	20	1230	60	5.8	13.8
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.5	Sprinkler							
* *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa, Sugar Beets, or Small Grain	3.0	3.5	Sprinkler							
Corn,Sorghum or Beans	3.0	3.5	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Grass	3.0	3.5	Corrugation	4	0.65	20	620	60	5.8	13.8
			Sprinkler							
* *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Irrigation not recommended.										
* *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow predominantly moderately slow permeability.

GROUP NO. 4

Sheet 1 of 3

(Intake Family 0.3) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa, or Grass	2.5	3.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa, or Grass	2.5	3.0	Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
		2.8	Furrow-R	39	1.5	60	2600	85	3.3	16.6
		2.8	Furrow-C	39	1.5	60	2600	70	4.0	14.1
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	0.8	22	2500	85	3.5	13.1
			Furrow-C	20	0.8	22	2500	70	4.3	11.1
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow -C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow -R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow- C	36	1.4	40	2600	70	4.3	11.1
			Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa, or Grass	2.5	3.0	Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
		2.8	Furrow-R	39	1.5	60	2600	85	3.3	17.0
		2.8	Furrow-C	39	1.5	60	2600	70	4.0	14.4
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	0.8	22	2500	85	3.5	13.1
			Furrow-C	20	0.8	22	2500	70	4.3	11.1
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	36	1.4	40	2600	85	3.5	13.1
		3.0	Furrow-C	36	1.4	40	2600	70	4.3	11.1
			Sprinkler							
* * * * * * * * * *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow predominantly moderately slow permeability.

GROUP NO. 4

Sheet 2 of 3

(Intake Family 0.3) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa, or Grass	2.5	3.0	Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	30	1.4	40	2150	85	3.5	13.1
		3.0	Furrow-C	30	1.4	40	2150	70	4.3	11.1
		2.7	Furrow-R	30	1.4	60	2150	85	3.2	17.7
		2.7	Furrow-C	30	1.4	60	2150	70	2.9	15.0
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	0.8	22	2500	85	3.5	13.1
		3.0	Furrow-C	20	0.8	22	2500	70	4.3	11.1
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	26	1.0	30	2600	85	3.5	13.1
		3.0	Furrow-C	26	1.0	30	2600	70	4.3	11.1
		3.0	Furrow-R	30	1.4	40	2150	85	3.5	13.1
		3.0	Furrow-C	30	1.4	40	2150	70	4.3	11.1
			Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa, or Grass	2.5	3.0	Corrugation	8	0.7	20	1150	60	5	11.7
			Sprinkler							
Corn Sorghum or Beans	2.5	3.0	Furrow-R	17	1.0	30	1700	80	3.8	13.8
		3.0	Furrow-C	17	1.0	30	1700	65	4.6	11.7
		3.0	Furrow-R	17	1.3	40	1310	80	3.8	14.2
		3.0	Furrow-C	17	1.3	40	1310	65	4.6	12.0
		2.5	Furrow-R	17	1.3	60	1310	80	3.1	17.7
		2.5	Furrow-C	17	1.3	60	1310	65	3.8	15.0
		3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	17	0.8	22	2130	80	3.8	11.7
			Furrow-C	17	0.8	22	2130	65	4.6	11.7
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	17	1.0	30	1700	80	3.8	13.8
		3.0	Furrow-C	17	1.0	30	1700	65	4.6	11.7
		3.0	Furrow-R	17	1.3	40	1310	80	3.8	14.2
		3.0	Furrow-C	17	1.3	40	1310	65	4.6	12.0
		3.0	Corrugation	8	0.7	20	1150	60	5.0	11.7
			Sprinkler							
* * * * * * * * * * * * * * * * * * * *										

R = Reuse C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, clay loam or silty clay loam surface layers and subsoils with slow predominantly moderately slow permeability.

GROUP NO. 4

Sheet 3 of 3

(Intake Family 0.3) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass	2.5	3.0	Corrugation	8	0.7	20	1140	60	5.0	1.7
or Small Grain			Sprinkler							
Corn, Sorghum	2.5	3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
or Beans			Sprinkler							
Sugar Beets	2.5	3.0	Sprinkler							
* *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa,	2.5	3.0	Sprinkler							
Sugar Beets,										
or Small Grain										
Corn,Sorghum	2.5	3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
or Beans			Sprinkler							
Grass	2.5	3.0	Corrugation	4	0.7	20	570	60	5.0	11.7
			Sprinkler							
* *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Irrigation not recommended.										
* *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or clay loam surface layers and subsoils moderate to moderately slow permeability.

GROUP NO. 5

Sheet 1 of 3

(Intake Family 0.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa, or Grass	4.0	5.0	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	4.0	Sprinkler							
* *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa	4.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
		3.8	Furrow-R	40	1.5	60	1740	85	4.5	15.2
		3.8	Furrow-C	40	2.3	60	1740	70	5.4	12.9
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	20	1.1	22	1820	85	4.7	12.0
		4.0	Furrow-C	20	1.1	22	1820	70	5.7	10.2
			Sprinkler							
Small Grain	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow -C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow -R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow- C	50	2.0	40	2500	70	5.7	10.2
			Sprinkler							
Grass	3.0	4.0	Sprinkler							
* *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa	4.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
		3.8	Furrow-R	40	2.2	60	1820	85	4.5	15.5
		3.8	Furrow-C	40	2.2	60	1820	70	5.4	13.1
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	20	1.1	22	1820	85	4.7	12.0
		4.0	Furrow-C	20	1.1	22	1820	70	5.7	10.2
			Sprinkler							
Small Grain	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	50	2.0	40	2500	85	4.7	12.0
		4.0	Furrow-C	50	2.0	40	2500	70	5.7	10.2
			Sprinkler							
Grass	3.0	4.0	Sprinkler							
R = Reuse				C = Cutback						

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or clay loam surface layers and subsoils moderate to moderately slow permeability.

GROUP NO. 5

Sheet 2 of 3

(Intake Family 0.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa	4.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	30	2.0	40	1500	85	4.7	12.0
		4.0	Furrow-C	30	2.0	40	1500	70	5.7	10.2
		3.7	Furrow-R	30	2.1	60	1430	85	4.4	15.8
		3.7	Furrow-C	30	2.1	60	1430	70	5.3	13.4
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	20	1.1	22	1820	85	4.7	12.0
			Furrow-C	20	1.1	22	1820	70	5.7	10.2
			Sprinkler							
Small Grain	3.0	4.0	Furrow-R	30	1.5	30	2000	85	4.7	12.0
		4.0	Furrow-C	30	1.5	30	2000	70	5.7	10.2
		4.0	Furrow-R	30	2.0	40	1500	85	4.7	12.0
		4.0	Furrow-C	30	2.0	40	1500	70	5.7	10.2
			Sprinkler							
Grass	3.0	4.0	Sprinkler							
* *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa	4.0	5.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Furrow-R	17	1.5	30	1130	80	5.0	12.9
		4.0	Furrow-C	17	1.5	30	1130	65	6.2	10.9
		4.0	Furrow-R	17	1.9	40	900	80	5.0	13.9
		4.0	Furrow-C	17	1.9	40	900	65	6.2	11.8
		3.4	Furrow-R	17	1.9	60	900	80	4.3	16.3
		3.4	Furrow-C	17	1.9	60	900	65	5.3	13.8
		4.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	4.0	Furrow-R	17	1.1	22	1550	80	5.0	12.0
			Furrow-C	17	1.1	22	1550	65	6.2	10.2
			Sprinkler							
Small Grain	3.0	4.0	Furrow-R	30	1.5	30	1130	80	5.0	12.9
		4.0	Furrow-C	30	1.5	30	1130	65	6.2	10.9
		4.0	Furrow-R	30	2.0	40	900	80	5.0	13.9
		4.0	Furrow-C	30	2.0	40	900	65	6.2	11.8
		4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Grass	3.0	4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							

R = Reuse C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or clay loam surface layers and subsoils moderate to moderately slow permeability.

GROUP NO. 5

Sheet 3 of 3

(Intake Family 0.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa	4.0	4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	4.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Small Grain or Grass	3.0	4.0	Corrugation	8	1.0	20	800	60	6.7	10.2
			Sprinkler							
Sugar Beets	2.5	3.0	Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa	4.0	5.0	Sprinkler							
Corn,Sorghum or S. Beets	3.0	4.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Small Grain or Grass	3.0	4.0	Sprinkler							
Grass	3.0	4.0	Corrugation	4	0.7	20	400	60	6.7	10.2
			Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Alfalfa	4.0	5.0	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	4.0	Sprinkler							
* * * * * * * * * * * * * * * * * * * *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability.

GROUP NO. 6

Sheet 1 of 3

(Intake Family 0.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa, Grass, Corn, Sorghum Beans, Sm. Gr.	3.0	3.5	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa or Grass	3.0	3.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	30	1.6	30	1900	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1900	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2400	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2400	70	5.0	8.5
		3.2	Furrow-R	40	2.2	60	1820	85	3.8	13.0
		3.2	Furrow-C	40	2.2	60	1820	70	4.6	11.0
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	20	1.2	22	1670	85	4.1	10.0
		3.5	Furrow-C	20	1.2	22	1670	70	5.0	8.5
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow -C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow -R	50	2.1	40	2380	85	4.1	10.0
		3.5	Furrow- C	50	2.1	40	2380	70	5.0	8.5
			Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa or Grass	3.0	3.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	30	1.6	30	1900	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1900	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2400	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2400	70	5.0	8.5
		3.2	Furrow-R	40	2.2	60	1820	85	3.8	13.0
		3.2	Furrow-C	40	2.2	60	1820	70	4.6	11.0
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	20	1.2	22	1670	85	4.1	10.0
		3.5	Furrow-C	20	1.2	22	1670	70	5.0	8.5
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	50	2.1	40	2380	85	4.1	10.0
		3.5	Furrow-C	50	2.1	40	2380	70	5.0	8.5
			Sprinkler							

R = Reuse C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability.

GROUP NO. 6

Sheet 2 of 3

(Intake Family 0.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa or Grass	3.0	3.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5	8.5
		3.5	Furrow-R	30	2.1	40	1430	85	4.1	10.3
		3.5	Furrow-C	30	2.1	40	1430	70	5.0	8.7
		3.1	Furrow-R	30	2.1	60	1430	85	3.7	13.6
		3.1	Furrow-C	30	2.1	60	1430	70	4.4	11.5
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	20	1.2	22	1670	85	4.1	10.0
		3.5	Furrow-C	20	1.2	22	1670	70	5.0	8.5
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	30	1.6	30	1880	85	4.1	10.0
		3.5	Furrow-C	30	1.6	30	1880	70	5.0	8.5
		3.5	Furrow-R	30	2.1	40	1430	85	4.1	10.3
		3.5	Furrow-C	30	2.1	40	1430	70	5	8.7
			Sprinkler							
* *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa or Grass	3.0	3.5	Corrugation	8	1.1	20	730	60	5.8	8.5
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Furrow-R	17	1.6	30	1070	80	4.4	10.0
		3.5	Furrow-C	17	1.6	30	1070	65	5.4	8.5
		3.5	Furrow-R	17	1.8	40	950	80	4.4	11.3
		3.5	Furrow-C	17	1.8	40	950	65	5.4	9.6
		2.8	Furrow-R	17	1.9	60	900	80	3.5	13.6
		2.8	Furrow-C	17	1.9	60	900	65	4.3	11.5
		3.5	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.5	Furrow-R	17	1.2	22	1420	80	4.4	8.5
			Furrow-C	17	1.2	22	1420	65	5.4	8.5
			Sprinkler							
Small Grain	3.0	3.5	Furrow-R	17	1.5	30	1070	80	4.4	10.0
		3.5	Furrow-C	17	1.6	30	1070	65	5.4	8.5
		3.5	Furrow-R	17	1.8	40	950	80	4.4	11.3
		3.5	Furrow-C	17	1.8	40	950	65	5.4	9.6
		3.5	Corrugation	8	1.1	20	730	60	5.8	8.5
			Sprinkler							

R = Reuse C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or clay loam surface layers and subsoils having moderate to moderately slow permeability.

GROUP NO. 6

Sheet 3 of 3

(Intake Family 0.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	3.0	3.0	Corrugation	8	1.1	20	730	60	5.0	7.0
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.5	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	2.5	3.0	Sprinkler							
* *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa, Sugar Beets or Small Grain	2.5	3.0	Sprinkler							
Corn,Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Grass	2.5	3.0	Corrugation	4	1.1	20	360	60	5.0	7.0
			Sprinkler							
* *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Alfalfa, Grass Corn, Sorghum Small Grain or Beans	4.0	5.0	Sprinkler							
* *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils.

GROUP NO. 7

Sheet 1 of 3

(Intake Family 1.0) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa	5.0	5.0	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa	5.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	1.5
		3.0	Furrow -C	30	2.8	30	1080	70	4.3	5.0
		3.0	Furrow -R	50	3.6	40	1400	85	3.5	4.2
		3.0	Furrow- C	50	3.6	40	1400	70	4.3	5.2
			Sprinkler							4.4
Grass	3.0	3.0	Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa	3.0	3.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
			Sprinkler							
Grass	3.0	3.0	Sprinkler							
	R = Reuse				C = Cutback					

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils.

GROUP NO. 7

Sheet 2 of 3

(Intake Family 1.0) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa	5.0	5.0	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.7
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.8
		2.3	Furrow-R	30	3.2	60	940	85	2.7	6.7
		2.3	Furrow-C	30	3.2	60	940	70	3.3	5.7
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.7
		3.0	Furrow-C	30	3.2	40	940	70	4.3	8.7
			Sprinkler							4.9
Grass	3.0	3.0	Sprinkler							
* *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa	3.0	3.0	Corrugation	8	1.8	20	450	60	5	4.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.3
		2.1	Furrow-R	17	2.8	60	610	80	2.6	6.7
		2.1	Furrow-C	17	2.8	60	610	65	3.2	5.7
		3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	17	2.1	22	810	80	3.8	5.0
		3.0	Furrow-C	17	2.1	22	810	65	4.6	4.2
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.3
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Grass	3.0	3.0	Corrugation							
			Sprinkler							

R = Reuse C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable, medium textured subsoils.

GROUP NO. 7

Sheet 3 of 3

(Intake Family 1.0) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa	3.0	3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.0	Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa	5.0	5.0	Sprinkler							
Corn,Sorghum or Beans	3.0	3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Grass	3.0	3.0	Corrugation	4	1.8	20	220	60	5.0	4.2
			Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Alfalfa, Grass	5.0	5.0	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Sprinkler							
* * * * * * * * * * * * * * * * * * * *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam or silt loam subsoils.

GROUP NO. 8

Sheet 1 of 3

(Intake Family 1.0) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa, Grass	2.5	3.0	Sprinkler							
Corn, Sorghum										
Beans, Sm. Gr.										
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa or Grass	2.5	3.0	Sprinkler							
Corn, Sorghum	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
or Beans		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow-C	50	3.6	40	1400	70	4.3	4.4
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow -C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow -R	50	3.6	40	1400	85	3.5	5.2
		3.0	Furrow- C	50	3.6	40	1400	70	4.3	4.4
			Sprinkler							
* * * * * * * * * * * * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa or Grass	2.5	3.0	Sprinkler							
Corn, Sorghum	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
or Beans		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.5	40	1430	85	3.5	5.3
		3.0	Furrow-C	50	3.5	40	1430	70	4.3	4.5
		2.5	Furrow-R	40	3.4	60	1180	85	2.9	6.7
		2.5	Furrow-C	40	3.4	60	1180	70	3.6	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	50	3.5	40	1430	85	3.5	5.3
		3.0	Furrow-C	50	3.5	40	1430	70	4.3	4.5
			Sprinkler							

R = Reuse C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam or silt loam subsoils.

(Intake Family 1.0)

GROUP NO. 8

Sheet 2 of 3

Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa or Grass	2.5	3.0	Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.8
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.9
		2.3	Furrow-R	30	3.2	60	940	85	2.7	6.7
		2.3	Furrow-C	30	3.2	60	940	70	3.3	5.7
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	20	2.1	22	950	85	3.5	5.0
		3.0	Furrow-C	20	2.1	22	950	70	4.3	4.2
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	30	2.8	30	1080	85	3.5	5.0
		3.0	Furrow-C	30	2.8	30	1080	70	4.3	4.2
		3.0	Furrow-R	30	3.2	40	940	85	3.5	5.8
		3.0	Furrow-C	30	3.2	40	940	70	4.3	4.9
			Sprinkler							
* *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa or Grass	2.5	3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.3
		2.1	Furrow-R	17	2.8	60	610	80	2.6	6.7
		2.1	Furrow-C	17	2.8	60	610	65	3.2	5.7
		3.0	Contour Furrow (Refer to 30" or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	2.5	3.0	Furrow-R	17	2.1	22	810	80	3.8	5.0
		3.0	Furrow-C	17	2.1	22	810	65	4.6	4.2
			Sprinkler							
Small Grain	2.5	3.0	Furrow-R	17	2.8	30	610	80	3.8	5.0
		3.0	Furrow-C	17	2.8	30	610	65	4.6	4.2
		3.0	Furrow-R	17	2.8	40	610	80	3.8	6.3
		3.0	Furrow-C	17	2.8	40	610	65	4.6	5.6
		3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							

R = Reuse   C = Cutback

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Moderately deep soils with silt loam, loam or very fine sandy loam surface layers and moderately permeable clay loam, loam or silt loam subsoils.

GROUP NO. 8

Sheet 3 of 3

(Intake Family 1.0) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa, Grass or Small Grain	2.5	3.0	Corrugation	8	1.8	20	450	60	5.0	4.2
			Sprinkler							
Corn, Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30"or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	2.5	3.0	Sprinkler							
* *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa, Beets or Small Grain	2.5	5.0	Sprinkler							
Corn,Sorghum or Beans	2.5	3.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Grass	2.5	3.0	Corrugation	4	1.8	20	220	60	5.0	4.2
			Sprinkler							
* *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Alfalfa, Grass Corn, Sorghum Beans or Small Grain	2.5	3.0	Sprinkler							
* *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability.

GROUP NO. 9

Sheet 1 of 3

(Intake Family 1.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum Beans, Grass or Small Grain	3.0	3.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.5 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	50	4.6	40	1090	85	3.5	3.9
		2.4	Furrow-R	40	4.4	60	910	85	2.8	5.0
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.7	22	740	85	3.5	3.6
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow -R	50	4.6	40	1090	85	3.5	3.9
			Sprinkler							
Grass	3.0	3.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	50	4.5	40	1120	85	3.5	4.0
		2.3	Furrow-R	40	4.3	60	930	85	2.7	5.0
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.7	22	740	85	3.5	3.6
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow -R	50	4.5	40	1120	85	3.5	4.0
			Sprinkler							
Grass	3.0	3.0	Sprinkler							
* * * * * * * * * *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability.

GROUP NO. 9

Sheet 2 of 3

(Intake Family 1.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPE 0.4%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow-R	30	4.1	40	740	85	3.5	4.3
		2.2	Furrow-R	30	4.1	60	770	85	2.5	5.0
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	20	2.7	22	740	85	3.5	3.6
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	30	3.7	30	810	85	3.5	3.6
		3.0	Furrow -R	30	4.1	40	740	85	3.5	4.3
			Sprinkler							
Grass	3.0	3.0	Sprinkler							
* *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPE 0.7%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Furrow-R	17	3.7	30	810	80	3.5	3.6
		3.0	Furrow-R	17	4.5	40	1120	80	3.5	4.0
		2.0	Furrow-R	17	4.3	60	930	80	2.7	5.0
		3.0	Contour Furrow (Refer to 30"or 40" furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	3.0	Furrow-R	17	2.7	22	630	80	3.8	3.1
			Sprinkler							
Small Grain	3.0	3.0	Furrow-R	17	3.6	30	480	80	3.8	3.8
		3.0	Furrow -R	17	3.6	40	480	80	3.8	4.7
			Sprinkler							
Grass	3.0	3.0	Sprinkler							
* *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with fine sandy loam and loam surface layers and subsoils that have moderately rapid permeability.

GROUP NO. 9

Sheet 3 of 3

(Intake Family 1.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 1.1 % TO 2.0% (DESIGN SLOPE 1.5%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum or Beans	3.0	3.0	Sprinkler							
Sugar Beets	3.0	3.0	Sprinkler							
Small Grain or Grass	3.0	3.0	Sprinkler							
* *										
SLOPE GROUP 2.1 To 4.0% (DESIGN SLOPE 3%) (Contour furrow or sprinkler with terraces)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum Beans, Beets or Small Grain	3.0	3.0	Sprinkler							
Grass	3.0	3.0	Sprinkler							
* *										
SLOPE GROUP 4.1 to 8% (DESIGN SLOPE 6.0%)										
Alfalfa	5.0	4.5	Sprinkler							
Corn, Sorghum Beans, Beets or Small Grain	3.0	3.0	Sprinkler							
* *										

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with with loamy fine sand or loamy sand with surface layers and moderately rapid to rapidly permeable subsoils.

GROUP NO. 10

Sheet 1 of 2

(Intake Family 1.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, Small Grain or Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Beans	3.0	2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.5	40	1120	80	2.5	2.6
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	20	2.9	22	690	80	2.5	2.3
			Sprinkler							
Small Grain	3.0	2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
			Furrow-R	50	4.5	40	1120	80	2.5	2.6
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Beans	3.0	2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.4	40	1140	80	2.5	2.7
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	20	2.9	22	690	80	2.5	2.3
			Sprinkler							
Small Grain	3.0	2.0	Furrow-R	30	4.1	30	740	80	2.5	2.2
		2.0	Furrow-R	50	4.5	40	1140	80	2.5	2.7
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPES 0.4%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Beans	3.0	2.0	Furrow-R	30	4.0	30	750	80	2.5	2.3
		2.0	Furrow-R	30	4.0	40	750	80	2.5	2.9
			Sprinkler							
Sugar Beets	3.0	2.0	Sprinkler							
Small Grain	3.0	2.0	Furrow-R	30	4.0	30	750	80	2.5	2.3
		2.0	Furrow-R	30	4.0	40	750	80	2.5	2.9
			Sprinkler							
Grass	3.0	2.0	Sprinkler							

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with with loamy fine sand or loamy sand with surface layers and moderately rapid to rapidly permeable subsoils.

GROUP NO. **10**

Sheet 2 of 2

(Intake Family 1.5) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPES 0.7%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Beans	3.0	2.0	Furrow-R	17	3.4	30	500	80	2.5	2.6
		1.9	Furrow-R	17	3.5	36*	490	80	2.5	2.9
		2.0	Contour Furrow (Refer to 30"or 40"furrow with design slope 0.4%)							
			Sprinkler							
Sugar Beets	3.0	2.0	Furrow-R	17	3.0	22	570	75	2.7	2.2
			Sprinkler							
Small Grain	3.0	2.0	Furrow-R	30	4.0	30	750	80	2.5	2.3
		2.0	Furrow-R	30	4.0	40	750	80	2.5	2.9
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 1.1% To 2.0% (DESIGN SLOPES 1.5%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Beans	3.0	2.0	Sprinkler							
Sugar Beets	3.0	2.0	Sprinkler							
Small Grain	3.0	2.0	Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 2.1% To 4.0% (DESIGN SLOPES 3.0%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, Beans, Beets	3.0	2.0	Sprinkler							
or Small Grain	3.0									
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 4.1% To 8.0% (DESIGN SLOPES 6.0%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, Beans, Beets	3.0	2.0	Sprinkler							
or Small Grain	3.0									
* * * * * * * * * *										

* 36"furrow spacing recommended instead of 40"to obtain sufficient lateral spread

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep soils with with loamy fine sand or loamy sand with surface layers and moderately rapid to rapidly permeable subsoils.

GROUP NO. 11

Sheet 1 of 1

(Intake Family 2.0) Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LESS THAN 0.05% (DESIGN SLOPE LEVEL)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, Small Grain or Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.05 TO 0.14% (DESIGN SLOPE 0.1%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, Small Grain	3.0	2.0	Furrow-R	30	5.4	30	560	70	2.9	1.8
		2.0	Furrow-R	50	5.7	40	880	70	2.9	2.2
			Sprinkler							
Grass	3	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.15 TO 0.25% (DESIGN SLOPE 0.2%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Small Grain	3.0	2.0	Furrow-R	30	5.4	30	560	70	2.9	1.8
		2.0	Furrow-R	50	5.7	40	880	70	2.9	2.2
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.26 TO 0.55% (DESIGN SLOPES 0.4%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Small Grain	3.0	2.0	Furrow-R	30	5.0	30	600	65	3.1	1.9
		2.0	Furrow-R	30	5.0	36*	600	65	3.1	2.2
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 0.56 TO 1.0% (DESIGN SLOPES 0.7%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, or Small Grain	3.0	2.0	Furrow-R	30	5.0	30	600	65	3.1	1.9
		2.0	Furrow-R	30	5.0	36*	600	65	3.1	2.2
			Sprinkler							
Grass	3.0	2.0	Sprinkler							
* * * * * * * * * *										
SLOPE GROUP 1.1 % To 8.0% (DESIGN SLOPES 1.5%, 3.0% AND 6.0%)										
Alfalfa	5.0	3.0	Sprinkler							
Corn, Sorghum, Small Grain or Grass	3.0	2.0	Sprinkler							

* Maximum furrow space to allow adequate spread

IRRIGATION DESIGN

GENERAL SOILS DESCRIPTION: Deep rapidly permeable soils with sand or fine sand textures throughout.

(Intake Family 3.0)

GROUP NO. 12

Sheet 1 of 1
Date: 1975

CROPS	NORMAL IRRIGATION DEPTH (feet)	NET MOISTURE TO BE REPLACED EACH IRRIGATION (inches)	IRRIGATION METHODS	MAXIMUM SIZE STREAM FOR FURROWS OR CORRUGATIONS (g.p.m.)	UNIT STREAM FURROWS OR CORRUGATIONS G.P.M./100' OF LENGTH (g.p.m.)	NORMAL FURROW OR CORRIGATION SPACING (inches)	MAXIMUM LENGTH OF RUN (feet)	EST. FIELD EFF. (%)	GROSS WATER USED (inches)	ESTIMATED TIME REQUIRED (hours)
1	2	3	4	5	6	7	8	9	10	11
SLOPE GROUP LEVEL TO 8.0% (DESIGN SLOPES: LEVEL, 0.1, 0.2, 0.4, 0.7, 1.5, 3.0, AND 6.0%)										
SLOPE GROUP 0.5 TO 0.25% (DESIGN SLOPES 0.1% AND 0.2%)										
Corn, Sorghum or Beans	3.0	1.5	Sprinkler							

(3) Design tables and their use

The irrigation design group sheets, Section KS652.0605(b)(2), Gravity Irrigation, give design data for the various soils listed. However, many times the conditions encountered will not be identical to the conditions on which the data for these sheets were based. For example, a given field may be 1000 feet long whereas the irrigation design sheet may state the maximum length of run to be1400 feet. In such cases, an adjustment needs to be made--it may involve reducing the stream size, changing the time of application, or reducing the net application of water applied. It could also be a combination of all these items.

There are several tables for making these adjustments, which in most cases will eliminate the need to perform many computations. A summary follows explaining which tables to use.

Tables KS6-3 and KS6-4 may be used to determine design for lengths and for furrow spacing other than those contained in the design worksheets. Combinations of various stream sizes “q” can be matched with various net depths of application “f" to arrive at the most satisfactory design.

Table KS6-5 gives a conversion table to change intake rates or application rates from gpm per 100 feet of furrow to inches per hour or to change inches per hour to gpm per 100 feet.

The needed opportunity time (T_o) is also given. Acceptable operating schedules for various values of T_o and time to apply gross application (T_A) are given in Table KS6-6.

Table KS6-7 provides approximate flow rates for various size siphon tubes for different heads of water.

Table KS6-8 lists clock times that work well with the operating schedules.

Table KS6-9 lists the acre-feet of water pumped in “T” hours.

Table KS6-2 Top Width of Furrow Stream - Inches

Parabolic Furrows n = .04

gpm	Slope - Ft./Ft.				
Q	.0005	.001	.002	.004	.007
50	21	19	18	-	-
45	20	19	17	-	-
40	20	18	17	-	-
35	19	18	16	15	-
30	19	17	16	15	-
25	18	16	15	14	-
20	17	15	14	13	12
15	16	14	13	12	11
10	14	13	12	11	10

Top Width of Furrow Stream - Inches
B.W. = 0.5’ SS=2:1 n=.04

gpm	Slope - Ft./Ft.				
Q	.0005	.001	.002	.004	.007
50	22	20	18	-	-
45	21	19	17		-
40	21	18	16	-	-
35	20	18	16	14	-
30	19	17	15	14	-
25	17	16	14	13	-
20	16	15	13	12	11
15	15	14	12	11	10
10	13	12	11	10	9

Table KS6-3 Opportunity Time (T_o) in Hours, Average Intake Rate (I_a) in Inches per Hour and Lateral Spread (LS) in Inches for Net Intake with Varying Values of "g"

Intake Family	Value of "g"	2.0" T_o	2.0" I_a	2.0" LS	2.5" T_o	2.5" I_a	2.5" LS	3.0" T_o	3.0" I_a	3.0" LS	3.5" T_o	3.5" I_a	3.5" LS	4.0" T_o	4.0" I_a	4.0" LS	4.5" T_o	4.5" I_a	4.5" LS
		Net Application -- Inches (Fn)																	
	0.90	4.9	.41	17	6.6	.38	19	8.5	.35	22	10.6	.33	25	12.8	.31	28	16.5	.29	31
	0.80	5.8	.34	18	7.8	.32	21	10.0	.30	24	12.5	.28	27	15.0	.27	30	17.8	.25	39
0.3	*0.75	6.4	.31	19	8.6	.29	22	11.1	.27	25	13.8	.25	28	16.9	.24	31	19.6	.23	33
	0.70	7.0	.29	20	9.5	.26	24	12.3	.24	27	15.2	.23	30	18.3	.22	33	21.5	.27	35
	0.60	8.7	.23	22	11.7	.21	27	15.0	.20	30	18.7	.19	33	22.7	.18	36	26.8	.17	39
	0.80	3.2	.63	14	4.2	.60	17	5.3	.56	19	6.5	.54	21	7.7	.52	23	9.0	.50	24
	0.70	3.8	.53	16	5.0	.50	19	6.3	.47	21	7.7	.45	23	9.2	.43	25	10.8	.42	27
0.5	*0.65	4.2	.58	17	5.5	.45	20	7.0	.43	22	8.5	.41	24	10.2	.39	26	11.9	.38	28
	0.60	4.6	.44	18	6.1	.41	21	7.7	.39	23	9.4	.37	26	11.3	.35	28	13.2	.34	30
	0.50	5.8	.35	20	7.7	.33	23	9.8	.31	26	12.2	.29	28	14.3	.28	311	16.7	.27	33
	0.75	2.4	.84	14	3.1	.81	16	3.9	.77	18	4.8	.73	20	5.8	.69	21	6.8	.66	23
	0.65	2.9	.70	15	3.8	.66	17	4.8	.63	19	5.9	.60	21	7.0	.58	23	8.1	.56	25
0.75	*0.60	3.2	.63	16	4.3	.58	18	5.4	.56	20	6.5	.54	22	7.7	.52	24	9.0	.50	26
	0.55	3.5	.57	17	4.7	.53	19,	6.0	.50	21	7.3	.48	24	8.7	.46	26	10.1	.45	28
	0.45	4.5	.45	19	6.0	.42	21	7.6	.40	23	9.3	.38	26	11.1	.36	29	13.0	.35	32
	0.70	1.8	.10	12	2.4	1.05	14	3.0	1.00	16	3.7	.96	18	4.3	.92	19	5.0	.90	20
	0.60	2.3	.90	14	2.9	.85	16	3.7	.82	18	4.5	.78	20	5.3	.75	21	6.2	.73	22
1.0	*0.55	2.6	.81	15	3.3	.76	17	4.2	.73	19	5.2	.70	21	6.0	.67	22	6.9	.65	23
	0.50	2.8	.72	16	3.7	.68	18	4.7	.65	20	5.7	.62	22	6.7	.60	23	7.8	.58	25
	0.40	3.7	.54	18	4.9	.51	20	6.2	.49	23	7.5	.47	25	8.9	.45	27	10.2	.44	29
	0.65	1.4	1.45	12	1.8	1.38	14	2.3	1.32	15	2.8	1.27	16	3.3	1.22	18			
	0.55	1.7	1.1	13	2.2	1.13	15	2.8	1.08	17	3.4	1.04	18	4.0	1.00	20			
1.5	*0.50	1.9	1.06	14	2.5	1.00	16	3.1	0.96	18	3.8	0.92	19	4.5	0.89	21			
	0.45	2.2	0.93	15	2.9	0.88	18	3.6	0.84	20	4.4	0.81	21	5.2	0.78	23			
	0.35	3.1	1.68	17	3.9	0.64	20	4.9	0.61	22	6.1	0.59	24	7.2	0.59	26			
	0.65	1.1	1.92	11	1.4	1.85	13	1.7	1.70	14	2.I	1.65	15						
	0.55	1.3	1.56	12	11.7	1.50	14	2.1	1.45	16	2.6	1.38	17						
2.0	*0.50	1.5	1.38	13	1.9	1.31	15	2.4	1.26	17	2.9	1.21	18						
	0.45	1.7	1.21	14	2.2	1.16	16	2.7	1.13	18	3.3	1.10	20						
	0.35	2.3	0.89	16	2.9	0.84	18	3.6	.80	20	4.4	.78	22						

$Fn = gat^b$ $LS = 4/3\ (d/y)\ t^{0.5}$

*Use for general design

Table KS6-4 Initial Application Rate in gpm per 100 Feet with Varying Value of "g" When $(W_1 + 4/3(d/y)t^{0.5})$ = >Furrow Spacing

Intake Family	Value of "g"	Net Application - Inches 2.0"			2.5"			3.0"			3.5"			4.0"			4.5"		
		30	36	40	30	36	40	30	36	40	30	36	40	30	36	40	30	36	40
	0.90	1.6	1.8	2.1	1.5	1.7	2.0	1.4	1.6	1.9	1.3	1.5	1.8	1.2	1.4	1.7	1.2	1.4	1.6
	0.80	1.3	1.6	1.8	1.2	1.5	1.7	1.2	1.4	1.6	1.1	1.3	1.5	1.1	1.3	1.4	1.0	1.2	1.3
0.3	*0.75	1.2	1.5	1.7	1.1	1.4	1.5	1.1	1.3	1.4	1.0	1.2	1.3	0.9	1.1	1.2	0.9	1.1	1.2
	0.70	1.1	1.4	1.5	1.0	1.3	1.4	1.0	1.2	1.3	0.9	1.1	1.2	0.8	1.0	1.1	0.8	0.9	1.0
	0.60	0.9	1.1	1.2	0.8	1.0	1.1	0.8	0.9	1.0	0.7	0.8	0.9	0.7	0.8	0.9	0.6	0.7	0.8
	0.80	2.5	3.0	3.3	2.3	2.8	3.1	2.2	2.6	2.9	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.6
	0.70	2.1	2.5	2.8	2.0	2.3	2.6	1.9	2.2	2.4	1.8	2.1	2.3	1.7	2.0	2.2	1.5	1.9	2.1
0.50	*0.65	1.9	2.3	2.6	1.8	2.1	2.4	1.7	2.0	2.2	1.6	1.9	2.1	1.5	1.8	2.0	1.4	1.7	1.9
	0.60	1.7	2.1	2.3	1.6	1.9	2.1	1.5	1.8	2.0	1.4	1.7	1.9	1.3	1.6	1.8	1.2	1.5	1.7
	0.50	1.4	1.6	1.8	1.3	1.5	1.7	1.2	1.5	1.7	1.1	1.4	1.6	1.1	1.3	1.5	1.0	1.2	1.4
	0.75	3.4	4.1	4.4	3.2	3.8	4.1	3.0	3.6	3.9	2.9	3.4	3.7	2.8	3.2	3.5	2.7	3.1	3.4
	0.65	2.8	3.4	3.7	2.6	3.2	3.5	2.5	2.0	3.3	2.4	2.8	3.1	2.3	2.7	3.0	2.2	2.6	2.9
0.75	*0.60	2.5	3.0	3.3	2.3	2.8	3.1	2.2	2.6	2.9	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.6
	0.55	2.2	2.7	3.0	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.6	1.8	2.2	2.5	1.7	2.1	2.4
	0.45	1.7	2.1	2.3	1.6	2.0	2.2	1.5	1.9	2.1	1.4	1.8	2.0	1.3	1.7	1.9	1.2	1.6	1.8
	0.70	4.3	5.2	5.7	4.1	4.9	5.5	3.9	4.7	5.2	3.7	4.5	5.0	3.6	4.3	4.8	3.5	4.2	4.7
	0.60	3.5	4.2	4.7	3.3	4.4	4.5	3.2	3.8	4.3	3.0	3.7	4.1	2.9	3.5	3.9	2.8	3.4	3.8
1.0	*0.55	3.2	3.8	4.3	3.0	3.6	4.0	2.9	3.4	3.8	2.7	3.3	3.6	2.6	3.2	3.5	2.5	3.1	3.4
	0.50	2.8	3.4	3.8	2.6	3.2	3.6	2.5	3.0	3.4	2.4	2.9	3.2	2.3	2.8	3.1	2.2	2.7	3.0
	0.40	2.1	2.5	2.8	2.0	2.4	2.7	1.9	2.3	2.5	1.8	2.2	2.4	1.7	2.1	2.3	1.6	2.0	2.2
	0.65	5.6	6.8	7.5	5.4	6.5	7.2	5.2	6.2	6.9	5.0	6.0	6.6	4.8	5.7	6.3			
	0.55	4.6	5.6	6.2	4.4	5.3	5.9	4.3	5.1	5.6	4.1	4.9	5.4	3.9	4.7	5.2			
1.5	*0.50	4.1	5.0	5.5	3.9	4.7	5.2	3.7	4.5	5.0	3.6	4.3	4.8	3.5	4.2	4.6			
	0.45	3.6	4.4	4.8	3.4	4.2	4.6	3.3	4.0	4.4	3.1	3.8	4.2	3.0	3.7	4.1			
	0.35	2.7	3.2	3.6	2.5	3.0	3.4	2.4	2.9	3.2	2.3	2.8	3.1	2.2	2.7	3.0			
	0.65	7.5	9.0	9.9	7.1	8.6	9.5	6.8	8.2	8.2	6.5	7.9	8.7						
	0.55	6.1	7.4	8.2	5.8	7.0	7.8	5.5	6.7	7.4	5.3	6.5	7.1						
2.0	*0.50	5.4	6.5	7.2	5.2	6.2	6.8	5.0	5.9	6.5	4.8	5.7	6.3						
	0.45	4.8	5.7	6.4	4.6	5.4	6.1	4.4	5.2	5.8	4.2	5.0	5.6						
	0.35	3.5	4.2	4.7	3.3	4.0	4.5	3.2	3.8	4.3	3.1	3.7	4.1						

When $(W_1 + 4/3(d/y)t^{0.5}) < W_2$, Increase planned net application as needed to a maximum increase of 35 percent to obtain desired average application and determine appropriate average application rate and time.

Initial application "q" = 1.5 Ia where Ia is average intake gpm/100 feet

*Use for general design

Table KS6-5 Conversion of Intake Rate from Gallons Per Minute Per 100 Feet of Furrow to Inches Depth over the Field

Intake Rate or Application Rate Per 100 Ft. of Furrow gpm	Intake Rate - Inches Per Hour for Following Furrow Spacing								
	20”	22”	30”	36”	40”	44”	48”	60”	72”
0.4	0.23	0.21	0.15	0.13	0.12	0.11	0.10	0.08	0.06
0.6	0.35	0.31	0.23	0.19	0.17	0.16	0.15	0.12	0.09
0.8	0.46	0.42	0.31	0.26	0.23	0.21	0.19	0.15	0.13
1.0	0.58	0.52	0.38	0.32	0.29	0.26	0.24	0.19	0.16
1.2	0.69	0.63	0.46	0.39	0.35	0.32	0.29	0.23	0.19
1.4	0.81	0.73	0.54	0.45	0.40	0.37	0.34	0.27	0.22
1.6	0.92	0.84	0.62	0.51	0.46	0.42	0.39	0.31	0.26
1.8	1.05	0.94	0.70	0.58	0.52	0.47	0.44	0.35	0.29
2.0	1.16	1.05	0.77	0.64	0.58	0.53	0.48	0.39	0.32
2.2	1.27	1.15	0.85	0.71	0.64	0.58	0.53	0.42	0.35
2.4	1.39	1.26	0.92	0.77	0.69	0.63	0.58	0.46	0.38
2.6	1.50	1.36	1.00	0.83	0.75	0.68	0.63	0.50	0.41
2.8	1.62	1.47	1.08	0.90	0.81	0.74	0.68	0.54	0.45
3.0	1.73	1.57	1.16	0.96	0.87	0.79	0.73	0.58	0.48
3.2	1.85	1.68	1.23	1.03	0.93	0.84	0.77	0.62	0.51
3.4	1.97	1.78	1.31	1.09	0.98	0.89	0.82	0.66	0.54
3.6	2.08	1.89	1.39	1.15	1.04	0.95	0.7	0.69	0.57
3.8	2.20	1.99	1.47	1.22	1.10	1.00	0.92	0.73	0.61
4.0	2.31	2.10	1.54	1.28	1.16	1.05	0.97	0.77	0.64
4.2	2.43	2.20	1.62	1.35	1.22	1.10	1.02	0.81	0.67
4.4	2.54	2.31	1.70	1.41	1.27	1.16	1.06	0.85	0.70
4.6	2.66	2.41	1.77	1.47	1.33	1.21	1.11	0.89	0.73
4.8	2.77	2.52	1.85	1.54	1.39	1.26	1.16	0.93	0.77
5.0	2.89	2.62	1.92	1.60	1.45	1.31	1.21	0.96	0.80
5.5	3.18	2.73	2.12	1.77	1.59	1.37	1.33	1.06	0.88
6.0	3.47	3.15	2.32	1.93	1.73	1.58	1.45	1.16	0.96
6.5	3.76	3.41	2.50	2.09	1.88	1.71	1.57	1.25	1.04
7.0	4.05	3.67	2.70	2.25	2.02	1.84	1.9	1.35	1.12
7.5	4.34	3.94	2.89	2.41	2.17	1.97	1.82	1.45	1.20
8.0	4.62	4.20	3.09	2.57	2.31	2.10	1.94	1.54	1.26

Intake rate = gpm per 100-foot row (11.55 / furrow spacing (in.))

Example: Application rate = 1.9 gpm per 100 feet
Furrows are spaced 36”

Then application rate in inches per hour is between 0.58 and 0.64 or 0.61 inch per hour.

Table KS6-6 Selection of Schedules for Furrow Irrigation

Re-Use Procedure		Cutback Procedure	
T_A (Hrs.) *	Operating Schedule	Needed T_o Hrs.	Operating Schedule
1.7 to 2.3	2.0	3.8 to 4.6	2-2-4
2.4 to 3.3	3.0	4.7 to 5.7	2.5-2.5-5
3.4 to 4.3	4.0	5.8 to 7.0	3-3-6
4.4 to 5.3	5.0	7.1 to 9.2	4-4-8
5.4 to 6.6	6.0	9.3 to 11.4	5-5-10
6.7 to 8.7	8.0	11.5 to 14.4	6-6-12
8.8 to 10.9	10.0	14.5 to 18.7	8-8-16
11.0 to 13.2	12.0	18.8 to 22.9	10-10-20
13.3 to 17.5	16.0	23.0 to 28.0	12-12-24
17.6 to 21.4	20.0		
21.5 to 26.0	24.0		

* $T_A = 1.18\ T_o$ (approximately)

Example: Soil intake family is 0.3. Net application is 3.0".
From Table KS6-3 T_o = 11.1 hrs. T_A would be (1.18)(11.1) = 13.1 hrs.
Then from above table, time to apply water for re-use system is 12 hours and for cutback system 5-5-10 hour schedule.

Table KS6-7 Approximate Flow of Various Size Siphon Tubes (Gallons per Minute)

Tube	Head Causing Flow through Tube*				
Size	2”	3”	4”	6”	9”
1/2”	1.3	1.6	1.8	2.1	2.7
3/4”	3	4	5	6	7
1”	5	6	7	9	11
1 1/4”	8	10	12	15	18
1 1/2”	13	16	18	24	28
2”	21	27	32	41	50
2 1/2”	32	40	48	54	65
3”	46	57	65	82	100
4”	86	106	122	153	200

*Head is the difference in elevation of water in the supply ditch and center of discharge end of tube or outlet water surface if discharge end is submerged.

Table KS6-8 Clock Time for Change of Furrow Streams
Operation Schedules--Time to Change--Days to Complete Cycle--Number Sets per Cycle

12-12-24	10-10-20	8-8-16	6-6-12**	5-5-10	4-4-8	3-3-6	2-2-4
6:00 a.m.	6:00 a.m.	6:00 a.m.	6:00 a.m.	6:00 a.m.	6:00 a.m.	6:00 a.m.	6:00 a.m.
6:00 p.m.	4:00 p.m.	2:00 p.m.	12:00 p.m.	11:00 a.m.	10:00 a.m.	9:00 a.m.	8:00 a.m.
6:00 a.m.	2:00 a.m.*	10:00 p.m.*	6:00 p.m.	4:00 p.m.	2:00 p.m.	12:00 p.m.	10:00 a.m.
Repeat	10:00 p.m.	2:00 p.m.	Repeat	Repeat	10:00 p.m.	6:00 p.m.	2:00 p.m.
2 days	8:00 a.m.	10:00 p.m.*	1 day	(Automatic pump shut-off at 2 a.m.)	2:00 a.m.*	9:00 p.m.*	4:00 p.m.
1 set	6:00 p.m.	6:00 a.m.	1 set		6:00 a.m.	12:00 P. M.*	6:00 p.m.
	2:00 p.m.	10:00 p.m.*			2:00 p.m.	Repeat	10:00 p.m.*
	12:00 a.m.*	6:00 a.m.		1 day 1 set	6:00 p.m.	1 day	12:00 p.m.*
	10:00 a.m. 6:00 p.m.	2:00 p.m.			10:00 p.m.*	2 sets	2:00 a.m.*
	Repeat	Repeat			Repeat		Repeat
	5 days	4 days			2 days		1 day
	3 sets	3 sets			3 sets		3 sets

* Indicates night operation

6:00 a.m. selected as starting time
Change accordingly for other times

**Example*:* A 6-6-12 hour schedule means water applied to even-numbered rows for 6 hours, then to odd-numbered rows for 6 hours, then to all rows for 12 hours.

Table KS6-9 Acre-Feet of Water Pumped in T Hours

T Hours	Pump Discharge - Gallons per Minute											
Pumping	200	300	400	500	600	700	800	900	1000	1100	1200	1300
6	0.22	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10	1.22	1.33	1.44
8	0.29	0.44	0.59	0.74	0.88	1.03	1.18	1.33	1.47	1.62	1.77	1.92
10	0.37	0.55	0.74	0.92	1.10	1.29	1.47	1.66	1.84	2.03	2.21	2.39
12	0.44	0.66	0.88	1.11	1.33	1.55	1.77	1.99	2.21	2.43	2.65	2.87
14	0.52	0.77	1.03	1.29	1.55	1.80	2.06	2.32	2.58	2.84	3.09	3.35
16	0.59	0.88	1.18	1.47	1.77	2.06	2.36	2.65	2.95	3.24	3.53	3.83
18	0.66	0.99	1.33	1.66	1.99	2.32	2.65	2.98	3.31	3.65	3.98	4.31
20	0.74	1.10	1.47	1.84	2.21	2.58	2.95	3.31	3.68	4.05	4.42	4.79
22	0.81	1.22	1.62	2.03	2.43	2.84	3.24	3.65	4.05	4.46	4.86	5.27
24	0.88	1.33	1.77	2.21	2.65	3.09	3.53	3.98	4.42	4.86	5.30	5.74
26	0.96	1.44	1.91	2.39	2.87	3.35	3.83	4.31	4.79	5.27	5.74	6.22
28	1.03	1.55	2.06	2.58	3.09	3.61	4.12	4.64	5.15	5.67	6.19	6.70
30	1.10	1.66	2.21	2.76	3.31	3.87	4.42	4.97	5.52	6.08	6.63	7.18
32	1.18	1.77	2.36	2.95	3.53	4.12	4.71	5.30	5.89	6.48	7.07	7.66
34	1.25	1.88	2.50	3.13	3.76	4.38	5.01	5.63	6.26	6.89	7.51	8.14
36	1.33	1.99	2.65	3.31	3.98	4.64	5.30	5.96	6.63	7.29	7.95	8.62
38	1.40	2.10	2.80	3.50	4.20	4.90	5.60	6.30	7.00	7.70	8.39	9.09
40	1.47	2.21	2.95	3.68	4.42	5.15	5.89	6.63	7.36	8.10	8.84	9.57
45	1.66	2.49	3.31	4.14	4.97	5.80	6.63	7.46	8.28	9.11	9.94	10.77
50	1.84	2.76	3.68	4.60	5.52	6.44	7.36	8.28	9.21	10.12	11.05	11.97

(c) Sprinkler irrigation

There have been a number of new acronyms created to describe the location of nozzles for center pivot sprinkler systems. To assist with a clearer understanding of these nozzle locations, the following explanations are intended to remove confusion. Refer to Figure KS6-1 for a picture of the locations.

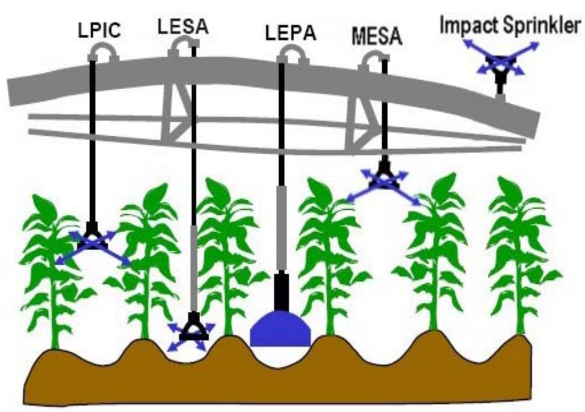
LPIC (Low Pressure in Canopy) - A form of spray application with sprinklers on drops within the crop canopy

LESA (Low Elevation Spray Application) - A form of spray application with sprinklers on drops near the ground (typically below the crop foliage) but not beyond 18 inches above the ground LESA wets the entire soil surface

LEPA (Low Energy Precision Application) - A form of surface irrigation that applies water to a particular area. It does not have overlapped wetted areas nor does it wet the entire soil surface. LEPA systems are typically composed of drag socks or bubblers that must travel in the same pattern or path as the row arrangement.

MESA (Mid-Elevation Spray Application) - A form of spray application with sprinklers on drops, typically positioned below the truss rods, above the mature crop canopy.

Figure KS6-1 - Nozzle Locations for Acronyms



(1) Center Pivot Evaluation and Design (CPED)

Center Pivot Evaluation and Design is a Windows 3.1 or greater program for assessment of center pivot performance. The program simulates the water distribution under a center pivot from various commercial nozzles as well as performs an evaluation from catch can data. This scientific model was adapted by Beccard and Heermann to include the effect of topographic differences in the resulting application depths along the radii of the center pivot in non-level fields. Included are pump and well characteristics specific to the system. The model was developed and is supported by the Agricultural Research Service (ARS) Water Management Research Unit in Fort Collins, Colorado. File cped-d.exe downloads for a 3-disk installation and transfers to other machines.

CPED is CCE-certified and is available for WinNT machines. Going to the Web site it can be accessed at:

http://servicecenter.usda.gov/release/#Certified
Under Software name, locate CPED
Description: Center Pivot Evaluation & Design
Date available: 3/9/2000
Location available: Download/12MB

It can also be accessed at:

ftp://ftp.wcc.nrcs.usda.gov/water_mgt/CCE-non_Models

Click on Download/12MB and store it in a directory. An Administrator is required to open the cped_inst.exe package. Once opened, the executable file will extract the CPED program and supporting data.

For non-CCE WinNT computers, the program can be accessed from the following Web site:

http://www.wcc.nrcs.usda.gov/nrcsirrig

When this site comes up, click “Water Management Models” and scroll down and click “CPED download (6.5mb).”

When downloaded, it is a zipped file with the title: cped-test.exe and is 7595 KB in size. It is a self-extracting file; and when unzipped, there are six files. The files can be stored in any directory that you choose. Clicking on setup.exe will initiate installation of the program. One of the files is the manual that can be accessed by Adobe Acrobat reader. The file name is Cpedvb3.pdf (1,381 KB).

The readme.txt file reads as follows:

> This version of the CPED program was updated on 3/15/2000. The only thing new is the updated sprinkler file.
>
> cpedl.zip = CPED program with support for linear systems.
>
> sys_info.mdb = updated sprinkler file
>
> **If downloading the new sprinkler file, download it into the main CPED directory. Ex: c:\cped
>
> If you are using a spreadsheet to create catch can data depth files, the format of the depth files is as follows:
>
> line 1: simulation type
> line 2: description of file
> line 3: units (ml or inch)
> line 4: unit conversion
> line 5: Hours/Revolution, Minimum Depth
> line 6 - end of file: Distance, Depth

Uninstalling:
Use the "Add/Remove Programs" tool within "Control Panel" to UNINSTALL CPED software. The "Control Panel" is accessible via "Settings" in the "Start" menu. From within the "Add/Remove Program Properties" window, scroll down and select "CPED" from the list of applications currently installed on your computer. Then click on "Add/Remove" to uninstall the CPED program.

For questions pertaining to CCE installation problems,
contact your system administrator.

NRCS technical support is offered by:
The Kansas NRCS state office engineer with lead responsibilities for irrigation
or
Jerry Walker, Water Management Engineer, Central National Technology Support Center, Fort Worth, Texas (telephone 817-509-3387)
(e-mail jerry.walker@ftw.usda.gov)

(2) Sprinkler intake rate

Intake rates under sprinkler irrigation do not conform to those for flood or furrow. Table KS6-10 has been prepared as a guide for maximum application rate. Fields irrigated by the sprinkler method often have varied and undulating slopes. The slope used in selecting the slope group in Table KS6-10 is the one found by using the weighted average slope method. A sprinkler system that will apply water at a rate equal to or less than the rate shown in the table will be satisfactory to use in applying water. A center pivot or other continuous move type sprinkler system is different from a stationary system in that its application rate is not a constant but rather it is changeable. At a given point in the field, the rate starts at zero, rises to a peak, and then drops off again to zero as the sprinkler system passes that point.

Sprinkler application rates are based on the sprinkler discharge, the spacing of the sprinklers on the lateral and either the lateral spacing on the mainline or the wetted diameter of the sprinkler. The equation to calculate the sprinkler application rate is:

$$I = \frac{96.3 \times q}{s_l \times s_m}$$

Where:
- I = average application rate (iph)
- q = sprinkler discharge (gpm)
- s_l = spacing of the sprinklers along the laterals (ft)
- s_m = spacing of laterals along mainline or wetted diameter (ft)

Example (Table KS6-10): Determine the maximum sprinkler application rates for the following conditions.

Sorghum on Harney silt loam (0.3 intake family) - Net application is 2.0 inches. Design slope is estimated to be 1 to 3 percent. Usual residue is estimated at 1500 pounds/acre. From Table KS6-10, the application rate for the above parameters and 2000 pounds of residue equals 0.6 inch/hour. For 1500 pounds of residue, 0.6 x .95 = 0.57 inch/hour maximum allowable application rate.

Same situation with net application reduced to 1.00 inch - From Table KS6-10, application rate for 2000 pounds of residue equals 1.5 inches/hour. For 1500 pounds, 1.5 x .95 = 1.43 inches/hour maximum allowable application rate.

Sprinkler systems have some capability of modifying the temperature in the plant environment both in frost protection and reducing high temperatures. Also, sprinkler systems can be used to apply fertilizers, soil amendments, and pesticides. These applications are known as chemigation.

Example: Steps for side roll sprinkler system

Given: Field is 1290 feet by 2600 feet, 77 acres (80 acres less roads), E 1/2 of SE 1/4, land slope 0.5 to 1.0 percent on Keith silt loam (0.5 intake family). The well, 15 feet inside the east edge of the field centered north to south, supplies 750 gpm at 65 psi. Average crop residue is 2000 pounds per acre or better.

The irrigator desires 7- or 11-hour settings using a side roll sprinkler system with 50- by 60-foot sprinkler and lateral spacing. The crop is alfalfa. Mainline is 1230 feet long and laterals are 1300 feet long north and south of the mainline. The field is nearly level.

(i) Determine net and gross application-- The crop will be irrigated when the available soil moisture in the root zone has been depleted by 50 percent. Use a root zone of 4 feet for alfalfa. Keith silt loam is in Irrigation Design Group 5 in Section KS652.0204(c). This shows that the available waterholding capacity for the top 4 feet of Keith soils is 9.4 inches. Fifty percent of this is 4.7 inches. This would be the maximum net irrigation. Consider 4.0 to 4.5 inches in planning the system.

(ii) Determine the sprinkler size-- The side roll would be 1300 feet long to fit the field. Sprinkler nozzle spacing at 50 feet requires 26 nozzles (1300 / 50 = 26). To distribute 750 gpm, the nozzle capacity would be 28.8 gpm (750 / 26 = 28.8). From Table KS6-16, a 3/8-inch nozzle will discharge 28.8 gpm at 54 psi with a 156-foot wetted diameter. The minimum lateral spacing from Kansas Conservation Practice Standard 442, Irrigation System, Sprinkler, is 50 percent of the wetted diameter for winds to 10 mph. Fifty percent of 156 is 78 feet; the lateral spacing of 60 feet is acceptable.

To calculate the average application rate while the side roll system is operating, use the following equation:

$$I = \frac{96.3 \times q}{s_l \times s_m}$$

Where: I = average application rate (iph)
q = sprinkler discharge (gpm)
s_l = spacing of the sprinklers along the laterals (ft.)
s_m = spacing of laterals along mainline or wetted diameter ft.)

Use q = 28.8 gpm, a sprinkler spacing of 50 feet, and a wetted diameter of 156 feet. This gives a rate of 0.36 inch per hour. To calculate the total precipitation applied per set, again use the equation for average application rate. For q = 28.8 gpm and a spacing of 50 by 60 feet, the application rate is .92 inch per hour. For a 7-hour set, the gross irrigation is 6.44 inches; and for an 11-hour set, the gross irrigation is 10.12 inches. Use the 7-hour set. From Table KS6-1, the estimated application efficiency is 80 percent.

6.44 inches x 0.8 = 5.2 inches net application

From Table KS6-10 (0.5 intake family and 0 to 1 percent slope), a net application of 4.5 inches will permit a maximum application rate of 0.6 iph for a field with 2000 pounds of residue. Therefore, an application rate of 0.36 iph is acceptable.

(iii) Determine size of lateral--Allowable variation in sprinkler lateral is 20 percent of design pressure. For a sprinkler pressure of 54 psi, the allowable loss in the line is 10.8 psi or 24.95 feet. Lines are 1300 feet long; spacings of nozzles are 50 feet with 26 nozzles per line. From Table KS6-15, Factor F = 0.36 for outlets in the middle. For a multiple outlet line, the theoretical allowable pressure loss in feet per 100 feet of lateral would be head loss h_l divided by factor F.

h_l = 24.95 ft. / (13 ft./199 ft. x 0.36)
= 5.33 ft. per 100 ft. of lateral

From Table KS6-14, a 5-inch lateral line carrying 750 gpm would have a friction loss of 11.74 feet per 100 feet of lateral, which is excessive. A 6-inch lateral line would have a friction loss of 4.81 feet per 100 feet of lateral, which is within the allowable friction loss of 5.33 feet so a 6-inch lateral line is required.

(iv) Determine size of mainline--When the side roll is at the west end of the field, the water will have to flow through the entire 1230 feet of pipe; and the friction losses are the greatest. The pressure at the entrance to the lateral should be the average sprinkler pressure plus half of the friction loss in the lateral or 54 + 4.9 or 58.9 psi. With 65 psi at the pump and 58.9 psi at the lateral, the pressure loss in the mainline should not exceed 6.1 psi or 14.09 feet or 1.15 feet per 100 feet.

From Table KS6-14, 8-inch pipe will have a loss of 1.18 feet per 100 feet at 750 gpm. This is a reasonable solution for economical pipe size for the mainline.

(v) Determine if system will meet crop need--

750 gpm / 450 gpm/ac.-in./hr. = 1.67 ac.-in./hour

Three 7-hour sets are as follows:

1.67 ac.-in./hr. x 21 hr./day (3 sets x 7 hr./set) or 35.07 ac.-in./day

Field has 77 acres:

35.07 / 77 = 0.455 in./day gross and at 80 percent efficiency is 0.455 x 0.8 or 0.36 inch per day net application

From Table KS4-5, peak consumptive use for corn under 4.5 inches net application is 0.295 inch per day. The system is adequate to meet peak consumptive.

(vi) Determine time to cover field--With one side roll in operation, 42 sets are required to cover the field at 3 settings per day. Time to irrigate the field is 42 divided by 3, which equals 14 days.

Table KS6-10 Maximum Sprinkler Application Rate (Inches/Hour) for 2000 Pounds Actual Residue at Planting

Irrig. Design Group	Design Slope Group	Net Irrigation Application (Inches)											
		0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
1& 2 (0.1)	0 - 1	4.8	3.0	1.0	0.6	0.4	0.3						
	1.1 - 3	4.8	0.8	0.5	0.4	0.3	0.2						
3 & 4 (0.3)	0.1	4.8	4.8	3.0	1.8	1.4	0.9	0.6	0.5	0.4	0.3	0.3	0.2
	1.1 - 3	4.8	2.4	1.5	1.2	1.0	0.6	0.5	0.4	0.3	0.2	0.2	0.2
	3.1 - 5	1.9	1.1	0.9	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.2	0.2
	>5	1.2	0.8	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2
5 & 6 (0.5)	0 - 1	4.8	4.8	4.2	3.0	2.2	1.5	1.1	1.0	0.9	0.8	0.6	0.4
	1.1 - 3	4.8	3.6	2.5	2.0	1.6	1.1	1.0	0.9	0.8	0.7	0.6	0.4
	3.1 - 5	2.8	1.9	1.5	1.2	1.1	1.0	0.8	0.7	0.6	0.5	0.4	0.4
	>5	1.8	1.4	1.1	1.0	1.0	0.8	0.7	0.6	0.6	0.4	0.4	0.3
7 & 8 (1.0)	0 - 1	4.8	4.8	4.8	4.8	4.2	3.0	2.5	2.1	1.9	1.6	1.4	1.2
	1.1 - 3	4.8	4.8	4.6	3.7	3.1	2.5	2.2	1.9	1.7	1.5	1.4	1.0
	3.1 - 5	4.8	3.2	3.2	2.8	2.5	2.0	1.8	1.5	1.4	1.4	1.1	1.0
	>5	3.1	2.6	2.2	2.1	1.9	1.6	1.5	1.4	1.3	1.2	1.0	0.9
9, 10, 11 & 12	All Design Slopes	(No restrictions within practical design criteria)											

Gilley, J.R., Suitability of Reduced Pressure Center-Pivot. Journal of Irrigation and Drainage, Vol. 110, No. 1, March, 1984. ASAE. Pages 22-34, Table 5

Allowable soil surface storage values for various slopes, (without artificial storage). (Included in Table KS6-10)

Slope (percent)	Available soil surface storage, (inches)
0 - 1	0.5
1.1 - 3	0.3
3.1 - 5	0.1
> 5	0.0

Dillon, et al, ASAE Transactions 1972, Pages 996 - 1001, Table 6

Application rate adjustment for residue other than 2000#

with >4000# residue use 125% of above rate
with 4000# residue use 120% of above rate
with 3500# residue use 115% of above rate
with 3000# residue use 110% of above rate
with 2500# residue use 105% of above rate
with 1500# residue use 95% of above rate
with 1000# residue use 90% of above rate
with <1000# residue use 85% of above rate

Table KS6-11 Precipitation Rates for Various Sprinkler Spacings and Discharge Rates (inches per hour)

Spacing	Gallons per Minute from Each Sprinkler																		
(feet)	1	2	3	4	5	6	7	8	9	10	11	12	15	18	20	25	30	35	40
20 x 20	0.24	0.48	0.72	0.96	1.20	1.44		1.92											
20 x 30	0.16	0.32	0.48	0.64	0.80	0.96		1.28		1.60		1.93							
20 x 40	0.12	0.24	0.36	0.48	0.60	0.72		0.96		1.20		1.45	1.81	2.17					
20 x 50	0.10	0.20	0.30	0.40	0.50	0.60		0.80		1.00		1.20	1.50	1.80	2.00				
20 x 60	0.08	0.16	0.24	0.32	0.40	0.48		0.64		0.80		0.96	1.20	1.44	1.60	2.00			
25 x 25	0.15	0.30	0.46	0.61	0.77	0.92		1.23		1.23		1.85	2.31						
30 x 30	0.11	0.21	0.32	0.43	0.54	0.64	0.75	0.86	0.96	1.07		1.28	1.61	1.93	2.14				
30 x 40		0.16	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80	0.88	0.96	1.2	1.45	1.61	2.01	2.40		
30 x 50		0.13	0.19	0.26	0.32	0.39	0.45	0.51	0.58	0.64	0.71	0.77	0.96	1.15	1.28	1.60	1.92		
30 x 60		0.11	0.16	0.21	0.27	0.32	0.37	0.43	0.48	0.54	0.59	0.64	0.80	0.96	1.07	1.54	1.61	1.87	2.14
40 x 40			0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.60	0.66	0.72	0.90	1.08	1.20	1.50	1.80	2.10	2.40
40 x 50				0.19	0.24	0.29	0.34	0.39	0.43	0.48	0.53	0.58	0.72	0.87	0.96	1.20	1.44	1.68	1.92
40 x60					0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.60	0.72	0.80	1.00	1.20	1.40	1.60
50 x 50					0.19	0.23	0.27	0.31	0.35	0.39	0.42	0.46	0.58	0.69	0.77	0.96	1.15	1.35	1.54
50 x 60						0.19	0.22	0.26	0.29	0.32	0.35	0.39	0.48	0.58	0.64	0.80	0.96	1.12	1.28
50 x 70							0.19	0.22	0.25	0.28	0.30	0.33	0.41	0.50	0.55	0.69	0.82	0.96	1.1
60 x 60								0.21	0.24	0.27	0.29	0.32	0.40	0.48	0.54	0.67	0.80	0.93	1.07
60 x 70									0.21	0.23	0.25	0.28	0.34	0.41	0.46	0.57	0.69	0.80	0.92
60 x 80										0.20	0.22	0.24	0.30	0.36	0.40	0.50	0.60	0.70	0.80

Table KS6-12 Gross Irrigation Application (Inches) for Design Efficiency

Net Irrig. Depth, Inches	Design Efficiency (Percent)							
	95	90	85	80	75	70	65	60
0.50	0.53	0.56	0.59	0.63	0.67	0.71	0.77	0.83
0.75	0.79	0.83	0.88	0.94	1.00	1.07	1.15	1.25
1.00	1.05	1.11	1.18	1.25	1.33	1.43	1.54	1.67
1.25	1.32	1.39	1.47	1.56	1.67	1.79	1.92	2.08
1.50	1.58	1.67	1.76	1.88	2.00	2.14	2.31	2.50
1.75	1.84	1.94	2.06	2.19	2.33	2.50	2.69	2.92
2.00	2.11	2.22	2.35	2.50	2.67	2.86	3.08	3.33
2.25	2.35	2.50	2.65	2.81	3.00	3.21	3.46	3.75
2.50	2.63	2.78	2.94	3.13	3.33	3.57	3.85	4.17
2.75	2.89	3.06	3.24	3.44	3.67	3.93	4.23	4.58
3.00	3.16	3.33	3.53	3.75	4.00	4.29	4.62	5.00
3.25	3.42	3.61	3.82	4.06	4.33	4.64	5.00	5.42
3.50	3.68	3.89	4.12	4.38	4.67	5.00	5.38	5.83
3.75	3.95	4.17	4.41	4.69	5.00	5.36	5.77	6.25
4.00	4.21	4.44	4.71	5.00	5.33	5.71	6.15	6.67
4.25	4.47	4.72	5.00	5.31	5.67	6.07	6.54	7.08
4.50	4.74	5.00	5.29	5.63	6.00	6.43	6.92	7.50
4.75	5.00	5.28	5.59	5.94	6.33	6.79	7.31	7.92
5.00	5.26	5.56	5.88	6.25	6.67	7.14	7.69	8.33

Table KS6-13 Irrigation Pipe Size by Size to Standard Dimension Ratios (SDR)

PLASTIC IRRIGATION PIPE (PIP)

Nominal Size (in.)	PIP O.D.* (in.)	PIP Inside Diameter by SDR (in.)						
		[22 psi]1/	[50 psi]1/	64 [63 psi]1/	51 [80 psi]1/	41 [100 psi]1/	32.5 [125 psi]1/	26 [160 psi]1/
4.00	4.130	- -	- -	4.001	3.968	3.929	3.876	3.812
6.00	6.140	6.000	5.988	5.948	5.899	5.840	5.762	5.668
8.00	8.160	8.000	7.948	7.905	7.840	7.762	7.658	7.532
10.00	10.200	10.000	9.948	9.881	9.800	9.702	9.572	9.415
12.00	12.400	12.160	12.098	11.858	11.760	11.643	11.487	11.298
15.00	15.300		14.992	14.822	14.700	14.554	14.358	14.123
18.00	18.701	- -	- -	18.117	17.968	17.789	17.550	17.262
21.00	22.047	- -	- -	21.358	21.182	20.972	20.690	20.351
24.00	24.803	- -	- -	24.028	23.830	23.593	23.277	22.895

POLYVINYL CHLORIDE PIPE (PVC)

Nominal Size (in.)	PVC O.D.* (in.)	PVC Inside Diameter by SDR (in.)			
		41	32.5	26	21
1.00	1.315	- -	- -	1.195	1.189
1.50	1.900	- -	- -	1.754	1.720
2.00	2.375	- -	- -	2.193	2.149
2.50	2.875	- -	- -	2.655	2.601
3.00	3.500	- -	- -	3.230	3.166
4.00	4.500	- -	4.280	4.154	4.072
6.00	6.625	- -	6.299	6.115	5.993
8.00	8.625	- -	8.208	7.964	7.808
10.00	10.750	- -	10.226	9.924	9.728
12.00	12.750	- -	12.128	11.770	11.538

IRON PIPE SIZE (IPS)

Nominal Size (in.)	IPS O.D.* (in.)	IPS Inside Diameter by SDR (in.)					
		64	41	32.5	26	21	13.5
0.50	0.840	- -	- -	- -	- -	- -	0.716
0.75	1.050	- -	- -	- -	- -	0.950	0.894
1.00	1.315	- -	- -	- -	- -	1.190	1.120
1.25	1.660	- -	- -	1.558	1.532	1.502	1.414
1.50	1.900	- -	- -	1.783	1.754	1.719	1.619
2.00	2.375	- -	- -	2.229	2.192	2.149	2.023
2.50	2.875	- -	- -	2.698	2.654	2.601	2.449
3.00	3.500	- -	3.329	3.285	3.231	3.167	2.981
4.00	4.500	4.359	4.280	4.223	4.154	4.071	3.833
5.00	5.563	5.389	5.292	5.221	5.135	5.033	- -
6.00	6.625	6.418	6.302	6.217	6.115	5.994	- -
8.00	8.625	8.355	8.204	8.094	7.962	7.804	- -
10.00	10.750	10.414	10.226	10.088	9.923	- -	- -
12.00	12.750	12.352	12.128	- -	11.769	- -	- -

*O.D. = Outside Diameter

Table KS6-14 Friction Loss in Feet per 100 Feet in Lateral and Main

Lines of Portable Aluminum Pipe With Couplings[1]

Flow rate (gpm)	4-inch[2] (0.050) (3.900)	5-inch[2] (0.050) (4.900)	6-inch[2] (0.058) (5.884)	8-inch[2] (0.072) (7.856)	10-inch[2] (0.091) (9.818)
100	0.85	0.28	0.12	0.03	0.01
120	1.20	0.39	0.16	0.04	0.01
140	1.59	0.52	0.22	0.05	0.02
160	2.04	0.67	0.28	0.07	0.02
180	2.54	0.83	0.34	0.08	0.03
200	3.08	1.01	0.42	0.10	0.03
220	3.68	1.21	0.50	0.12	0.04
240	4.32	1.42	0.58	0.14	0.05
260	5.01	1.65	0.68	0.17	0.06
280	5.75	1.89	0.78	0.19	0.06
300	6.54	2.15	0.88	0.22	0.07
320	7.37	2.42	0.99	0.24	0.08
340	8.24	2.71	1.11	0.27	0.09
360	9.16	3.01	1.24	0.30	0.10
380	10.13	3.33	1.37	0.33	0.11
400	11.14	3.66	1.50	0.37	0.12
420	12.19	4.01	1.64	0.40	0.14
440	13.28	4.37	1.79	0.44	0.15
460	14.42	4.75	1.95	0.48	0.16
480	15.61	5.14	2.11	0.52	0.17
500	16.83	5.54	2.27	0.56	0.19
550	20.08	6.61	2.71	0.66	0.22
600	23.59	7.76	3.18	0.78	0.26
650	27.37	9.00	3.69	0.90	0.31
700	31.39	10.33	4.24	1.04	0.35
750	35.67	11.74	4.81	1.18	0.40
800	40.20	13.23	5.42	1.33	0.45
850	44.97	14.80	6.07	1.49	0.50
900	50.00	16.45	6.75	1.65	0.56
950	55.26	18.18	7.46	1.83	0.62
1000	60.77	19.99	8.20	2.01	0.68

[1] Based on Hazen-Williams formula (from National Engineering Handbook [NEH], Section 15, Equation 11-15 for C = 130) and 30-foot pipe lengths, 20-foot pipe increase by 7%, and 40-foot pipe decrease by 3%

[2] Outside diameter, wall thickness, and inside diameter in parentheses.

Table KS6-15 Reduction Coefficients (F) For Computing Friction Loss in Pipe with Multiple Outlets[1]

Number of Outlets	F[2] (end)	F[3] (mid)
1	1.00	1.00
2	0.64	0.52
3	0.53	0.44
4	0.49	0.41
5	0.46	0.40
6	0.44	0.39
7	0.43	0.38
8	0.42	0.38
9	0.41	0.37
10 - 11	0.40	0.37
12 - 14	0.39	0.37
15 - 20	0.38	0.36
21 - 35	0.37	0.36
>35	0.36	0.36

[1] Based on Christiansen's formula (from NEH-15, Chapter 11, Equations 11-16a and 11-16b)

[2] F(end) is for first sprinkler at far end of first pipe joint.

[3] F(mid) is for first sprinkler at middle of first pipe joint.

(3) Center pivot sprinkler design
Use the CP Nozzle computer program or Form KS-ENG-22. These are to be used for the design of a center pivot sprinkler system. An EXCEL spreadsheet KS-ENG-22 is also available for designing a center pivot sprinkler system. The following are the steps used in filling out Form KS-ENG-22:

(i) List soils information, land slopes, intake families, and design groups. Refer to KS652.0204 for information on irrigated soils. If more than one soil is present with different intake families, design the system for the soil that occurs on the majority of the area. Document if special attention is needed for other areas.

(ii) List the crop to be grown and pounds of crop residue per acre at planting time.

(iii) Determine the water supply flow rate in gallons per minute (gpm) to be delivered to the system (Q). If at all possible, this should be measured by a flowmeter. If not, the amount could be estimated. One way to estimate the water supply in an existing system is by the following procedure:

- Measure the outside circumference of the pipe and divide by π(3.14) to find the diameter of the system pipe.
- Take nozzle pressure readings at each end of the system.
- Measure the distance between the two nozzles in feet.
- Determine the net plus or minus elevation differences in feet between these two nozzle locations.
- Knowing the pressure loss due to friction from the above item, refer to Table KS6-18 for the estimated gpm in the pipe.

(iv) Estimate the wetted radius (R) of the center pivot sprinkler. This is the distance from the pivot point to the point past the end of the center pivot that is receiving adequate water. Also, determine the distance from the pivot point to the outer drive wheel (r).

(v) Record the wetted diameter of the largest lateral nozzle (w). This can be determined using one of the Tables KS6-16 through KS6-16f. Also, record the nozzle pressure used in determining the wetted diameter.

(vi) Using Table KS6-12, estimate the efficiency of the system.

(vii) Determine the desired net application per pass of the center pivot sprinkler system (d) (inches).

(viii) Calculate the gross application per pass (D) (inches). Net application divided by efficiency equals gross application.

(ix) Record the area irrigated (A) (acres) by using the wetted radius. Table KS6-17 can be used to calculate this.

(x) Calculate the time to irrigate the area once (T). Take 18.75 times the gross application (D) times the area irrigated (A) and divide by the system flow rate (Q).

Time to Irrigate Entire Area Once (T) = 18.75 x D x A / Q (18.75 is conversion from ac.-in./gpm to days)

(xi) Divide system flow rate (Q) by area (A) to obtain gpm/acre.

(xii) Find the minimum irrigation requirement, gpm/acre, from the appropriate Tables KS4-10, KS4-10a, KS4-11, KS4-11a, KS4-12, or KS4-12a. The gpm/acre value determined in Item (xi) must equal or exceed this figure. If not, either reduce the acres (A) or increase the gpm (Q) to the system.

(xiii) Using Table KS6-10, find the maximum allowable application rate for the intake family, slope, net irrigation, and crop residue determined above.

(xiv) The design application rate is calculated by 192.6 times the distance to outer drive wheel (r) times system flow rate (Q) divided by the product of the wetted radius (R) squared and the wetted diameter of the largest nozzle (w). This is the maximum application rate.

$$\text{Design Application Rate} = \frac{(192.6 \times r \times Q)}{(R^2 \times w)}$$

(xv) The design application rate shall not exceed the maximum allowable application rate. If it does, then decrease the system flow rate or increase the nozzle wetted diameter as needed.

Example (Center Pivot Sprinkler Design): Form KS-ENG-22. See Figures KS6-2 and KS6-2A.

Given: Location is Ulysses area. The soil is Ulysses silt loam, (intake family 0.5, design group 5) from page KS2-8. The crop is corn with a usual residue of 2000 pounds. Land slope is 1.0 percent and water supply (well) is 675 gpm. The wetted radius of the system (R) is 1300 feet and the distance from the pivot to the outer drive wheel (r) is 1250 feet. The wetted diameter (w) of the largest nozzle, 1/4 inch, is 40 feet at 20 psi.

The estimated efficiency is 85 percent; and with a desired net application of 1.0 inch, the gross application per pass is 1.0 / .85 = 1.183 inches. Area irrigated is 121.9 acres, and the time to apply 1.33 inches to 121.9 acres is:

$$\frac{(18.75 \times 1.33 \text{ in.} \times 121.9 \text{ acres})}{675 \text{ gpm}} = 4.0 \text{ days.}$$

The design gpm/acre is:

675 gpm / 121.9 acres = 5.5 gpm/acre

This meets the "80 percent chance" gross minimum requirement of 4.7 gpm/acre for corn from Table KS4-10.

Maximum allowable application rate, Table KS6-10, for 0.5 intake family, 0 to 1 percent slope, 2000 pounds residue, and 1.0 inch net application = 4.2 inches/hour. The design application rate is:

$$\frac{(192.6 \times 1250 \text{ ft.} \times 675 \text{ gpm})}{[\,(1300 \text{ feet})^2 \times 40 \text{ ft.}]} = 2.40 \text{ in./hr.}$$

The design application rate is less than the maximum allowable. The design is acceptable.

Note: When possible, it is best to change the depth applied so that one pass is not a whole day (24.0 hrs.) or multiple of whole days so that when running continuously, the same portions of the field are watered during the daytime when evaporation and wind are highest.

Table KS6-15A Current Standard Center Pivot Pipe Sizes and Plug Spacing

Manufacturer	Plug Spacing (feet)	Common Pivot Riser Pipe Size (inches)		Common Lateral Pipe Size (inches)		Common Lateral Pipe Size (inches)		Other Commonly Used Pipe Size (inches)		Other Commonly Used Pipe Size (inches)	
		Inside Dia. (I.D.)	Wall Thick-ness (W.T.)	Nominal	I.D.	Nominal	I.D.	Nominal	I.D.	Nominal	I.D.
T&L	9.8	7.73	0.134[1/]	6 5/8	6.41	8	7.79	4	3.79	6	5.79
Reinke	9.5	7.79	0.105	6 5/8	6.43	8	7.80	3	2.78	6	5.80
Valley	9.0	7.79	0.105	6 5/8	6.41	8 5/8	8.41	4	3.79	6	5.79
Zimmatic	7.5	7.78	0.105	6 5/8	6.395	8	7.78	4	3.78	5 9/16	5.369

Other pipe sizes and plug spacings are possible based upon the manufacturer and age of the system. If unsure of the pipe size or plug spacing, contact the NRCS field engineer or the pivot technical representative/manufacturer/dealer.

[1/] If consideration is being given to placing a flowmeter in the vertical riser pipe of the T&L pivot, consult a T&L representative because hydraulic lines may interfere with installation.

Figure KS6-2 Form KS-ENG-22

USDA NRCS | **CENTER PIVOT SPRINKLER DESIGN** | **KS-ENG-22 Rev. 11/01**

Irrigator/Owner: ______________ County: ________
Legal Description: ______________ Plan No. ________

Note: Design data is from National Engineering Handbook Part 652, Irrigation Guide (IG), KS652.0605(c) and KS652.0408.
________ percent chance rainfall used for this design.

Soil:	______________	
Intake Family:	______________	
Design Group:		
Crop:	________	
Residue:	________	lbs/ac
Land Slope:	________	%
Design Flowrate (Q) (system - end gun flowrate):	________	gpm
Center Pivot Wetted Radius (R):	________	ft
Center Pivot Angle of Rotation (a):	________	degrees
Distance from Pivot to Outer Drive Wheel (r):	________	ft
Wetted Diameter of Largest Lateral Nozzle (w):	________	ft
System Efficiency (E) (IG Table KS6-1):	________	%
Desired Net Application (d):	________	in
Daily Irrigation Duration:		hrs/day
Gross Application (D) D = d/E:	________	in
Area Irrigated by Center Pivot Wetted Radius (A) (IG Table KS6-17):	________	ac
Time to Irrigate Entire Area Once (T) T = (18.75*D*A)/Q:	________	days
T = (18.75 x x) / = days		
(value entered automatically in the Excel spreadsheet)		
Design gpm/acre = Q/A:	________	gpm/ac
Minimum Gross Irrigation Requirement for Sprinkler: IG Tables KS4-10, KS4-10a, KS4-11, KS4-11a, KS4-12, or KS4-12a		gpm/ac
Maximum Allowable Application Rate (IG Table KS6-10): (value entered automatically in the Excel spreadsheet)	________	in/hr
Minimum Wetted Diameter of Largest Nozzle:	________	ft
Outer Drive Wheel Travel Speed:	________	ft/min
Design Application Rate = $(192.6 \cdot r \cdot Q)/(R^2 \cdot w)$:	________	in/hr

Rate = (192.6 x ________ x ________) / (______ ^{2} x ________) = ________ in./hr.

NOTE: If "Design gpm/acre" < "Minimum Gross Irrigation Requirement for Sprinkler," then this is an INADEQUATE IRRIGATION DESIGN and one must reduce acres, change crop, or increase water supply.

NOTE: If "Design Application Rate" > "Maximum Allowable Application Rate," then this is an INADEQUATE IRRIGATION DESIGN and one needs to decrease flow rate (Q) or desired net application (d) or increase wetted diameter (w).

Planned by: ______________ Date: ________

Checked by: ______________ Date: ________

Note: This form is available as an Excel spreadsheet.

Figure KS6-2A Example of Form KS-ENG-22 using Excel spreadsheet

USDA
NRCS

CENTER PIVOT SPRINKLER DESIGN

KS-ENG-22
Rev. 11/01

Irrigator/Owner: Who Knows County: Grant
Legal Description: Plan No.

Note: Design data is from National Engineering Handbook Part 652, Irrigation Guide (IG), KS652.0605(c) and KS652.0408.
80 percent chance rainfall used for this design.

Soil:	ULYSSES SILT LOAM	
Intake Family:	0.5	
Design Group:	5	
Crop:	corn	
Residue:	2000	lbs/ac
Land Slope:	1	%
Design Flowrate (Q) (system - end gun flowrate):	675	gpm
Center Pivot Wetted Radius (R):	1300	ft
Center Pivot Angle of Rotation (a):	360	degrees
Distance from Pivot to Outer Drive Wheel (r):	1250	ft
Wetted Diameter of Largest Lateral Nozzle (w):	40	ft
System Efficiency (E) (Table KS6-1):	85	%
Desired Net Application (d):	1.00	in
Daily Irrigation Duration:	24	hrs/day
Gross Application (D) D = d/E:	1.18	in
Area Irrigated by Center Pivot Wetted Radius (A) (IG Table KS6-17):	121.88	ac
Time to Irrigate Entire Area Once (T) T = 18.75*D*A/Q:	3.98	days
T = (18.75 x ________ x _______) / _______ = _____ days)		
(value entered automatically in the Excel spreadsheet)		
Design gpm/acre = Q/A:	5.54	gpm/ac
Minimum Gross Irrigation Requirement for Sprinkler:	4.16	gpm/ac
IG Tables KS4-10, KS4-10a, KS4-11, KS4-11a, KS4-12, or KS4-12a (value entered automatically in the Excel spreadsheet)		
Maximum Allowable Application Rate (IG Table KS6-10):	4.20	in/hr
(value entered automatically in the Excel spreadsheet)		
Minimum Wetted Diameter of Largest Nozzle:	22.89	ft
Outer Drive Wheel Travel Speed:	1.37	ft/min
Design Application Rate = (192.6*r*Q)/(R^{2*w}):	2.40	in/hr

Planned by: Joe Technician Date: 10/02/01

Checked by: Jane Doe Date: 10/02/01

Table KS6-16 Senninger Nozzle Discharge and Wetted Diameter for Sprinkler Nozzles

Nozzle Size (Inches)		Nozzle Pressure (pounds per square inch [psi])										
		25	30	35	40	45	50	55	60	65	70	75
3/32	Flow (gpm)	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0			
	Dia. (feet)	61	63	64	66	67	68	69	70			
7/64	Flow (gpm)	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.7			
	Dia. (feet)	67	69	70	71	72	74	75	77			
1/8	Flow (gpm)	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.6		
	Dia. (feet)	72	74	76	78	79	81	82	84	85		
9/64	Flow (gpm)	2.9	3.2	4.3	3.6	3.8	4.0	4.2	4.4	4.6		
	Dia. (feet)	78	80	81	83	85	86	88	90	92		
5/32	Flow (gpm)	3.5	3.9	4.2	4.5	4.7	5.0	5.2	5.5	5.7	5.9	
	Dia. (feet)	84	86	88	90	91	93	95	96	98	99	
11/64	Flow (gpm)	4.3	4.7	5.1	5.4	5.7	6.0	6.3	6.6	6.8	7.1	
	Dia. (feet)	90	92	94	96	98	100	102	103	105	106	
3/16	Flow (gpm)	5.0	5.5	6.0	6.4	6.8	7.2	7.5	7.8	8.1	8.4	8.7
	Dia. (feet)	95	97	100	102	104	106	108	110	111	113	114
13/64	Flow (gpm)	5.9	6.5	7.1	7.6	8.1	8.5	8.9	9.2	9.5	9.8	10.2
	Dia. (feet)	100	103	106	108	111	112	114	116	118	120	122
7/32	Flow (gpm)	6.8	7.6	8.3	8.9	9.4	9.9	10.3	10.7	11.2	11.6	12.0
	Dia. (feet)	106	109	111	113	115	117	119	121	123	125	126
1/4	Flow (gpm)		9.9	10.7	11.4	12.1	12.8	13.5	14.1	14.8	15.4	16.0
	Dia. (feet)		113	116	119	122	125	128	131	133	136	139
9/32	Flow (gpm)		12.4	13.4	14.3	15.2	16.1	17.0	17.9	18.7	19.5	20.3
	Dia. (feet)		118	122	125	129	132	135	139	141	144	146
5/16	Flow (gpm)		15.2	16.5	17.7	18.9	20.0	21.0	22.0	23.0	23.9	24.8
	Dia. (feet)		124	128	132	135	139	143	146	149	152	154
11/32	Flow (gpm)			19.7	21.1	22.4	23.6	24.8	25.9	27.0	28.1	29.2
	Dia. (feet)			133	139	143	146	150	153	156	159	161
3/8	Flow (gpm)			22.8	24.4	26.0	27.6	29.2	30.6	32.0	33.3	34.5
	Dia. (feet)			140	145	149	154	157	160	163	165	168
13/32	Flow (gpm)			27.2	29.1	30.9	32.7	34.3	35.9	37.4	38.9	40.3
	Dia. (feet)			147	152	156	159	163	166	169	172	174
7/16	Flow (gpm)				33.9	35.9	37.8	39.7	41.5	43.3	45.1	46.8
	Dia. (feet)				158	162	165	169	172	175	179	181
15/32	Flow (gpm)				38.9	41.1	43.3	45.4	47.4	49.4	51.4	58.3
	Dia. (feet)				163	167	172	175	179	182	184	187
1/2	Flow (gpm)				43.6	46.0	48.4	50.7	53.0	55.3	57.5	59.6
	Dia. (feet)				169	174	178	182	184	188	191	193
17/32	Flow (gpm)					51.6	54.0	56.4	58.8	61.2	63.5	65.8
	Dia. (feet)					179	184	188	192	194	196	199
9/16	Flow (gpm)					57.5	60.6	63.6	66.5	69.4	72.2	74.9
	Dia. (feet)					185	189	193	196	199	202	204
5/8	Flow (gpm)					70.0	73.6	77.2	80.8	84.4	87.8	91.0
	Dia. (feet)					190	194	198	201	204	207	211

From the Kansas Irrigation Guide 12/92

Table KS6-16a Senninger Spray Nozzle Discharge and Wetted Diameter (Performance Data)

	Sprinkler Base pressure (psi)							Sprinkler Base pressure (psi)					
	6	10	15	20	25	30		6	10	15	20	25	30
#5 Nozzle - Beige (5/64")							#16 Nozzle - Orange (1/4")						
	0.43	0.55	0.66	0.76	0.87	0.97		4.48	5.79	6.91	8.03	8.93	9.82
Dia. At 6' Ht. (ft)	13.0	15.0	16.5	18.0	19.5	21.0	Dia. At 6' Ht. (ft)	29.0	30.0	32.5	35.0	36.5	38.0
Dia. At 9' Ht. (ft)	17.0	19.0	20.5	22.0	23.3	24.5	Dia. At 9' Ht. (ft)	30.9	33.2	36.2	39.3	41.0	42.7
Dia. At 12' Ht. (ft)	21.0	23.0	24.5	26.0	27.0	28.0	Dia. At 12' Ht. (ft)	32.9	36.5	40.0	43.6	45.5	47.3
#6 Nozzle - Gold (3/32")							#17 Nozzle - Dark Green (17/64")						
	0.64	0.82	0.98	1.14	1.27	1.40		5.03	6.50	7.76	9.01	10.02	11.03
Dia. At 6' Ht. (ft)	16.8	18.7	30.0	21.3	22.5	23.8	Dia. At 6' Ht. (ft)	29.3	30.2	32.8	35.5	36.9	38.3
Dia. At 9' Ht. (ft)	19.7	22.0	23.9	25.8	26.9	28.1	Dia. At 9' Ht. (ft)	31.4	33.6	36.6	39.7	41.5	43.2
Dia. At 12' Ht. (ft)	22.6	25.3	27.8	30.3	31.3	32.3	Dia. At 12' Ht. (ft)	33.5	37.0	40.5	44.0	46.0	48.0
#7 Nozzle - Lime (7/64")													
	0.87	1.12	1.34	1.56	1.73	1.90		5.62	7.25	8.65	10.04	11.15	12.25
Dia. At 6' Ht. (ft)	20.6	22.3	23.5	24.7	25.7	26.7	Dia. At 6' Ht. (ft)	29.6	30.5	33.2	36.0	37.3	38.6
Dia. At 9' Ht. (ft)	22.4	24.9	27.3	29.7	30.7	31.7	Dia. At 9' Ht. (ft)	31.6	33.8	36.9	40.1	41.9	43.6
Dia. At 12' Ht. (ft)	24.3	27.6	31.1	34.7	35.7	36.7	Dia. At 12' Ht. (ft)	33.7	37.2	40.7	44.2	46.4	48.6
#8 Nozzle - Lavender (1/8")							#19 Nozzle - Black (9/64")						
	1.12	1.45	1.73	2.01	2.23	2.45		6.19	7.99	9.54	11.08	12.32	13.55
Dia. At 6' Ht. (ft)	24.5	26.0	27.0	28.0	28.7	29.5	Dia. At 6' Ht. (ft)	29.9	30.7	33.6	36.5	37.7	38.9
Dia. At 9' Ht. (ft)	25.2	28.0	30.7	33.5	34.4	35.3	Dia. At 9' Ht. (ft)	31.9	34.1	37.2	40.5	42.3	44.1
Dia. At 12' Ht. (ft)	26.0	30.0	34.5	39.0	40.0	41.0	Dia. At 12' Ht. (ft)	33.9	37.4	40.9	44.5	46.9	49.3
#9 Nozzle - Grey (9/64")													
	1.41	1.82	2.17	2.52	2.79	3.06		6.78	8.75	10.44	12.13	13.56	14.99
Dia. At 6' Ht. (ft)	25.8	27.0	28.2	29.5	30.3	31.2	Dia. At 6' Ht. (ft)	30.2	31.0	34.0	37.0	38.1	39.2
Dia. At 9' Ht. (ft)	26.5	29.1	31.9	34.7	35.7	36.6	Dia. At 9' Ht. (ft)	32.1	34.3	37.6	40.9	42.6	44.3
Dia. At 12' Ht. (ft)	27.3	31.2	35.6	40.0	41.0	42.0	Dia. At 12' Ht. (ft)	34.1	37.6	41.2	44.8	47.4	49.9
#10 Nozzle - Tourquoise (5/32")							#21 Nozzle - Mustard (21/64")						
	1.74	2.25	2.69	3.12	3.47	3.81		7.37	9.52	11.36	13.20	14.81	16.41
Dia. At 6' Ht. (ft)	26.6	28.0	29.5	31.0	32.0	33.0	Dia. At 6' Ht. (ft)	30.4	31.2	34.3	37.5	38.5	39.5
Dia. At 9' Ht. (ft)	27.6	30.3	33.1	36.0	37.0	38.0	Dia. At 9' Ht. (ft)	32.3	34.5	37.8	41.3	43.2	45.1
Dia. At 12' Ht. (ft)	28.7	32.6	36.8	41.0	42.0	43.0	Dia. At 12' Ht. (ft)	34.2	37.8	41.4	45.1	47.9	50.6
#11 Nozzle - Yellow (11/64")							#22 Nozzle - Maroon (11/32")						
	2.05	2.65	3.21	3.76	4.17	4.57		7.97	10.29	12.28	14.27	16.09	17.90
Dia. At 6' Ht. (ft)	27.1	28.5	30.1	31.7	33.1	34.5	Dia. At 6' Ht. (ft)	30.6	31.5	34.7	38.0	38.9	39.8
Dia. At 9' Ht. (ft)	28.6	31.2	34.0	36.8	38.1	39.3	Dia. At 9' Ht. (ft)	32.4	34.7	38.2	41.7	43.6	45.1
Dia. At 12' Ht. (ft)	30.0	34.0	38.0	41.8	43.0	44.0	Dia. At 12' Ht. (ft)	34.3	38.0	41.7	45.4	48.3	51.2
#12 Nozzle - Red (3/16")							#23 Nozzle - Cream (23/64")						
	2.45	3.16	3.81	4.45	4.96	5.47		8.86	11.18	13.34	15.50	17.50	19.49
Dia. At 6' Ht. (ft)	27.5	29.0	30.7	32.5	34.2	36.0	Dia. At 6' Ht. (ft)	30.8	31.7	35.1	38.5	39.3	40.4
Dia. At 9' Ht. (ft)	29.4	31.7	34.5	37.4	38.9	40.4	Dia. At 9' Ht. (ft)	32.6	34.9	38.5	41.7	44.5	46.5
Dia. At 12' Ht. (ft)	30.6	34.5	38.4	42.2	43.5	44.7	Dia. At 12' Ht. (ft)	34.4	38.2	41.9	45.7	48.8	51.9
#13 Nozzle - White (13/64")							#24 Nozzle - Dark Blue (3/8")						
	2.92	3.77	4.50	5.23	5.84	6.44		9.34	12.06	14.40	16.73	18.88	21.03
Dia. At 6' Ht. (ft)	27.9	29.2	31.2	33.2	34.8	38.5	Dia. At 6' Ht. (ft)	31.0	32.0	35.5	39.0	39.7	40.4
Dia. At 9' Ht. (ft)	29.9	32.1	35.0	37.9	39.4	40.9	Dia. At 9' Ht. (ft)	32.7	35.1	38.8	42.5	44.5	46.5
Dia. At 12' Ht. (ft)	31.2	35.0	38.8	42.6	44.0	45.3	Dia. At 12' Ht. (ft)	34.4	38.4	42.2	46.0	49.3	52.5
#14 Nozzle - Blue (7/32")							#25 Nozzle - Copper (25/64")						
	3.40	4.39	5.24	6.09	6.82	7.54		10.10	13.04	15.56	18.08	20.35	22.61
Dia. At 6' Ht. (ft)	28.3	29.5	31.7	34.0	35.5	37.0	Dia. At 6' Ht. (ft)	31.2	32.2	35.8	39.5	40.1	40.7
Dia. At 9' Ht. (ft)	30.2	32.5	35.4	38.4	40.0	41.5	Dia. At 9' Ht. (ft)	32.9	35.3	39.0	42.8	44.8	46.8
Dia. At 12' Ht. (ft)	31.8	35.5	39.2	43.0	44.5	46.0	Dia. At 12' Ht. (ft)	34.6	38.5	42.3	46.2	49.5	52.8
#15 Nozzle - Dark Brown (15/64")							#26 Nozzle - Bronze (13/32")						
	3.91	5.05	6.03	7.00	7.82	8.64		10.92	14.10	16.83	19.56	21.88	24.20
Dia. At 6' Ht. (ft)	28.7	29.7	32.1	34.5	36.0	37.5	Dia. At 6' Ht. (ft)	31.4	32.5	36.2	40.0	40.5	41.0
Dia. At 9' Ht. (ft)	30.5	32.8	35.8	38.9	40.5	42.1	Dia. At 9' Ht. (ft)	33.0	35.5	39.3	43.1	45.1	47.0
Dia. At 12' Ht. (ft)	32.3	36.0	39.6	43.3	45.0	46.7	Dia. At 12' Ht. (ft)	34.7	38.6	42.4	46.3	49.7	53.0

NOTES: Using flat medium-grooved deflector pad with no wind
At 12’ height - for concave pad subtract 5’ from above diameters
At 9’ height - for concave pad add 5’, for convex pad subtract 5’ from above diameters
At 6’ height - for concave pad add 5’, for convex pad subtract 5’ from above diameters
For 180 spray nozzle use ½ of diameter from above for same nozzle size and pressure
For wobbler pad add 10’ to the above diameters

From the Kansas Irrigation Guide 12/92

Table KS6-16b Senninger LDN (Low Drift Nozzle) Discharge and Wetted Diameter

	Sprinkler Base pressure (psi)			
	6	10	15	20
#5 Nozzle - Beige (5/64")				
	0.43	0.55	0.66	0.76
Dia. At 3' Ht. (ft)	11.0	13.8	16.0	17.6
Dia. At 9' Ht. (ft)	13.8	19.2	25.2	31.6
#6 Nozzle - Gold (3/32")				
	0.64	0.82	0.98	1.14
Dia. At 3' Ht. (ft)	12.4	15.6	18.0	19.6
Dia. At 9' Ht. (ft)	17.2	22.0	27.6	33.8
#7 Nozzle - Lime (7/64")				
	0.87	1.12	1.34	1.56
Dia. At 3' Ht. (ft)	13.8	17.4	20.0	21.6
Dia. At 9' Ht. (ft)	20.2	24.6	29.8	36.0
#8 Nozzle - Lavender (1/8")				
	1.12	1.45	1.73	2.01
Dia. At 3' Ht. (ft)	15.2	19.0	21.8	23.6
Dia. At 9' Ht. (ft)	22.8	27.2	32.0	38.0
#9 Nozzle - Grey (9/64")				
	1.41	1.82	2.17	2.52
Dia. At 3' Ht. (ft)	16.4	20.4	23.2	25.4
Dia. At 9' Ht. (ft)	25.0	29.6	34.2	40.0
#10 Nozzle - Tourquoise (5/32")				
	1.74	2.25	2.69	3.12
Dia. At 3' Ht. (ft)	17.6	21.8	24.6	27.0
Dia. At 9' Ht. (ft)	26.8	31.6	36.2	42.0
#11 Nozzle - Yellow (11/64")				
	2.05	2.65	3.21	3.76
Dia. At 3' Ht. (ft)	18.6	23.0	26.0	28.4
Dia. At 9' Ht. (ft)	28.2	33.2	38.2	43.8
#12 Nozzle - Red (3/16")				
	2.45	3.16	3.81	4.45
Dia. At 3' Ht. (ft)	19.6	24.0	27.0	29.6
Dia. At 9' Ht. (ft)	29.4	34.6	40.0	45.6
#13 Nozzle - White (13/64")				
	2.92	3.77	4.50	5.23
Dia. At 3' Ht. (ft)	20.4	24.8	27.8	30.6
Dia. At 9' Ht. (ft)	30.2	35.8	41.6	47.2
#14 Nozzle - Blue (7/32")				
	3.40	4.39	5.24	6.09
Dia. At 3' Ht. (ft)	21.2	25.4	28.6	31.4
Dia. At 9' Ht. (ft)	31.0	36.8	43.0	48.6
#15 Nozzle - Dark Brown (15/64")				
	3.91	5.05	6.03	7.00
Dia. At 3' Ht. (ft)	17.5	21.0	24.6	27.0
Dia. At 9' Ht. (ft)	26.2	29.8	35.0	41.0

	Sprinkler Base pressure (psi)			
	6	10	15	20
#16 Nozzle - Orange (1/4")				
	4.48	5.79	6.91	8.03
Dia. At 3' Ht. (ft)	18.4	22.0	26.4	29.0
Dia. At 9' Ht. (ft)	26.6	30.6	26.4	42.4
#17 Nozzle - Dark Green (17/64")				
	5.03	6.50	7.76	9.01
Dia. At 3' Ht. (ft)	19.2	23.1	28.5	31.2
Dia. At 9' Ht. (ft)	27.0	31.5	37.8	43.9
#18 Nozzle - Purple (9/32")				
	5.62	7.25	8.65	10.04
Dia. At 3' Ht. (ft)	20.1	24.6	30.8	33.4
Dia. At 9' Ht. (ft)	27.6	32.6	39.2	45.5
#19 Nozzle - Black (9/64")				
	6.19	7.99	9.54	11.08
Dia. At 3' Ht. (ft)	21.0	25.9	32.9	35.4
Dia. At 9' Ht. (ft)	28.2	33.8	40.8	47.2
#20 Nozzle - Dark Tourquoise (5/16")				
	6.78	8.75	10.44	12.13
Dia. At 3' Ht. (ft)	22.0	25.4	30.0	34.6
Dia. At 9' Ht. (ft)	30.0	36.8	44.2	52.0
#21 Nozzle - Mustard (21/64")				
	7.37	9.52	11.36	13.20
Dia. At 3' Ht. (ft)	22.4	26.0	31.0	36.2
Dia. At 9' Ht. (ft)	31.0	38.0	45.4	53.2
#22 Nozzle - Maroon (11/32")				
	7.97	10.29	12.28	14.27
Dia. At 3' Ht. (ft)	23.0	27.0	32.2	38.0
Dia. At 9' Ht. (ft)	32.0	39.2	47.0	54.8
#23 Nozzle - Cream (23/64")				
	8.86	11.18	13.34	15.50
Dia. At 3' Ht. (ft)	23.6	28.2	33.8	40.2
Dia. At 9' Ht. (ft)	33.0	40.4	48.8	57.2
#24 Nozzle - Dark Blue (3/8")				
	9.34	12.06	14.40	16.73
Dia. At 3' Ht. (ft)	24.2	29.6	36.0	42.8
Dia. At 9' Ht. (ft)	34.0	41.6	50.8	59.6
#25 Nozzle - Copper (25/64")				
	10.10	13.04	15.56	18.08
Dia. At 3' Ht. (ft)	31.2	32.2	35.8	39.5
Dia. At 9' Ht. (ft)	32.9	35.3	39.0	42.8
#26 Nozzle - Bronze (13/32")				
	10.92	14.10	16.83	19.56
Dia. At 3' Ht. (ft)	31.4	32.5	36.2	40.0
Dia. At 9' Ht. (ft)	33.0	35.5	39.3	43.1

NOTE: Diameters are shown in feet.
Performance data is based on the LDN using single, double and triple flat series deflector pads with no wind. Consult Senninger for details on other pad performance.
1999 (LDN 991)

Table KS6-16c Senninger *i-wob* Nozzle Discharge and Wetted Diameter for Spray Nozzles

Nozzle Size and Colors		Nozzle Pressure (psi)	STANDARD ANGLE 10	STANDARD ANGLE 15	STANDARD ANGLE 20	LOW ANGLE 10	LOW ANGLE 15	LOW ANGLE 20
#7 - Lime	(7/64")	Flow (gpm)	1.12	1.34	1.56			
		Dia. At 3' Ht. (ft)	36.9	40.1	42.5			
		Dia. At 6' Ht. (ft)	39.6	43.2	44.4			
#8 - Lavender	(1/8")	Flow (gpm)	1.45	1.73	2.01			
		Dia. At 3' Ht. (ft)	38.0	41.3	43.8			
		Dia. At 6' Ht. (ft)	40.6	44.2	45.8			
#9 Gray	(9/64")	Flow (gpm)	1.82	2.17	2.52			
		Dia. At 3' Ht. (ft)	39.0	42.2	45.1			
		Dia. At 6' Ht. (ft)	41.6	45.2	47.2			
#10 Turquoise	(5/32")	Flow (gpm)	2.25	2.69	3.12			
		Dia. At 3' Ht. (ft)	40.0	43.0	46.0			
		Dia. At 6' Ht. (ft)	42.6	46.2	48.4			
#11 Yellow	(1164")	Flow (gpm)	2.65	3.21	3.76			
		Dia. At 3' Ht. (ft)	40.9	43.8	46.8			
		Dia. At 6' Ht. (ft)	43.6	47.2	49.6			
#12 Red	(3/16")	Flow (gpm)	3.16	3.81	4.45	3.16	3.81	4.45
		Dia. At 3' Ht. (ft)	41.8	44.6	47.6	37.4	41.6	43.2
		Dia. At 6' Ht. (ft)	44.6	48.0	50.8	43.6	45.6	49.6
#13 White	(13/64")	Flow (gpm)	3.77	4.50	5.23	3.77	4.50	5.23
		Dia. At 3' Ht. (ft)	42.6	45.4	48.4	38.2	42.0	43.6
		Dia. At 6' Ht. (ft)	45.6	48.8	51.8	44.8	46.2	49.8
#14 Blue	(7/32")	Flow (gpm)	4.39	5.24	6.09	4.39	5.24	6.09
		Dia. At 3' Ht. (ft)	43.4	46.1	49.2	38.8	42.4	44.0
		Dia. At 6' Ht. (ft)	46.6	49.4	52.8	45.6	46.8	50.0
#15 Dark Brown	(15/64")	Flow (gpm)	5.05	6.03	7.00	5.05	6.03	7.00
		Dia. At 3' Ht. (ft)	44.2	46.8	49.9	39.2	42.8	44.4
		Dia. At 6' Ht. (ft)	47.6	50.0	53.6	46.0	47.4	50.2
#16 Orange	(1/4")	Flow (gpm)	5.79	6.91	8.03	5.79	6.91	8.03
		Dia. At 3' Ht. (ft)	44.8	47.4	50.6	39.6	43.2	44.8
		Dia. At 6' Ht. (ft)	48.4	50.6	54.4	46.4	47.8	50.6
#17 Dark Green	(17/64")	Flow (gpm)	6.50	7.76	9.01	6.50	7.76	9.01
		Dia. At 3' Ht. (ft)	45.2	48.0	51.3	40.0	43.6	45.2
		Dia. At 6' Ht. (ft)	49.0	51.0	55.0	46.8	48.4	50.8
#18 Purple	(9/32")	Flow (gpm)	7.25	8.65	10.04	7.25	8.65	10.04
		Dia. At 3' Ht. (ft)	45.4	48.5	52.0	40.6	44.2	45.6
		Dia. At 6' Ht. (ft)	49.4	51.4	55.4	47.2	48.8	51.0

Table KS6-16c (continued)

Nozzle Size and Colors		Nozzle Pressure (psi)	STANDARD ANGLE 10	STANDARD ANGLE 15	STANDARD ANGLE 20	LOW ANGLE 10	LOW ANGLE 15	LOW ANGLE 20
#19 Black	(19/64")	Flow (gpm)	7.99	9.54	11.08	7.99	9.54	11.08
		Dia. At 3' Ht. (ft)	45.5	48.9	52.6	40.8	44.4	45.6
		Dia. At 6' Ht. (ft)	49.8	51.8	55.8	47.6	49.2	51.2
#20 Dark Turquoise	(5/16")	Flow (gpm)	8.75	10.44	12.13	8.75	10.44	12.13
		Dia. At 3' Ht. (ft)	45.6	49.3	53.2	41.0	44.8	45.6
		Dia. At 6' Ht. (ft)	50.2	52.2	56.2	47.6	49.6	51.4
#21 Mustard	(21/64")	Flow (gpm)	9.52	11.36	13.20	9.52	11.36	13.20
		Dia. At 3' Ht. (ft)	45.7	49.6	53.7	41.2	45.0	45.7
		Dia. At 6' Ht. (ft)	50.6	52.6	56.6	47.6	49.8	51.4
#22 Maroon	(11/32")	Flow (gpm)	10.29	12.28	14.27	10.29	12.28	14.27
		Dia. At 3' Ht. (ft)	45.8	49.9	54.1	41.2	45.2	45.7
		Dia. At 6' Ht. (ft)	51.0	53.0	56.9	47.7	50.4	51.5
#23 Cream	(23/64")	Flow (gpm)	11.18	13.34	15.50	11.18	13.34	15.50
		Dia. At 3' Ht. (ft)	45.9	50.1	54.3	41.3	45.4	45.8
		Dia. At 6' Ht. (ft)	51.2	53.4	57.1	47.7	50.8	51.6
#24 Dark Blue	(3/8")	Flow (gpm)	12.06	14.40	16.73	12.06	14.40	16.73
		Dia. At 3' Ht. (ft)	46.0	50.2	54.4	41.4	45.6	45.8
		Dia. At 6' Ht. (ft)	51.4	53.6	57.2	47.8	51.0	51.6

NOTE: Figures reflect actual test data obtained under ideal conditions.

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Table KS6-16d Nelson Pivot 3000 Series 3TN Nozzle Discharge

No.# Color Stripe	#9 Light Blue *Beige*	#10 Beige	#11 Beige *Gold*	#12 Gold	#13 Gold *Lime*	#14 Lime	#15 Lime *Lavender*	#16 Lavender	#17 Lavender *Gray*	#18 Gray	#19 Gray *Turquoise*	#20 Turquoise
PSI	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
6	0.34	0.42	0.50	0.61	0.71	0.82	0.95	1.08	1.22	1.36	1.53	1.70
10	0.44	0.54	0.65	0.79	0.92	1.06	1.23	1.40	1.58	1.75	1.97	2.19
15	0.53	0.66	0.79	0.96	1.13	1.29	1.51	1.71	1.93	2.14	2.41	2.69
20	0.62	0.76	0.92	1.11	1.30	1.49	1.74	1.98	2.23	2.48	2.79	3.10
25	0.69	0.85	1.02	1.24	1.46	1.67	1.95	2.21	2.50	2.77	3.12	3.47
30	0.76	0.93	1.12	1.36	1.59	1.83	2.14	2.42	2.74	3.03	3.41	3.80
40	0.87	1.07	1.29	1.57	1.84	2.11	2.47	2.80	3.16	3.50	3.94	4.39
50	0.97	1.20	1.45	1.76	2.06	2.36	2.76	3.13	3.53	3.91	4.41	4.90

No.# Color Stripe	#21 Turquoise *Yellow*	#22 Yellow	#23 Yellow *Red*	#24 Red	#25 Red *White*	#26 White	#27 White *Blue*	#28 Blue	#29 Blue *Dark Brown*	#30 Dark Brown	#31 Dark Brown *Orange*	#32 Orange
PSI	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
6	1.84	2.04	2.22	2.44	2.64	2.87	3.07	3.35	3.58	3.83	4.06	4.36
10	2.38	2.64	2.86	3.16	3.41	3.70	3.97	4.32	4.62	4.94	5.24	5.63
15	2.91	3.23	3.50	3.86	4.17	4.53	4.86	5.29	5.66	6.06	6.41	6.89
20	3.36	3.73	4.05	4.46	4.82	5.23	5.61	6.11	6.53	6.99	7.40	7.96
25	3.76	4.17	4.52	4.99	5.38	5.85	6.27	6.83	7.30	7.82	8.28	8.90
30	4.12	4.56	4.96	5.47	5.90	6.41	6.87	7.48	8.00	8.56	9.07	9.75
40	4.76	5.27	5.72	6.31	6.81	7.40	7.94	8.64	9.24	9.89	10.47	11.26
50	5.32	5.89	6.40	7.06	7.61	8.28	8.87	9.66	10.33	11.06	11.71	12.59

No.# Color Stripe	#33 Orange *Dark Green*	#34 Dark Green	#35 Dark Green *Purple*	#36 Purple	#37 Purple *Black*	#38 Black	#40 Dark Turquoise	#42 Mustard	#44 Maroon	#46 Cream	#48 Dark Blue	#50 Copper
PSI	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
6	4.65	4.94	5.20	5.47	5.84	6.18	6.85	7.60	8.33	9.12	9.96	10.77
10	6.00	6.37	6.72	7.06	7.54	7.97	8.85	9.81	10.75	11.77	12.86	13.91
15	7.35	7.81	8.23	8.65	9.24	9.77	10.84	12.01	13.17	14.41	15.75	17.03
20	8.49	9.01	9.50	9.98	10.67	11.28	12.51	13.87	15.20	16.64	18.19	19.67
25	9.49	10.08	10.62	11.16	11.92	12.61	13.99	15.51	17.00	18.61	20.33	21.99
30	10.39	11.04	11.64	12.23	13.06	13.81	15.33	16.99	18.62	20.38	22.28	24.09
40	12.00	12.75	13.44	14.12	15.08	15.95	17.70	19.61	21.50	23.54	25.72	27.82
50	13.42	14.25	15.02	15.79	16.86	17.83	19.79	21.93	24.04	26.31	28.76	31.10

NOTE: This flow data was obtained under ideal test conditions and may be adversely affected by poor hydraulic entrance conditions, turbulence, or other factors. Nelson Irrigation makes no representation regarding sprinkler flow rate accuracy under various plumbing and drop pipe conditions.

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Table KS6-16e Nelson Spray I, II, and III Series (2RN & 3RN) Nozzle Discharge

SPRAY-II

BASE PSI	2RN NOZZLE SIZE										
	#4 .031" 1/32"	#5 .039" 5/128"	#6 .047" 3/64"	#7 .055" 7/128"	#8 .062" 1/16"	#9 .070" 9/128"	#10 .078" 5/64"	#11 .086" 11/128"	#12 .094" 3/32"	#13 .102" 13/128"	#14 0.109" 7/64"
	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
10	0.10	0.15	0.21	0.29	0.38	0.48	0.58	0.70	0.83	0.97	1.12
15	0.12	0.18	0.26	0.35	0.46	0.58	0.71	0.86	1.02	1.19	1.37
20	0.14	0.21	0.30	0.41	0.53	0.67	0.82	0.99	1.17	1.37	1.58
30	0.17	0.26	0.37	0.50	0.65	0.81	1.00	1.20	1.43	1.67	1.92
40	0.19	0.30	0.42	0.57	0.74	0.94	1.15	1.39	1.64	1.92	2.21

BASE PSI	2RN NOZZLE SIZE										
	#15 0.117" 15/128"	#16 .125" 1/8"	#17 .133" 17/128"	#18 .141" 9/64"	#19 .148" 19/128"	#20 .156" 5/32"	#21 .164" 21/128"	#22 .172" 11/64"	#23 .180" 23/128"	#24 .188" 3/16"	#25 .195" 25/128"
	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
10	1.28	1.45	1.63	1.83	2.03	2.24	2.46	2.68	2.92	3.17	3.43
15	1.57	1.77	1.99	2.23	2.47	2.73	2.99	3.27	3.57	3.87	4.18
20	1.80	2.04	2.30	2.56	2.84	3.14	3.45	3.77	4.11	4.45	4.82
30	2.20	2.49	2.80	3.13	3.47	3.83	4.21	4.60	5.01	5.43	5.87
40	2.53	2.87	3.22	3.60	4.00	4.41	4.84	5.30	5.77	6.26	5.76

BASE PSI	2RN NOZZLE SIZE										
	#26 .203" 13/64"	#27 .211" 27/128"	#28 .219" 7/32"	#29 .227" 29/128"	#30 .234" 15/64"	#31 .242" 31/128"	#32 .250" 1/4"	#33 .258" 33/128"	#34 .266" 17/64"	#35 0.273" 35/128"	
	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	
10	3.69	3.97	4.25	4.55	4.85	5.16	5.48	5.81	6.14	6.49	
15	4.51	4.84	5.19	5.55	5.92	6.30	6.68	7.08	7.50	7.92	
20	5.19	5.58	5.98	6.39	6.81	7.25	7.70	8.16	8.63	9.11	
30	6.33	6.80	7.29	7.79	8.31	8.84	9.39	9.95	10.53	11.12	
40	7.29	7.83	8.39	8.97	9.57	10.18	10.81	11.46	12.12	12.80	

Table KS6-16e (continued)

SPRAY-II											
BASE PSI	2RN NOZZLE SIZE										
	#4 .031" 1/32"	#5 .039" 5/128"	#6 .047" 3/64"	#7 .055" 7/128"	#8 .062" 1/16"	#9 .070" 9/128"	#10 .078" 5/64"	#11 .086" 11/128"	#12 .094" 3/32"	#13 .102" 13/128"	#14 0.109" 7/64"
	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
10	0.10	0.15	0.21	0.29	0.38	0.48	0.58	0.70	0.83	0.97	1.12
15	0.12	0.18	0.26	0.35	0.46	0.58	0.71	0.86	1.02	1.19	1.37
20	0.14	0.21	0.30	0.41	0.53	0.67	0.82	0.99	1.17	1.37	1.58
30	0.17	0.26	0.37	0.50	0.65	0.81	1.00	1.20	1.43	1.67	1.92
40	0.19	0.30	0.42	0.57	0.74	0.94	1.15	1.39	1.64	1.92	2.21
BASE PSI	2RN NOZZLE SIZE										
	#15 0.117" 15/128"	#16 .125" 1/8"	#17 .133" 17/128"	#18 .141" 9/64"	#19 .148" 19/128"	#20 .156" 5/32"	#21 .164" 21/128"	#22 .172" 11/64"	#23 .180" 23/128"	#24 .188" 3/16"	#25 .195" 25/128"
	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM
10	1.28	1.45	1.63	1.83	2.03	2.24	2.46	2.68	2.92	3.17	3.43
15	1.57	1.77	1.99	2.23	2.47	2.73	2.99	3.27	3.57	3.87	4.18
20	1.80	2.04	2.30	2.56	2.84	3.14	3.45	3.77	4.11	4.45	4.82
30	2.20	2.49	2.80	3.13	3.47	3.83	4.21	4.60	5.01	5.43	5.87
40	2.53	2.87	3.22	3.60	4.00	4.41	4.84	5.30	5.77	6.26	5.76
BASE PSI	2RN NOZZLE SIZE										
	#26 .203" 13/64"	#27 .211" 27/128"	#28 .219" 7/32"	#29 .227" 29/128"	#30 .234" 15/64"	#31 .242" 31/128"	#32 .250" 1/4"	#33 .258" 33/128"	#34 .266" 17/64"	#35 0.273" 35/128"	
	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	GPM	
10	3.69	3.97	4.25	4.55	4.85	5.16	5.48	5.81	6.14	6.49	
15	4.51	4.84	5.19	5.55	5.92	6.30	6.68	7.08	7.50	7.92	
20	5.19	5.58	5.98	6.39	6.81	7.25	7.70	8.16	8.63	9.11	
30	6.33	6.80	7.29	7.79	8.31	8.84	9.39	9.95	10.53	11.12	
40	7.29	7.83	8.39	8.97	9.57	10.18	10.81	11.46	12.12	12.80	

NOTE: Performance data shown is based on SPRAY-II with ½ “thread connection. Performance data using ¾” thread sizes may be obtained from Nelson Irrigation Corp.

Coverage Diameter in Feet

Spray I, II, and III - Pivots and Laterals								
Nozzle Size	#12		#20		#28		#35	
Spray Plate	FLS	FLMG	FLS	FLMG	FLS	FLMG	FLS	FLMG
Diameter at: 12'Spray Height	24'	30'	32'	38'	38'	46'	42'	48'
6"Spray Height	18'	28'	22'	32'	30'	40'	32'	42'

NOTE: Pressure will have an effect on spray diameter. Test data is at 20 psi with no wind.

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Table KS6-16f Valley Spray Nozzle Performance GPM

NOZZLE SIZE Number	BASE PRESSURE PSI							
	6 psi	10 psi	15 psi	20 psi	25 psi	30 psi	35 psi	40 psi
5				0.50	0.56	0.61	0.69	0.74
6	0.56	0.72	0.88	0.97	1.09	1.19	1.29	1.38
7	0.74	0.96	1.17	1.27	1.46	1.56	1.69	1.80
8	0.99	1.28	1.57	1.73	1.94	2.12	2.29	2.45
9	1.26	1.62	1.99	2.12	2.37	2.59	2.80	2.99
10	1.53	1.97	2.42	2.56	2.87	3.14	3.39	3.62
11	1.72	2.22	2.72	3.10	3.47	3.80	4.11	4.39
12	2.17	2.60	3.43	3.87	4.33	4.74	5.12	5.47
13	2.46	3.18	3.90	4.45	4.98	5.46	5.89	6.30
14	2.86	3.69	4.52	5.05	5.65	6.18	6.68	7.14
15	3.35	4.33	5.30	5.89	6.59	7.22	7.80	8.34
16	3.89	5.02	6.15	6.75	7.55	8.27	8.93	9.54
17	4.36	5.63	6.89	7.69	8.60	9.42	10.18	10.88
18	4.68	6.30	7.71	8.50	9.51	10.41	11.25	12.02
19	5.17	6.68	8.18	9.58	10.72	11.74	12.68	13.55
20	6.06	7.83	9.59	10.66	11.92	13.06	14.10	15.08
21	6.65	8.59	10.52	11.87	13.28	14.54	15.71	16.79
22	7.54	9.73	11.92	13.43	15.02	16.45	17.77	18.99
23	8.20	10.59	12.97	14.37	16.07	17.60	19.01	20.53
24	9.02	11.64	14.26	15.79	17.66	19.34	20.89	22.33
25	9.38	12.88	15.78	17.34	19.38	21.24	22.94	24.53
26	NOT RECOMMENDED			18.76	20.98	22.98	24.82	26.53
27				20.58	23.01	25.21	27.23	29.11
28				21.60	24.15	26.45	28.57	30.54
29				23.55	26.33	28.84	31.15	33.31
30				24.95	27.90	30.56	33.01	35.28

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Table KS6-17 Center Pivot Component and Area Relationships

Total System Length (in feet) 1/	% of Water Applied in Last 100 ft. 2/	Area Covered in Acres 3/		
		Without Using End Gun	With End Gun Used Only in Corners	With End Gun Used on Entire Circle
500	36.0	18.0	22.0	26.0
550	33.1	21.8	26.2	30.5
600	30.6	26.0	30.8	35.3
650	28.4	30.5	36.0	40.6
700	26.5	35.3	41.3	46.2
750	24.8	40.6	47.2	52.1
800	23.4	46.2	53.3	58.4
850	22.1	52.1	59.8	65.1
900	21.0	58.1	66.7	72.2
950	20.0	65.1	74.0	79.5
1000	19.0	72.1	81.7	87.3
1050	18.1	79.5	89.5	95.4
1100	17.4	87.3	98.0	103.9
1150	16.6	95.3	106.6	112.7
1200	16.0	103.9	115.7	121.9
1250	15.4	112.7	123.8	131.4
1300	14.8	121.9	134.0	141.4
1350	14.3	131.4	145.0	151.6
1400	13.8	141.4	155.2	162.3
1450	13.3	151.6	166.5	173.3
1500	12.9	162.3	177.7	184.6

1/ Generally last tower approximately 50 feet from end
2/ Less volume of end gun when used
3/ Based on 100-foot gun coverage

Example: System is 1300 feet long.
Then 14.8 percent of water is applied in last 100 feet.
121.9 acres are covered without using end gun.

Table KS6-18 Pressure Loss in Center Pivot System (psi)

System Length Feet	Pipe Size Inches	Flowrate at Pivot Point 300 gpm	400 gpm	500 gpm	600 gpm	700 gpm	800 gpm	900 gpm	1000 gpm	1100 gpm	1200 gpm
600	4	11	18	27							
	5	3.5	6	9							
700	5	4	7	11	15						
	6	1.7	3	4.5	6						
800	5	4.5	8	12	18	24					
	6	2	3.5	5	7	10					
900	5	5	9	14	20	27	34				
	6	2.3	4	6	8	11	14				
	6.5					7	10				
1000	5	5.5	10	16	23	30	38				
	6	2.6	4.5	6.5	9	12	15	19			
	6.5					8	11	14			
1100	5	6	11	17	25	33	42				
	6	3	5	7	10	13	17	21	26		
	6.5				6	9	12	15	18		
1200	5		12	19	27	36					
	6		5.5	7.5	11	15	19	23	28	35	
	6.5		3.5	5	7	10	13	16	19	23	
1300	6			8	12	16	20	25	31	37	45
	6.5			5.5	8	11	14	17	21	25	30
	7				5	7	9	12	15	18	22
1400	6				13	17	22	27	33	40	48
	6.5				9	12	15	19	23	27	32
	7				6	8	10	13	16	19	23
1500	6					18	23	29	35	42	51
	6.5					13	16	20	24	28	34
	7					9	11	14	17	20	24
1600	6						25	31	37	45	54
	6.5						17	21	26	30	36
	7						12	15	18	21	25
1700	6							33	39	47	57
	6.5							23	27	32	38
	7							16	19	22	26
1800	6								41	50	60
	6.5								29	34	40
	7								20	23	27

(4) Continuous move volume gun system (traveling gun) design

A typical continuous move volume gun system (traveling sprinkler system) consists of the following major components: pumping plant, mainline, flexible hose, traveler unit, and gun sprinkler. Pumping plants and mainline were discussed under Periodic-Move Sprinkler Systems. More detailed information on traveling sprinklers can be found in the National Engineering Handbook, Section 15, Chapter 11 - Sprinkle Irrigation.

(i) Sprinkler selection--Sprinkler characteristics that need to be considered are nozzle size and type, operating pressure, jet trajectory, and sprinkler body design. The operating conditions that enter into the selection process are soil infiltration characteristics; desired depth and frequency of irrigation; towpath length, potential towpath spacings, and number of paths for each potential spacing; wind conditions; crop characteristics; and the mechanical properties of the soil.

Gun sprinklers used in most travelers have trajectory angles ranging between 18^o and 32^o. For average conditions, trajectories between 23^o and 25^o are satisfactory. This range gives reasonable uniformity in moderate winds, has gentle enough drop impact for most crops and soils, and is suitable for operation on varying slopes. Most gun sprinklers can be fitted with either tapered or orifice-ring nozzles. Tapered nozzles have a greater distance of throw, and the ring nozzles have smaller droplet size for the same discharge and pressure.

Typical nozzle discharges and diameters of coverage are presented in Table KS6-19 for gun sprinklers with 24^o angles of trajectory and tapered nozzles. The wetted diameter would increase or decrease about 1 percent for each 1^o change in trajectory angle. Ring nozzles sized to give the same pressures would produce diameters that are about 5 percent smaller than those presented in the table.

Both full-circle and part-circle gun sprinklers are available in all nozzle types and size ranges. Some sprinklers need to be operated with part-circle coverage to give even water distribution, a dry path, or both. The use of part-circle sprinklers increases the application rate.

The actual application rate at which water must infiltrate into the soil to eliminate runoff is approximately given by this equation:

$$I = \frac{96.3\ q}{pi(0.45w)^2} \times \frac{360}{w^o}$$

Where: I = approximate actual application rate (iph)
q = sprinkler discharge (gpm)
pi = 3.1415...
w = wetted diameter (ft.)
w^o = portion of circle receiving water (degrees)

The traveler selected should provide the required flow rate and power to drag the hose at the travel speeds necessary to meet the design criteria. Controls to provide a uniform speed of travel that will not vary more than about 10 percent as the traveler moves from one end of the field to the other and positive shutoff at the end of travel are essential.

(ii) Towpath spacing--Tests have shown that application uniformity is considerably affected by wind velocity and direction, quantity of water output, jet trajectory, type of nozzle, and operating pressure. The tests have also shown that a towpath spacing of 80 percent of the wetted diameter would produce excellent uniformity under very calm wind conditions, whereas closer spacings would produce excessive application midway between adjacent towpaths.

Table KS6-20 gives recommended towpath spacing for 23^o to 25^o trajectory sprinklers as a function of wetted diameter and anticipates average wind velocities. These towpath spacings will ensure full coverage midway between towpaths. The higher percentage values should be used for tapered nozzles and the lower values for ring nozzles.

(iii) Travel speed--The travel speed should be set to traverse the length of the towpath so that there will be little downtime and either 1 or 2 setups per day. For a 1320-foot run with 2 sets and 1 hour to move the traveler to the next towpath and set up, the travel speed would be approximately 2 ft./min. One set per day should have a travel speed of 0.9 to 1.0 ft./min. In some cases, the traveler has to be stationary at each end of the run to allow the full irrigation to be applied to the entire field.

(iv) Application depth--The rate of application is unaffected by travel speed, but the depth of application is a function of speed. The average depth of water applied per irrigation by a traveling sprinkler can be computed by:

$$d = \frac{1.605\ q}{W\ S}$$

Where: d = gross depth of application (in.)
q = sprinkler discharge (gpm)
W = towpath spacing (ft.)
S = travel speed (ft./min.)

(v) Friction losses in hose and traveler--To calculate the pressure required at the pump to operate the sprinkler, the friction losses in the hose and through the traveler should be determined. These losses are then added to the sprinkler pressure to determine the total pressure needed. More information on hose and traveler friction losses can be found in the National Engineering Handbook, Section 15, Chapter 11 - Sprinkle Irrigation.

Example: The field is 1/2 mile long and 1/4 mile wide with a well in the middle of the long side. The traveler has a sprinkler with a 1.4-inch nozzle, which will discharge 500 gpm at 80 psi. The traveler will water 270^o of the circle. Net irrigation requirement is 1.5 inches per pass.

From Table KS6-19 the wetted diameter is 450 feet. Using the equation for calculating application rate for travelers with q = 500 gpm, w = 450 feet, and $w^o = 270^o$ the rate is 0.50 iph.

From Table KS6-20 for 450 feet of wetted diameter and 75 percent coverage, the towpath spacing is 338 feet. For the field, this would equate to 8 towpaths of 325 feet each. The traveler will take a full day for each towpath. Travel speed is 1300 feet divided by 23 hours (1 hour to move traveler) for a rate of .94 ft./min.

Application depth for q = 500 gpm, W = 325 feet, and S = .94 ft./min. is 2.63 inches. At an efficiency of 70 percent, the net application is 1.84 inches. It will require 8 days to irrigate the entire field, and the average water applied per day would be .23 inch on the entire field.

Table KS6-19 Typical Discharges and Wetted Diameters for Gun Sprinklers with 24-Degree Angles of Trajectory and Tapered Nozzles Operating when There Is No Wind

	Tapered Nozzle Size (in)									
	0.8		1.0		1.2		1.4		1.6	
Sprinkler Pressure	Sprinkler Discharge and Wetted Diameter									
psi	gpm	ft	gpm	ft	gpm	ft	gpm	ft	gpm	ft
60	143	285	225	325	330	365	- -	- -	- -	- -
70	155	300	245	340	355	380	480	435	- -	- -
80	165	310	260	355	380	395	515	455	675	480
90	175	320	275	365	405	410	545	470	715	495
100	185	330	290	375	425	420	475	480	755	510
110	195	340	305	385	445	430	605	490	790	520
120	205	350	320	395	465	440	630	500	825	535

Table KS6-20 Recommended Towpath Spacings for Traveling Sprinklers

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	- -	- -

Use the lower percent numbers for ring nozzles and the higher percent for numbers for tapered nozzles for the three wind speeds.

(d) Microirrigation

(1) System components

For a schematic of the general system, refer to Figures 6-14 and 6-19 in Section 652.0603 and KS6-4 in this Kansas Section KS652.0605.

(i) Injection system--In addition to the information provided in Section 652.0603(f)(8), if injecting fertilizer or chemicals into a system which is connected directly to a ground water or surface source (well, river, or pond), then the injection system must meet the requirements of the Kansas Chemigation Safety Law. The person operating the system is also required to have a Chemigation User's Permit and a Chemical Applicator's Permit. Applications are available at some groundwater management districts (GMDs) and Kansas Division of Water Resources (DWR) offices.

For manual injection of fertilizer or chemicals, the minimum required safety equipment is: mainline check valve, vacuum breaker, and low-pressure drain (see Figure KS6-5). To use automatic injection, a complete interlock system in addition to the equipment mentioned above is required. For more information, contact the Kansas Department of Agriculture - Division of Plant Health.

***(ii) Mainline* --**This line carries the main flow away from the water source. It is usually PVC pipe, 3/4 to 1½ inches in diameter, and is normally buried. Usual depth is from 24 to 30 inches or below frost line. Polyethylene (PE) pipe may also be used.

(iii) Manifold or sub-mains--This is an extension of the mainline from which the lateral lines branch off. These lines are usually PVC or PE and can be on the surface or buried with individual risers to the ground surface for each lateral line. The lateral lines lead off from one or both sides of the manifold depending on the system layout. Pipe size usually runs from 1/2 to 1 inch in diameter.

***(iv) Drains*--**Drain valves or plugs should be installed at all low points in the system. Drain plugs should be installed at the end of the manifold and the lateral lines. This will permit drainage and also periodic flushing of the system.

(v) Media filters - The following is a discussion of media filters by William L. Pyle, PE, Agricultural Engineer, Ag Systems Hawaii.

a) Vertical tank media filters work better than horizontal tank media filters over the long run because horizontal tank filters eventually suffer a reduction in through-flow capacity. In every case, the sides of the sand media closest to the curved sideshell are the most difficult to achieve a thorough cleaning action during backflushing. As this media contamination accumulates along the curved side-shell, the backflush action becomes increasingly concentrated in the middle of the media bed, eventually settling down to about half the media bed being effective as a filter medium.

A vertical media filter can sometimes suffer some media compaction in extreme situations. However, horizontal tank filters stack very nicely in industrial situations where they have to be installed in a limited space, like an equipment room, and seemingly work well for swimming pools, where the contaminant loading and chlorine concentration conditions are quite different than in an agricultural situation using surface waters.

b) ALL media filters require "tuning" the backflush process to eliminate media loss, there is NO excuse for media loss. A valve is required in the backflush line in EVERY installation--no exceptions. To backflush, use a 12-inch by 12-inch box with an 80-mesh screen bottom held under the discharge of the backflush line, open the valve slowly during backflush until sand is seen in the screen box, then back off until no sand is seen in the backflush water. Lock down the valve somehow so it cannot be tampered with. Most sand media loss is due to the backflow rate being set too high and "blowing" sand out of the system. It is advisable to do a random spot check occasionally when the system is backflushing to see if any sand is being lost. Some manufacturers make a backflush restriction valve that requires a very large wrench to set it, and it stays set once the correct setting is achieved.

c) Media filters provide an ideal location for certain organic colonies (bacteria, etc.) to develop. This leads to sand compaction, deterioration of media filter operation, and downstream contamination of the drip system.

Adequate chlorination of the media filters on a frequent basis is a must. On large systems (average 250 acres per filter station), it is advisable to chlorinate the entire drip system, starting at the intake, every 24 hours for half an hour at 10 parts per million (ppm) using gas chlorinators. For smaller systems, solid chlorine or chlorox works well. By trial and error, using chlorine checks in the field and edging up from a low rate until 10 ppm is reached is the safest way to determine a correct dosage for a given system. Testing done in the 1980s in Hawaii determined that 1 ppm chlorine applied 24 hours a day, or a "hot shot" of half an hour once a day at 10 ppm were required to keep the sand media clean over the long term. There are other agents available that will work equally well at keeping biological contamination of the sand media bed from developing, but chlorine has been found to be safe and relatively inexpensive.

d) Check the media tanks often (about once a month). Open a tank, reach in, and feel the sand. Stir it around with your hand. You can tell if the sand is smooth and clean after a backflush or if there are hard spots or compacted areas that aren't getting cleaned up. Call your supplier if there are problems. Tank systems that allow easy access to the media bed for inspection are recommended.

e) The so-called automatic "self-cleaning" screen systems don't seem to work very well where there is organic loading in the surface water source--if hard silt is the only contaminant, then screens can probably handle it. In the "self-cleaning" screen systems, there are too many moving parts, most of these parts work in dirty water, the wear factor is extremely high, replacement parts are very expensive, the head loss through the filter is quite high compared to a media filter, and the organics seem to build up on the screen surface and eventually require disassembly of the filter to give the screen a good scrubbing to clean it up.

(vi) Other

- Lateral lines installed along the ground surface should be "snaked" along the rows. This allows for contraction and expansion due to temperature changes. Five percent of the total length is added to compensate for the variation.
- Five extra feet should be added to the end of the manifold and laterals (beyond last emitter). This provides temporary storage for sediments that pass through the filter(s). These may be flushed out periodically.
- Cutoff valves should be installed at the front of each lateral line to permit greater flexibility in system operation. Individual lines can be shut off for repair and maintenance while the remainder of the system operates. The valves also help when flushing the system or when

injecting fertilizer or chemicals. A system design with the valves could allow for removal of laterals for storage after the season or allow access for tillage.

- Fixtures (pressure regulators, gauges, filters, etc.) should be mounted off the ground surface to prevent breakage. Install guard posts as needed to protect fixtures from machinery, livestock, etc.

(2) Design criteria
The majority of the design criteria can be found in Section 652.0603(g)(8).

***(i) Surveying*--** For instructions on the type of surveys needed, see the electronic Field Office Technical Guide (eFOTG) > Section IV > Conservation Practices > Irrigation System, Microirrigation (441) > Practice Documentation Requirement.

(ii) Design considerations

- Water pressure at the source (after the filter) will depend on the type of emitters to be used. For stem crops (trees and shrubs), the pressure at the emitters is generally 20 psi. Emitters for other crops may have a lower pressure. The starting pressure will need to be higher to make up for the pressure loss in the distribution lines. If necessary, use a pressure regulator to maintain the starting pressure.
- When sizing the mainline and laterals, try to hold the pressure drop across any lateral to 10 psi or less (10 percent of desired operating pressure) when the system is operating. This will result in a more uniform emitter discharge.

(3) System design
The design steps can be found in Section 652.0603(g)(9).

- Surveying**--**Refer to the Kansas Standard for Irrigation System, MicroIrrigation (formerly Trickle) - Code 441.
- The net amount of water applied to the soil profile below the wetted areas can be calculated with the equation found in Step 1 of Section 652.0603(g)(9).

  The constant “C” = 1.604 = units conversion constant (12 in./ft./7.48 gal./cu. ft.)

(4) System design using Form KS-ENG-428(JS)
The Form KS-ENG-428(JS) can be found in the Kansas Supplement to Chapter 6 of National Engineering Handbook Part 650 - Engineering Field Handbook (EFH). A sample is shown in Figure KS6-3.

(i) Plot ground elevation shots on the profile view of the mainline, manifold, and lateral line which represents the maximum operating condition for the system. Usually this will be the longest lateral line carrying the most flow and with the most uphill elevation difference. Sometimes it may be necessary to make more than one design to determine this condition. List row number and plotting scale under the profile view. For very simple systems (50 gallons per hour [gph] or less and 300 feet or less individual lateral length) with less than 5 feet elevation difference, it may not be necessary to plot the hydraulic grade line.

(ii) Under the Hydraulic Design Data section list:

a) Total system Q in gph and gallons per minute (gpm)

b) Water pressure at the hydrant or source in pounds per square inch (psi) along with the ground elevation at this location

c) Convert psi to feet of head by multiplying psi x 2.31. Add the feet of head to the ground elevation at the source to obtain the elevation of the hydraulic grade line (H.G.L.) at this point. Enter the Q and H.G.L. on the first line of the design table.

d) Select a mainline pipe size for Reach A. The size will usually run from 3/4 to 1½ inches in diameter for most systems. Find the feet of head loss for Reach A for the Q being carried. If the head loss is in feet of head loss per 100 feet of pipe, convert to head loss for the length of pipe installed. List all of this information in the design table on the line for Reach A. Subtract the head loss in feet for this reach from the H.G.L. elevation at the source. This gives the H.G.L. elevation at the end of Reach A or at the start of Reach B.

e) Reach B is the first section of the manifold. The length will equal the row spacing if the manifold is buried or row spacing plus 5 percent (for expansion and contraction) if the manifold is installed on the ground surface. Select a pipe size (usually 3/4 inch) for the manifold. Subtract the gph going to the first row from the total Q to find the Q carried by Reach B. Find the head loss (in feet) for Reach B. Subtract the head loss in feet from the H.G.L. elevation at the end of Reach A (beginning of Reach B) and list in the table of the line for Reach B along with the pipe diameter, Q, reach length, (in feet) and feet of head loss. This will be the H.G.L. elevation at the end of Reach B or the start of Reach C.

f) Continue the above sequence for each section or reach of the manifold until the row representing the maximum condition is reached. Usually this will be the outside row, but it may be the longest row or the one with the most uphill elevation difference.

g) Select the lateral tubing size. Usually ½-inch diameter tubing is sufficient for row lengths of 500 feet or less. Determine the head loss (in feet) across the lateral for the gph to be carried. Multiply the head loss for the entire length of pipe by the reduction factor for the number of emitters on the lateral. Subtract this from the H.G.L. elevation at the beginning of the lateral that gives the elevation of the H.G.L. at the end of the line. Length of lateral for calculations includes added length for snaking.

(iii) Plot the H.G.L. for the system on the profile view using the values from the design table for the different locations along the system. Subtract the ground elevations at each location from the H.G.L., which shows the pressure head available at that point. Divide the pressure head in feet by 2.31 to obtain psi. Check all high points to make sure there is sufficient pressure available so the emitters will operate properly. Usually anything less than 10 psi would be reason enough to revise the design.

(5) Pipe friction values to use in microirrigation design

(i) Friction loss

Friction loss information supplied by the manufacturer may be used in system design if the type and sizes of tubing or pipe are known in advance.

However, generally the exact brand and type of tubing that will be installed is not known prior to system design. In this situation, the NRCS procedure for determining friction losses should be used. For the vast majority of conditions encountered in Kansas, the NRCS procedure gives friction loss values of sufficient accuracy, especially if the inside pipe or tubing diameters are known. Refer to Chapter 7 of National Engineering Handbook Section 15 (NEH-15) for a detailed explanation of the NRCS procedure. For typical design situations, the NRCS procedure may be considered to consist of four components, which are summarized below:

1) Friction loss in pipe or tubing--This is the loss in pressure or head due to friction

between flowing water and the sides of the pipe. The NRCS procedure uses a specialized form of the Darcy-Weisbach formula to calculate friction loss. For plastic pipes of 5-inch diameter or smaller, the following equation may be used:

$$J = \frac{(0.133)(Q^{1.75})}{(D^{4.75})}$$

Where: Q = gpm
D = inside diameter (inches) of pipe
J = feet of friction loss/100-foot of pipe length

This is the equation used to develop Tables KS6-21, KS6-21a, and KS6-23 for friction head loss for microirrigation tubing.

Table KS6-24, Friction Head Loss in Small Diameter PVC Pipe (SDR 21), uses the Hazen-Williams equation for PVC friction loss.

There are a couple of excel spreadsheets developed at various area offices for computing friction loss for aboveground microirrigation pipelines (dripline on ground surface) that can reduce the need for hand calculations. Check with your area engineering staff or the NRCS state engineer responsible for irrigation issues for the spreadsheets being used.

2) Head Losses through Fittings--Losses due to fittings are usually insignificant when compared to friction losses occurring in mains, manifolds, and laterals. For most designs, these losses can be neglected. Where fitting losses are significant, refer to Chapter 7 of NEH-15 for design information. Generally, the only significant loss is through the filter, but this can be ignored if the system design pressure is measured after the filter.

3) Multiple Outlet Loss Reduction Factors--Laterals with uniformly spaced outlets will experience less head loss than closed pipes due to decreasing flow along the length of the laterals. Correction factors to use with the J-equation listed above are given in Table KS6-22.

4) Emitter Connection Losses--These are friction losses that occur due to protrusion of the barbs of the emitters into the lateral tubing. The extent of the friction losses is dependent upon the size of the barb and the diameter of the tubing. For typical barbs, 6-foot emitter spacing, and 1/2 to 3/4-inch tubing, friction losses may increase by 5 to 10 percent due to emitter connections. In most windbreak applications, emitter connection losses will not be significant and may be neglected. These losses should be considered when emitter spacings are less than 5 feet, when crop production is involved (e.g., row crops and orchards), or when precision irrigation is required.

(ii) A notation should be made on the plans as to what criteria was used in the design

Sample Problem: Use NRCS design criteria. Reference sample design, Form KS-ENG-428(JS), (Figure KS6-3).

Given: 5-row windbreak - 500-foot row length; 525-foot lateral length

Emitters - Rows 1 - 85 on 6-foot spacing; Rows 2, 3, 4, and 5 - 50 each on 10-foot spacing

Total = 285 - pressure compensating; 1.0 gph flow rating, 20 psi design pressure

Mainline - L = 100 feet

Manifold - L = 100 feet, 25-foot row spacing

Q = 285 gph or 4.75 gpm

Pressure at water source = assume 30 psi

Elevation at source = 49.2 feet

Solution: Draw plan view of windbreak as shown on sample plan.

Plot ground profile as shown on sample plan.

Assume maximum condition will be at the end of Row 1 when the system is operating.

Fill in Hydraulic Design Data, Q = 285 gph, 4.75 gpm; water source pressure = 30 psi; and elevation at source = 49.2.

Multiply 30 psi x 2.31 = 69.3 feet. Add this to the ground elevation at the source (49.2) = 118.5, elevation of H.G.L. at the hydrant or source. On line 1 of the design table, list "Source" under reach, 285 gph under "Q," and 118.5 under "H.G.L."

Select ¾-inch diameter pipe (I.D. = 0.80 inch) for Reach A.
--From Table KS6-21, for I.D. of 0.80 inch, determine friction loss for Q of 285 gph = 5.87 feet per 100 feet. With only one outlet, the reduction factor from Table KS6-22 is 1.
--Total head loss is 5.87 x 1 x 1 = 5.9 feet. Subtract 5.9 feet from the elevation of the H.G.L. at the source (118.5) = <u>112.6</u> = H.G.L. elevation at the end of Reach A or the start of the manifold.
--List pipe size, Q, length, feet loss per 100 feet, reduction factor, total feet loss, and H.G.L. on line 2, Reach A of the design table.

Select ¾-inch diameter pipe (I.D. = 0.80 inch) for manifold. Reach B length: 25 feet (row spacing). Q = 285 - 50 (Q for row 5) = 235 gph being carried by Reach B.
--From Table KS6-21, for I.D. of 0.80 inch, determine friction loss for Q of 235 gph = 4.19 feet per 100 feet. With only one outlet, the reduction factor from Table KS6-22 is 1.
--Total head loss is 4.19 x 0.25 x 1 = 1.0 foot. Subtract 1.0 foot from the elevation of the H.G.L. at the start of the reach (112.6) = <u>111.6</u>, H. G. L. elevation at the end of Reach B or start of Reach C.
--List pipe size, Q, length, feet loss per 100 feet, reduction factor, total feet loss, and H.G.L. on line 3, Reach B of the design table.

Compute the friction losses for each of the remaining reaches of the manifold as follows using Tables KS6-21 and KS6-22:

<u>Reach C</u> - Q = 235 - 50 = 185 gph, loss = 2.76 x 0.25 x l = 0.7 foot, H.G.L. = 110.9

<u>Reach D</u> - Q = 185 - 50 = 135 gph, loss = 1.59 x 0.25 x l = 0.4 foot, H.G.L. = 110.5

<u>Reach E</u> - Q = 135 - 50 = 85 gph, loss = 0.71 x 0.25 x l = 0.2 foot, H.G.L. = 110.3

Compute friction loss in row 1, (Reach F) Q = 85 gph, length = 500 + (5% snaking x 500 feet) = 525 feet--use 1/2 inch diameter (I.D. = 0.58 inch) tubing.
--From Table KS6-21, for I.D. of 0.58 inch, determine friction loss for Q = 85 gph = 3.25 feet per 100 feet. With 85 outlets, the reduction factor from Table KS6-22 is 0.36.
--Total head loss is 3.25 x 5.25 x 0.36 = 6.1 feet. Subtract 6.1 feet from the elevation of the H.G.L. at the start of the row (110.3) = 104.2, H.G.L. at the end of row 1.
--List pipe size, Q, length, feet loss per 100 feet, reduction factor, total feet loss, and H.G.L. on line 7, Reach F.

Plot the H.G.L. for the system on the profile view using the elevations from the design table for the various locations along the system.

Compute pressure head at the following points along the system:

Station 1+00 (end of Reach A) = (H.G.L. - ground elevation) / 2.31 = (112.6 - 50.0) / 2.31 = 27.1 psi

Station 2+00 (end of Reach E) = (110.3 - 50.4) /2.31 = 25.9 psi

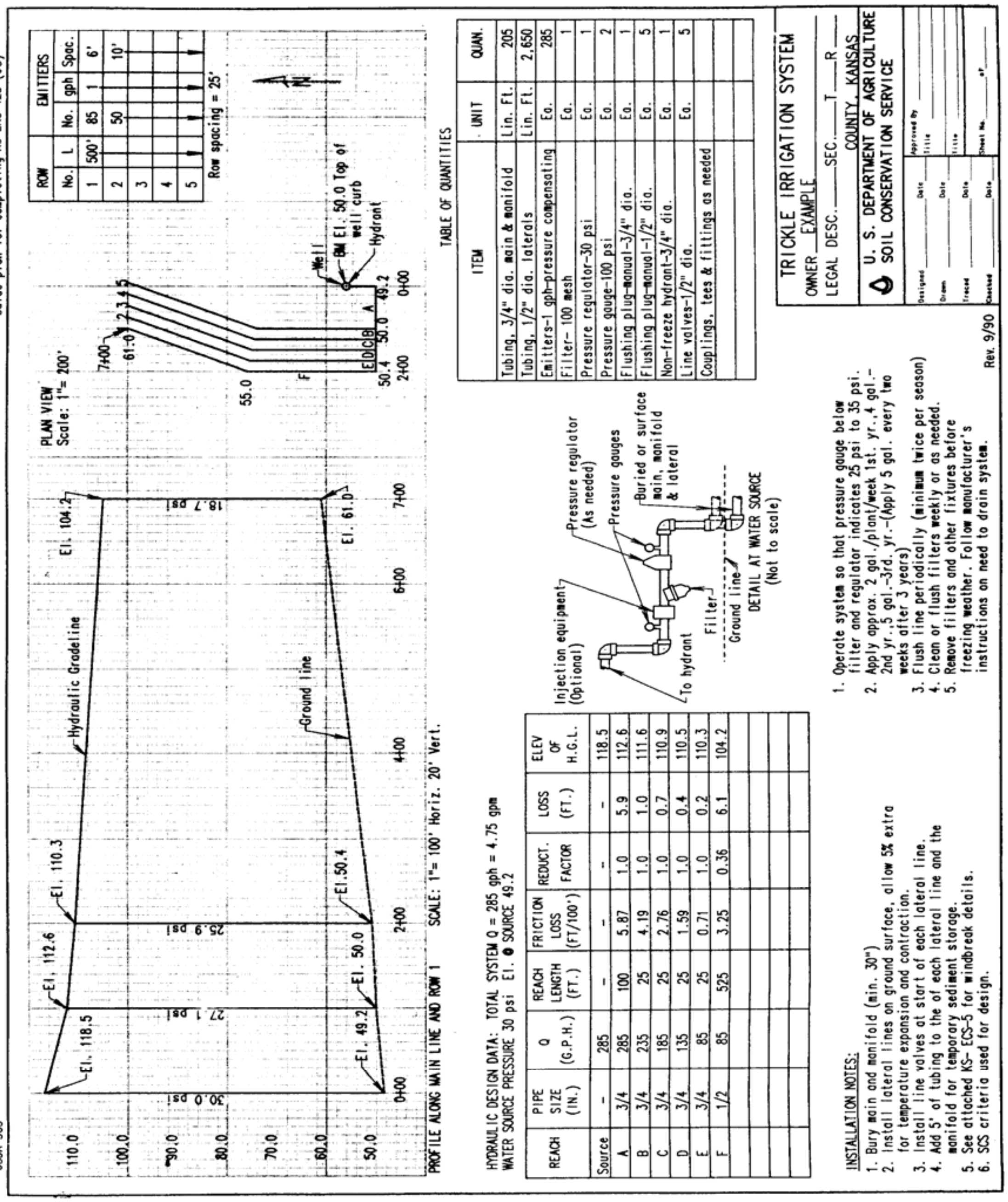
Station 7+00 (end of Reach F) = (104.2 - 61.0) / 2.31 = 18.7 psi

System Analysis

The average pressure in the lateral (Reach F) 22.3 psi. This is close to the 20-psi design pressure. The pressure is adequate to properly operate all emitters in the system.

The difference in pressure across row 1 (25.9 - 18.7 = 7.2 psi) is less than 10 psi.

Figure KS6-3 Sample of Microirrigation (Trickle) Design



ROW No.	ROW L	EMITTERS No.	EMITTERS gph	EMITTERS Spac.
1	500'	85	1	6'
2		50		10'
3				
4				
5				

REACH	PIPE SIZE (IN.)	Q (G.P.H.)	REACH LENGTH (FT.)	FRICTION LOSS (FT/100')	REDUCT. FACTOR	LOSS (FT.)	ELEV OF H.G.L.
Source	-	285	-	-	-	-	118.5
A	3/4	285	100	5.87	1.0	5.9	112.6
B	3/4	235	25	4.19	1.0	1.0	111.6
C	3/4	185	25	2.76	1.0	0.7	110.9
D	3/4	135	25	1.59	1.0	0.4	110.5
E	3/4	85	25	0.71	1.0	0.2	110.3
F	1/2	85	525	3.25	0.36	6.1	104.2

ITEM	UNIT	QUAN.
Tubing, 3/4" dia. main & manifold	Lin. Ft.	205
Tubing, 1/2" dia. laterals	Lin. Ft.	2,650
Emitters-1 gph-pressure compensating	Ea.	285
Filter- 100 mesh	Ea.	1
Pressure regulator-30 psi	Ea.	1
Pressure gauge-100 psi	Ea.	2
Flushing plug-manual-3/4" dia.	Ea.	1
Flushing plug-manual-1/2" dia.	Ea.	5
Non-freeze hydrant-3/4" dia.	Ea.	1
Line valves-1/2" dia.	Ea.	5
Couplings, tees & fittings as needed		

INSTALLATION NOTES:

1. Bury main and manifold (min. 30")
2. Install lateral lines on ground surface, allow 5% extra for temperature expansion and contraction.
3. Install line valves at start of each lateral line.
4. Add 5' of tubing to the of each lateral line and the manifold for temporary sediment storage.
5. See attached KS- ECS-5 for windbreak details.
6. SCS criteria used for design.

1. Operate system so that pressure gauge below filter and regulator indicates 25 psi to 35 psi.
2. Apply approx. 2 gal./plant/week 1st. yr.,4 gal.-2nd yr.,5 gal.-3rd. yr.-(Apply 5 gal. every two weeks after 3 years)
3. Flush line periodically (minimum twice per season)
4. Clean or flush filters weekly or as needed.
5. Remove filters and other fixtures before freezing weather. Follow manufacturer's instructions on need to drain system.

Figure KS6-4 Components of a Microirrigation System (Drip Emitter on Ground Surface)

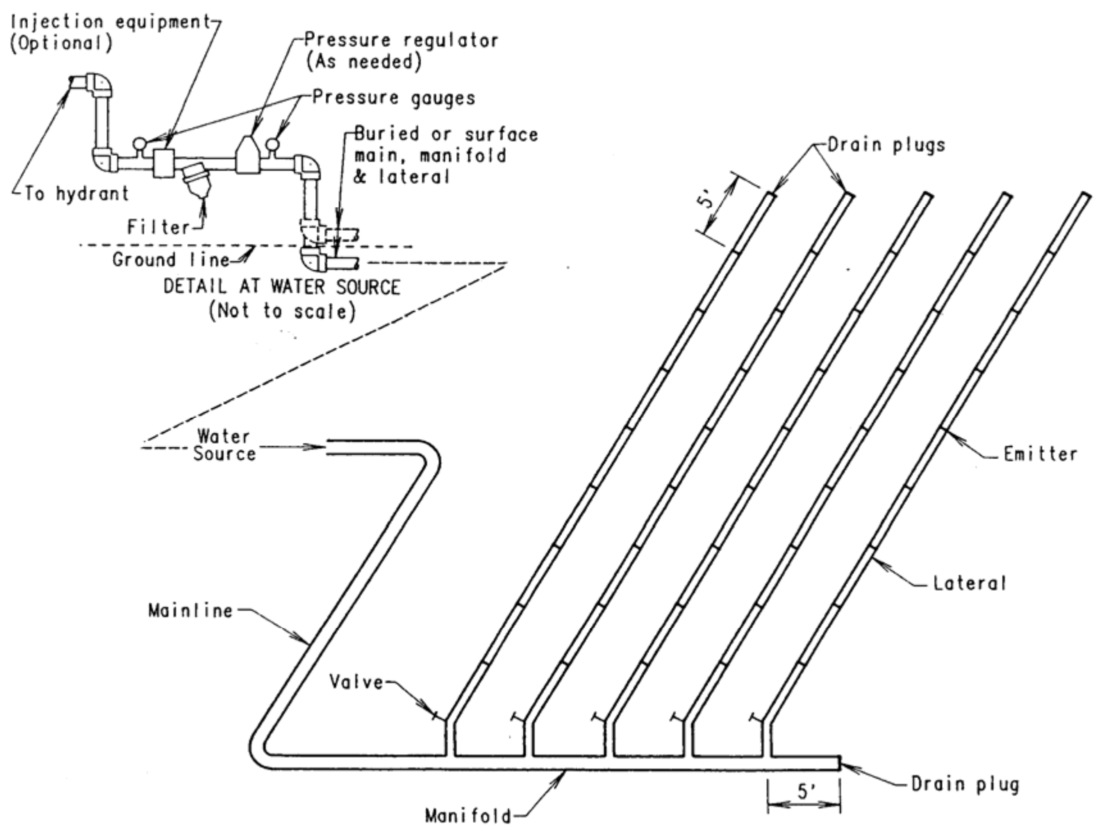


Figure KS6-5 Injection/Chemigation Safety Equipment

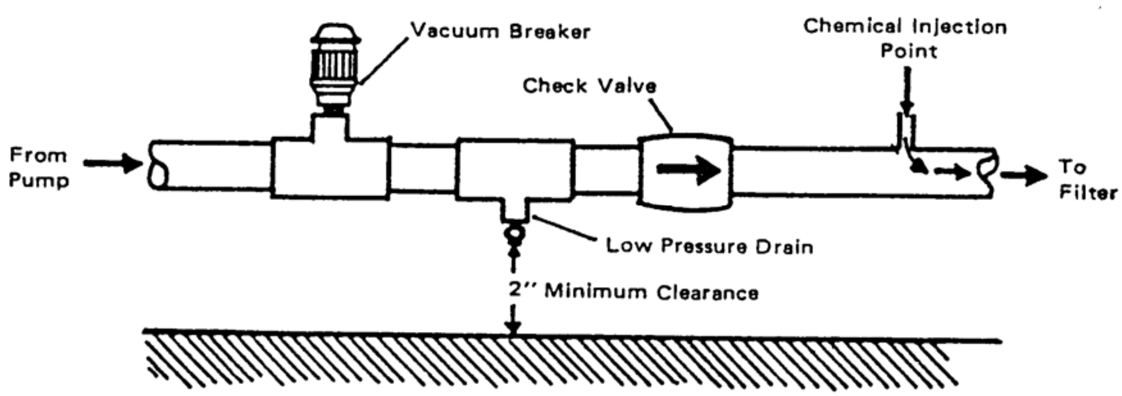


Table KS6-21 Friction Head Loss for Microirrigation Tubing
½-Inch Tubing (I.D. = 0.58”)
Feet per 100 Feet of Length

Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)
1	0.00	0.02	84	3.19	1.70	159	9.73	3.22	201	14.67	4.07
2	0.00	0.04	86	3.32	1.74	160	9.84	3.24	202	14.80	4.09
4	0.02	0.08	88	3.46	1.78	161	9.95	3.26	203	14.93	4.11
6	0.03	0.12	90	3.60	1.82	162	10.06	3.28	204	15.05	4.13
8	0.05	0.16	92	3.74	1.86	163	10.17	3.30	205	15.18	4.15
10	0.08	0.20	94	3.88	1.90	164	10.27	3.32	206	15.31	4.17
12	0.11	0.24	96	4.03	1.94	165	10.38	3.34	207	15.44	4.19
14	0.14	0.28	98	4.17	1.98	166	10.50	3.36	208	15.57	4.21
16	0.17	0.32	100	4.32	2.02	167	10.61	3.38	209	15.71	4.23
18	0.22	0.36	102	4.48	2.06	168	10.72	3.40	210	15.84	4.25
20	0.26	0.40	104	4.63	2.10	169	10.83	3.42	211	15.97	4.27
22	0.31	0.45	106	4.79	2.15	170	10.94	3.44	212	16.10	4.29
24	0.36	0.49	108	4.95	2.19	171	11.05	3.46	213	16.24	4.31
26	0.41	0.53	110	5.11	2.23	172	11.17	3.48	214	16.37	4.33
28	0.47	0.57	112	5.27	2.27	173	11.28	3.50	215	16.50	4.35
30	0.53	0.61	114	5.44	2.31	174	11.40	3.52	216	16.64	4.37
32	0.59	0.65	116	5.61	2.35	175	11.51	3.54	217	16.77	4.39
34	0.65	0.69	118	5.78	2.39	176	11.63	3.56	218	16.91	4.41
36	0.72	0.73	120	5.95	2.43	177	11.74	3.58	219	17.04	4.43
38	0.80	0.77	122	6.12	2.47	178	11.86	3.60	220	17.18	4.45
40	0.87	0.81	124	6.30	2.51	179	11.98	3.62	221	17.32	4.47
42	0.95	0.85	126	6.48	2.55	180	12.09	3.64	222	17.46	4.49
44	1.03	0.89	128	6.66	2.59	181	12.21	3.66	223	17.59	4.51
46	1.11	0.93	130	6.84	2.63	182	12.33	3.68	224	17.73	4.53
48	1.20	0.97	132	7.03	2.67	183	12.45	3.70	225	17.87	4.55
50	1.29	1.01	134	7.22	2.71	184	12.57	3.72	226	18.01	4.57
52	1.38	1.05	136	7.40	2.75	185	12.69	3.74	227	18.15	4.59
54	1.47	1.09	138	7.60	2.79	186	12.81	3.76	228	18.29	4.61
56	1.57	1.13	140	7.79	2.83	187	12.93	3.78	229	18.43	4.63
58	1.67	1.17	142	7.99	2.87	188	13.05	3.81	230	18.57	4.66
60	1.77	1.21	144	8.18	2.91	189	13.17	3.83	231	18.71	4.68
62	1.87	1.25	146	8.38	2.96	190	13.29	3.85	232	18.85	4.70
64	1.98	1.30	148	8.59	3.00	191	13.42	3.87	233	19.00	4.72
66	2.09	1.34	150	8.79	3.04	192	13.54	3.89	234	19.14	4.74
68	2.20	1.38	151	8.89	3.06	193	13.66	3.91	235	19.28	4.76
70	2.32	1.42	152	9.00	3.08	194	13.79	3.93	236	19.43	4.78
72	2.43	1.46	153	9.10	3.10	195	13.91	3.95	237	19.57	4.80
74	2.55	1.50	154	9.20	3.12	196	14.04	3.97	238	19.72	4.82
76	2.67	1.54	155	9.31	3.14	197	14.16	3.99	239	19.86	4.84
78	2.80	1.58	156	9.41	3.16	198	14.29	4.01	240	20.01	4.86
80	2.93	1.62	157	9.52	3.18	199	14.41	4.03	241	20.15	4.88
82	3.05	1.66	158	9.63	3.20	200	14.54	4.05	242	20.30	4.90

Based on the equation $J = (0.133 \times Q^{1.75})/D^{4.75}$

Where: J = Head Loss in ft./100 ft. of line
Q = Flow in gpm
D = Inside Diameter (I.D.) in inches

Table KS6-21a Friction Head Loss for Microirrigation Tubing
¾-Inch Tubing (I.D. = 0.80”)
Feet per 100 Feet of Length

Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)	Q (GPH)	J	Vel. (fps)
2	0.00	0.02	82	0.66	0.87	162	2.18	1.72	242	4.41	2.57	322	7.26	3.43	402	10.71	4.28
4	0.00	0.04	84	0.69	0.89	164	2.23	1.74	244	4.47	2.60	324	7.34	3.45	404	10.80	4.30
6	0.01	0.06	86	0.72	0.91	166	2.28	1.77	246	4.53	2.62	326	7.42	3.47	406	10.90	4.32
8	0.01	0.09	88	0.75	0.94	168	2.33	1.79	248	4.60	2.64	328	7.50	3.49	408	10.99	4.34
10	0.02	0.11	90	0.78	0.96	170	2.38	1.81	250	4.66	2.66	330	7.58	3.51	410	11.09	4.36
12	0.02	0.13	92	0.81	0.98	172	2.42	1.83	252	4.73	2.68	332	7.66	3.53	412	11.18	4.38
14	0.03	0.15	94	0.84	1.00	174	2.47	1.85	254	4.80	2.70	334	7.74	3.55	414	11.28	4.40
16	0.04	0.17	96	0.87	1.02	176	2.52	1.87	256	4.86	2.72	336	7.83	3.57	416	11.37	4.43
18	0.05	0.19	98	0.91	1.04	178	2.57	1.89	258	4.93	2.74	338	7.91	3.60	418	11.47	4.45
20	0.06	0.21	100	0.94	1.06	180	2.63	1.91	260	5.00	2.77	340	7.99	3.62	420	11.56	4.47
22	0.07	0.23	102	0.97	1.09	182	2.68	1.94	262	5.06	2.79	342	8.07	3.64	422	11.66	4.49
24	0.08	0.26	104	1.01	1.11	184	2.73	1.96	264	5.13	2.81	344	8.15	3.66	424	11.76	4.51
26	0.09	0.28	106	1.04	1.13	186	2.78	1.98	266	5.20	2.83	346	8.24	3.68	426	11.85	4.53
28	0.10	0.30	108	1.07	1.15	188	2.83	2.00	268	5.27	2.85	348	8.32	3.70	428	11.95	4.55
30	0.11	0.32	110	1.11	1.17	190	2.89	2.02	270	5.34	2.87	350	8.40	3.72	430	12.05	4.57
32	0.13	0.34	112	1.14	1.19	192	2.94	2.04	272	5.41	2.89	352	8.49	3.74	432	12.15	4.60
34	0.14	0.36	114	1.18	1.21	194	2.99	2.06	274	5.48	2.91	354	8.57	3.77	434	12.25	4.62
36	0.16	0.38	116	1.22	1.23	196	3.05	2.09	276	5.55	2.94	356	8.66	3.79	436	12.35	4.64
38	0.17	0.40	118	1.25	1.26	198	3.10	2.11	278	5.62	2.96	358	8.74	3.81	438	12.44	4.66
40	0.19	0.43	120	1.29	1.28	200	3.16	2.13	280	5.69	2.98	360	8.83	3.83	440	12.54	4.68
42	0.21	0.45	122	1.33	1.30	202	3.21	2.15	282	5.76	3.00	362	8.92	3.85	442	12.64	4.70
44	0.22	0.47	124	1.37	1.32	204	3.27	2.17	284	5.83	3.02	364	9.00	3.87	444	12.74	4.72
46	0.24	0.49	126	1.41	1.34	206	3.32	2.19	286	5.90	3.04	366	9.09	3.89	446	12.85	4.74
48	0.26	0.51	128	1.45	1.36	208	3.38	2.21	288	5.98	3.06	368	9.18	3.92	448	12.95	4.77
50	0.28	0.53	130	1.49	1.38	210	3.44	2.23	290	6.05	3.09	370	9.26	3.94	450	13.05	4.79
52	0.30	0.55	132	1.53	1.40	212	3.50	2.26	292	6.12	3.11	372	9.35	3.96	452	13.15	4.81
54	0.32	0.57	134	1.57	1.43	214	3.55	2.28	294	6.19	3.13	374	9.44	3.98	454	13.25	4.83
56	0.34	0.60	136	1.61	1.45	216	3.61	2.30	296	6.27	3.15	376	9.53	4.00	456	13.35	4.85
58	0.36	0.62	138	1.65	1.47	218	3.67	2.32	298	6.34	3.17	378	9.62	4.02	458	13.46	4.87
60	0.38	0.64	140	1.69	1.49	220	3.73	2.34	300	6.42	3.19	380	9.71	4.04	460	13.56	4.89
62	0.41	0.66	142	1.73	1.51	222	3.79	2.36	302	6.49	3.21	382	9.80	4.06	462	13.66	4.92
64	0.43	0.68	144	1.78	1.53	224	3.85	2.38	304	6.57	3.23	384	9.89	4.09	464	13.77	4.94
66	0.45	0.70	146	1.82	1.55	226	3.91	2.40	306	6.64	3.26	386	9.98	4.11	466	13.87	4.96
68	0.48	0.72	148	1.86	1.57	228	3.97	2.43	308	6.72	3.28	388	10.07	4.13	468	13.97	4.98
70	0.50	0.74	150	1.91	1.60	230	4.03	2.45	310	6.80	3.30	390	10.16	4.15	470	14.08	5.00
72	0.53	0.77	152	1.95	1.62	232	4.09	2.47	312	6.87	3.32	392	10.25	4.17			
74	0.55	0.79	154	2.00	1.64	234	4.15	2.49	314	6.95	3.34	394	10.34	4.19			
76	0.58	0.81	156	2.04	1.66	236	4.22	2.51	316	7.03	3.36	396	10.43	4.21			
78	0.61	0.83	158	2.09	1.68	238	4.28	2.53	318	7.11	3.38	398	10.52	4.23			
80	0.64	0.85	160	2.14	1.70	240	4.34	2.55	320	7.18	3.40	400	10.62	4.26			

Based on the equation $J = (0.133 \times Q^{1.75})/D^{4.75}$

Where: J = Head Loss in ft./100 ft. of line
Q = Flow in gpm
D = Inside Diameter (I.D.) in inches

Table KS6-22 Multiple Outlet Friction Loss Reduction Factors

F = Reduction Factor
N = Number of Outlets (emitters)

The reduction factors are to be used with the NRCS "J" equation to calculate friction losses.

NO. OF OUTLETS N	REDUCTION FACTOR F		NO. OF OUTLETS N	REDUCTION FACTOR F
1	1.00		9	0.42
2	0.65		10 - 11	0.41
3	0.55		12 - 15	0.40
4	0.50		16 - 20	0.39
5	0.47		21 - 30	0.38
6	0.45		31 - 70	0.37
7	0.44		>70	0.36
8	0.43			

Use of Table KS6-23, Friction Head Loss in Smooth Plastic Pipelines--Table KS6-23 may be used to calculate friction loss in mainlines that connect the water source to the manifold. It should be used for smooth inside-diameter pipelines typically made of PVC or PE plastic. This table is derived from the NRCS "J" equation and is for SDR 21 pipe. For pipes other than SDR 21, select the appropriate correction factor listed in the table below and multiply it by the friction loss from Table KS6-23.

SDR Number	Correction Factor
13.5	1.33
17	1.13
21	1.00
26	0.91
32.5	0.84
41	0.79
51	0.75

Table KS6-23 Friction Head Loss in Smooth Plastic Pipelines
SDR 21 - IPS Pipe
Feet per 100 Feet of Length

FLOW	PIPE DIAMETER *(INCHES)*				FLOW	PIPE DIAMETER *(INCHES)*				FLOW	PIPE DIAMETER *(INCHES)*			
Q	1	1.25	1.5	2	Q	1	1.25	1.5	2	Q	1	1.25	1.5	2
(GPM)	*(1.189 ID)*	*(1.502 ID)*	*(1.720 ID)*	*(2.149 ID)*	(GPM)	*(1.189 ID)*	*(1.502 ID)*	*(1.720 ID)*	*(2.149 ID)*	(GPM)	*(1.189 ID)*	*(1.502 ID)*	*(1.720 ID)*	*(2.149 ID)*
0.0	0.00	0.00	0.00	0.00	7.0					14.0				
0.2	0.00	0.00	0.00	0.00	7.2	1.85	0.61	0.32	0.11	14.2	6.07	2.00	1.05	0.36
0.4	0.01	0.00	0.00	0.00	7.4	1.94	0.64	0.34	0.12	14.4	6.22	2.05	1.08	0.37
0.6	0.02	0.01	0.00	0.00	7.6	2.03	0.67	0.35	0.12	14.6	6.37	2.10	1.10	0.38
0.8	0.04	0.01	0.01	0.00	7.8	2.13	0.70	0.37	0.13	14.8	6.53	2.15	1.13	0.39
1.0	0.06	0.02	0.01	0.00	8.0	2.22	0.73	0.39	0.13	15.0	6.68	2.20	1.16	0.40
1.2	0.08	0.03	0.01	0.00	8.2	2.32	0.77	0.40	0.14	15.2	6.84	2.25	1.18	0.41
1.4	0.11	0.03	0.02	0.01	8.4	2.42	0.80	0.42	0.15	15.4	7.00	2.31	1.21	0.42
1.6	0.13	0.04	0.02	0.01	8.6	2.52	0.83	0.44	0.15	15.6	7.16	2.36	1.24	0.43
1.8	0.16	0.05	0.03	0.01	8.8	2.63	0.87	0.45	0.16	15.8	7.32	2.41	1.27	0.44
2.0	0.20	0.06	0.03	0.01	9.0	2.73	0.90	0.47	0.16	16.0	7.48	2.47	1.30	0.45
2.2	0.23	0.08	0.04	0.01	9.2	2.84	0.94	0.49	0.17	16.2	7.65	2.52	1.32	0.46
2.4	0.27	0.09	0.05	0.02	9.4	2.95	0.97	0.51	0.18	16.4	7.81	2.57	1.35	0.47
2.6	0.31	0.10	0.05	0.02	9.6	3.06	1.01	0.53	0.18	16.6	7.98	2.63	1.38	0.48
2.8	0.35	0.12	0.06	0.02	9.8	3.17	1.05	0.55	0.19	16.8	8.15	2.69	1.41	0.49
3.0	0.40	0.13	0.07	0.02	10.0	3.29	1.08	0.57	0.20	17.0	8.32	2.74	1.44	0.50
3.2	0.45	0.15	0.08	0.03	10.2	3.40	1.12	0.59	0.20	17.2	8.49	2.80	1.47	0.51
3.4	0.50	0.16	0.09	0.03	10.4	3.52	1.16	0.61	0.21	17.4	8.66	2.86	1.50	0.52
3.6	0.55	0.18	0.10	0.03	10.6	3.64	1.20	0.63	0.22	17.6	8.84	2.91	1.53	0.53
3.8	0.60	0.20	0.10	0.04	10.8	3.76	1.24	0.65	0.23	17.8	9.02	2.97	1.56	0.54
4.0	0.66	0.22	0.11	0.04	11.0	3.88	1.28	0.67	0.23	18.0	9.19	3.03	1.59	0.55
4.2	0.72	0.24	0.12	0.04	11.2	4.01	1.32	0.69	0.24	18.2	9.37	3.09	1.62	0.56
4.4	0.78	0.26	0.14	0.05	11.4	4.13	1.36	0.72	0.25	18.4	9.55	3.15	1.65	0.57
4.6	0.84	0.28	0.15	0.05	11.6	4.26	1.40	0.74	0.26	18.6	9.74	3.21	1.69	0.59
4.8	0.91	0.30	0.16	0.05	11.8	4.39	1.45	0.76	0.26	18.8	9.92	3.27	1.72	0.60
5.0	0.98	0.32	0.17	0.06	12.0	4.52	1.49	0.78	0.27	19.0	10.11	3.33	1.75	0.61
5.2	1.05	0.34	0.18	0.06	12.2	4.65	1.53	0.81	0.28	19.2	10.29	3.39	1.78	0.62
5.4	1.12	0.37	0.19	0.07	12.4	4.79	1.58	0.83	0.29	19.4	10.48	3.45	1.81	0.63
5.6	1.19	0.39	0.21	0.07	12.6	4.92	1.62	0.85	0.30	19.6	10.67	3.52	1.85	0.64
5.8	1.27	0.42	0.22	0.08	12.8	5.06	1.67	0.88	0.30	19.8	10.86	3.58	1.88	0.65
6.0	1.34	0.44	0.23	0.08	13.0	5.20	1.71	0.90	0.31	20.0	11.05	3.64	1.91	0.66
6.2	1.42	0.47	0.25	0.09	13.2	5.34	1.76	0.92	0.32	20.2	11.25	3.71	1.95	0.68
6.4	1.51	0.50	0.26	0.09	13.4	5.48	1.81	0.95	0.33	20.4	11.44	3.77	1.98	0.69
6.6	1.59	0.52	0.27	0.10	13.6	5.63	1.86	0.97	0.34	20.6	11.64	3.84	2.02	0.70
6.8	1.67	0.55	0.29	0.10	13.8	5.77	1.90	1.00	0.35	20.8	11.84	3.90	2.05	0.71
7.0	1.76	0.58	0.30	0.11	14.0	5.92	1.95	1.03	0.36	21.0	12.04	3.97	2.08	0.72

Based on the equation $J = (0.133 \times Q^{1.75}) / D^{4.75}$

Where: J = Head Loss in ft./100 ft. of line
Q = Flow in GPM
D = Inside Diameter (I.D.) in inches

Table KS6-24 Friction Head Loss in Small Diameter PVC Pipe (SDR 21)
Feet per 100 Feet of Length

3/4" Dia.

Q (GPM)	0.930" (ID)
1.0	0.14
1.2	0.19
1.4	0.26
1.6	0.33
1.8	0.41
2.0	0.50
2.2	0.60
2.4	0.70
2.6	0.82
2.8	0.94
3.0	1.06
3.2	1.20
3.4	1.34
3.6	1.49
3.8	1.65
4.0	1.81
4.2	1.98
4.4	2.16
4.6	2.35
4.8	2.54
5.0	2.74
5.2	2.94
5.4	3.16
5.6	3.38
5.8	3.60
6.0	3.84
6.2	4.08
6.4	4.33
6.6	4.58
6.8	4.84
7.0	5.11
7.2	5.38
7.4	5.66
7.6	5.95
7.8	6.24
8.0	6.54

1" Dia.

Q (GPM)	1.189" (ID)
2.0	0.15
2.2	0.18
2.4	0.21
2.6	0.25
2.8	0.28
3.0	0.32
3.2	0.36
3.4	0.41
3.6	0.45
3.8	0.50
4.0	0.55
4.2	0.60
4.4	0.65
4.6	0.71
4.8	0.77
5.0	0.83
5.2	0.89
5.4	0.95
5.6	1.02
5.8	1.09
6.0	1.16
6.2	1.23
6.4	1.31
6.6	1.38
6.8	1.46
7.0	1.54
7.2	1.63
7.4	1.71
7.6	1.80
7.8	1.89
8.0	1.98
8.2	2.07
8.4	2.16
8.6	5.95
8.8	6.24
9.0	6.54

1 1/4" Dia.

Q (GPM)	1.502" (ID)
3.8	0.16
4.1	0.18
4.4	0.21
4.7	0.24
5.0	0.27
5.3	0.30
5.6	0.33
5.9	0.36
6.2	0.39
6.5	0.43
6.8	0.47
7.1	0.51
7.4	0.55
7.7	0.59
8.0	0.63
8.3	0.68
8.6	0.72
8.9	0.77
9.2	0.82
9.5	0.87
9.8	0.92
10.1	0.97
10.4	1.03
10.7	1.08
11.0	1.14
11.3	1.20
11.6	1.26
11.9	1.32
12.2	1.38
12.5	1.45
12.8	1.51
13.1	1.58
13.4	1.65
13.7	1.71
14.0	1.78
14.3	1.86

1 1/2" Dia.

Q (GPM)	1.72 (ID)
6.0	0.19
6.4	0.22
6.8	0.24
7.2	0.27
7.6	0.30
8.0	0.33
8.4	0.36
8.8	0.39
9.2	0.42
9.6	0.46
10.0	0.49
10.4	0.53
10.8	0.57
11.2	0.61
11.6	0.65
12.0	0.69
12.4	0.74
12.8	0.78
13.2	0.83
13.6	0.87
14.0	0.92
14.4	0.97
14.8	1.02
15.2	1.07
15.6	1.13
16.0	1.18
16.4	1.24
16.8	1.29
17.2	1.35
17.6	1.41
18.0	1.47
18.4	1.53
18.8	1.59
19.2	1.66
19.6	1.72
20.0	1.79

Friction Loss computed using Hazen-Williams equation with C = 150 and SDR 21 pipe

$$H_l = \{[12.0228 \times Q] / [(42.2298 \times (D^{2.63})]\}^{1.8519}$$

Where: Q is the flow in gpm
D is the inside pipe diameter in inches

(6) Subsurface Drip Irrigation (SDI)

(i) General--This section provides direction for the design of SDI systems. Much of the following information comes directly from professional papers provided from references written by Kansas State University (KSU) Research and Extension engineers. KSU continues to develop appropriate methodology for successful utilization of SDI technology in the U.S. Central Great Plains. Information pertaining to this technology is available at the KSU SDI Web site: http://www.oznet.ksu.edu/sdi/

Sections 652.0603 and 652.0604 provide some general assistance with drip (trickle) and subsurface drip irrigation design and can serve to supplement the information in this paper. Irrigation and nutrient amounts must be managed together to prevent leaching. The SDI system must also be properly designed to ensure system longevity.

(ii) Crops and soils consideration--The crop and soil type will dictate SDI system capacity, dripline spacing, emitter spacing, and installation depth. The SDI system capacity must be able to satisfy the peak water requirement of the crop through the combination of the applied irrigation amount, precipitation, and stored soil water. If sufficient water supply is available, the field size, shape, and topography, along with the dripline hydraulic characteristics, will dictate the number of zones.

Wide spacing will not uniformly supply crop water needs and will likely result in excess deep percolation for many soil types. Studies on silt loam soils in western Kansas conducted by KSU have indicated that 60-inch dripline spacing is optimal for a cornrow spacing of 30 inches. Though a slightly wider spacing may work for 36-inch cornrow spacing, this might limit successful use of the system for crops grown in a narrow row pattern or a corn and wheat or other crop rotation. As a rule of thumb, dripline spacing is related to crop row spacing while emitter spacing is more closely related to crop plant spacing. To achieve water conservation and water quality protection, careful attention should be given to dripline spacing and emitter spacing.

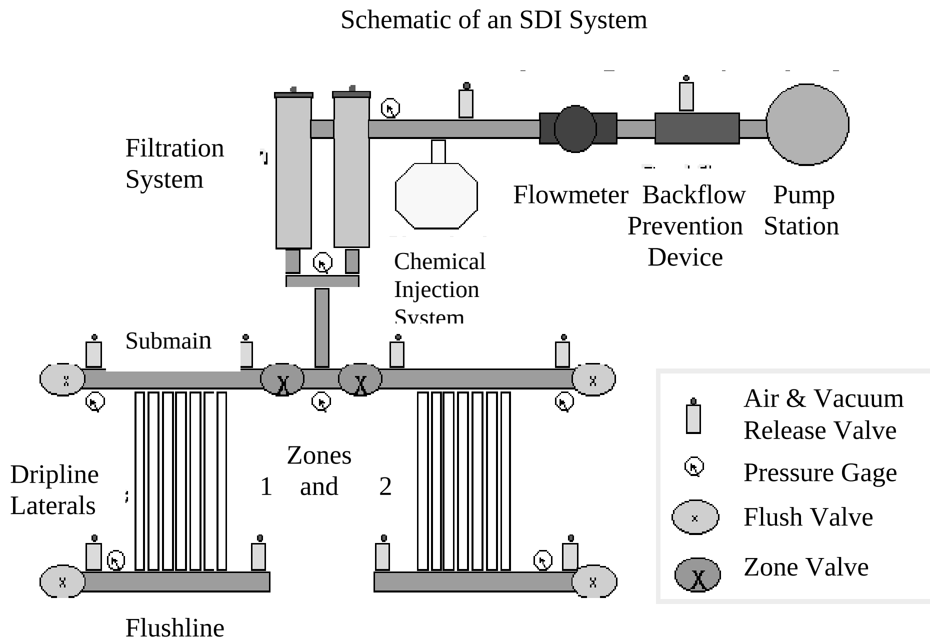
Deep installations reduce the potential for soil evaporation and also allow for a wider range of tillage practices. There may also be some reduced potential for chemical, biological, and root plugging of the emitters for the deeper installations. Acceptable results have been obtained with depths of 16 to 18 inches in KSU studies in western Kansas on deep silt loam soils. Some producers in the Central Great Plains region are opting for installations in the 12 to 14 inch depth range to give more flexibility in germination. Dripline should probably be installed above any restrictive clay layers that might exist in the soil.

The orientation of driplines with respect to crop rows has not been a critical issue with SDI systems used for corn production on the deep silt loam soils. KSU research has shown either parallel or perpendicular orientations are acceptable.

(iii) Hydraulic design--Water distribution problems may be difficult or impossible to correct for an improperly designed SDI system (Lamm, Rogers, and Spurgeon. 1998). A schematic of a typical SDI system showing the necessary components is shown in Figure KS6-7. The actual requirements in equipment, their sizes, and their location are dependant on the actual design; but elements of all these components should be present in all systems.

Successful operation of an SDI system begins with a proper hydraulic design. The design needs to satisfy constraints dictated by crop, soil type and characteristics, field size, shape, topography, water source, and supply. Disregarding design constraints will likely result in a system that is costly in both time and money to operate and will likely increase the chance of system failure.

Figure KS6-7 Component Requirements of a Subsurface Drip Irrigation (SDI) System



(Courtesy of F. R. Lamm, D. H. Rogers, and W. E. Spurgeon. 1998. Design and management considerations for subsurface drip irrigation systems.)

System failure might result in the loss of the total capital investment (Lamm, Rogers, and Spurgeon. 1998).

a) Dripline--Whenever possible, dripline laterals should be installed downslope on slopes of less than 2 percent. On steeper terrain, the driplines should be made along the field contour, and/or techniques for pressure control should be employed.

Drip tubing comes in various inside diameters (ID) and wall thicknesses. Depending on the manufacturer, the tubing may be available in ½-inch, $^5/_8$-inch, $^7/_8$-inch, 1-inch, and 1$^3/_8$-inch ID. The larger the diameter, the longer the fill and drain time.

b) Emitters--Many lay-flat drip tape products have an emitter exponent of approximately 0.5. A 20 percent change in pressure along the dripline would result in a 10 percent change in flowrate if the exponent were 0.5.

As a rule of thumb, flowrates should not change more than 10 percent along the dripline in a properly designed system. The overall effect on uniformity is specific to the field slope, length of run, dripline capacity, and diameter.

Uniformity criteria established by ASAE Engineering Practice EP-405.

Flow variation < 10%

Emission Uniformity (Eu) > 80%

The coefficient of manufacturing variation, Cv, is a statistical term used to describe this variation. Some dripline products are inherently difficult to manufacture with consistency and, therefore, may have a high Cv. Other products may suffer from poor quality control. The American Society of Agricultural Engineers (ASAE) has established Cv ranges for line-source driplines. A Cv of less than 10 percent is considered good.

Very small emitters in SDI systems may be prone to clogging by the various constituents of the wastewater (0.15 and 0.24 gal/hr/emitter in a Gray County, Kansas, study experienced plugging). Higher-flow emitter sizes (0.4, 0.6, and 0.92 gal/hr/emitter) showed little sign of clogging in the ongoing field test in Gray County, Kansas (Trooien et al. 1999). However, small emitters have been successfully used without problems for fresh water sources.

The absence of emitter clogging indicates that emitters of these sizes may be adequate for use with lagoon wastewater. For the silt loam soils in western Kansas, 24-inch emitter spacing appears to work satisfactorily for corn, wheat, and alfalfa. Using the lowest practical emitter flow rate minimizes costs. Decreasing the length of run or the zone area increases the cost of both installation and operation.

For the installation of drip tubing, the outlets should always face upward. This reduces potential for clogging by allowing any fine sand, silt, clay, or other inorganic particles to settle in the pipe below and away from the outlets. Additionally, with the outlets at the top of the tubing provides better uniformity for time of application throughout the line and zone.

c) Filtration, flushing, and water treatment plugging of the dripline emitters is the major cause of system failure. Plugging can be caused by physical, chemical, or biological materials. <u>The filtration system is one of the most important components of the SDI system</u>. Improper filter selection can result in an SDI system that is difficult to maintain and a system prone to failure.

Screen or sand media filters are used to remove the suspended solids such as silt, sand, and organic and inorganic debris. Refer to 652.0603(f)(3) and KS652.0605(d)(1)(v) for additional information on media filters. Surface water often requires more extensive filtration than ground water, but filtration is required for all systems. Wastewater use will require filtration with disk or sand media filters. Screen filters will probably not be adequate. In the Ingalls, Kansas, installation, an automated spin-disk filter was selected. It is programmed to backflush whenever the pressure drop across the filter reaches a programmed threshold (7 psi change across the filter system), or on a minimum time interval, whichever happens first. Backflush water is discharged back into the lagoon (Trooien et al. 1999).

Chemical reactions in the water can cause precipitates, such as iron or calcium deposits to form inside the driplines. Plugging can be caused by either natural water conditions or by chemicals such as fertilizer added to the water.

To avoid chemical clogging, the water must be analyzed to determine what chemicals are prevalent and which chemical additives should be avoided. Injection of chlorine into the driplines on a periodic basis is required to stop the biological activity. *A thorough chemical analysis of the water source should be made prior to development of the SDI system*.

A flushing system is recommended at the distal end of the dripline laterals (Figure K6-7) to assist in removing sediment and other materials that may accumulate in the dripline during the season. This is in addition to a proper filtration system. A useful way to provide for flushing is to connect all the distal ends of the driplines in a zone to a common submain or header that is called the flushline. This allows the flushing to be accomplished at one point. Two distinct advantages that exist for having a flushing line system are:

--If a dripline becomes plugged or partially plugged, water can be provided below the plug by the interconnected flushline.

--If a dripline break occurs, positive water pressure on both sides of the break will limit sediment intrusion into the line. Generally, a minimum flow velocity of 1 to 2 feet/second is considered adequate for flushing dripline laterals (Lamm et al. 1997). This flow velocity will require careful sizing of the mains, submains, flushline mains, and valving.

Pressure gages should be installed on riser pipes at each of the four corners of the closed-loop zone. Recorded pressures from these gages and flow rates from the system flowmeter can be compared from one event to the next to help reveal system performance problems. Check valves, air vents, and vacuum breakers may be required at various points in the system to prevent back siphoning of chemically treated water into the water supply and also to prevent ingestion of soil into the driplines at system shutdown.

d) Installation--The installation of SDI systems warrants comment. The six-page paper Installation Issues for SDI Systems, by Lamm et al. 1997, available at the KSU SDI Web site http://www.oznet.ksu.edu/sdi/, provides a concise explanation of items that need to be addressed before and during the installation of a subsurface dripline.

NRCS state standards and specifications series 430 (for the various types of underground pipeline) should cover the installation of the mainline and submains. One needs to make sure that the dripline and dripline connectors are compatible.

5) Management--Improper management of an SDI system can result in system failure, which might mean the loss of the total capital investment.

The performance of the SDI system components can be evaluated by monitoring the flowrate and pressures in each zone. Pressure gages should be installed on riser pipes from the submain and flushline at each of the four corners of the zone. Disregarding day-to-day management can result in problems such as poor water distribution, low crop yields, and even system failure. Irrigation scheduling must be employed as some of the visual indicators of overirrigation (such as runoff) no longer exist with this type of irrigation. Overirrigation can dramatically increase deep percolation, which can increase ground water contamination.

The irrigation frequency is important. When salts in the root zone are a problem, a rain that does not saturate essentially the entire root zone will permit salts to move upward into the root zone if the normal irrigation schedule is not maintained. Frequent wetting of the soil every 2 or 3 days for 2 to 4 hours (rather than 8-hour sets) is more effective in maintaining lateral and upward capillary movement of the water. Longer water applications tend to allow gravity to draw water downward below the root zone.

(iv) Dripline hydraulic characteristics--Pressure losses occur when water flows through a pipe due to friction. These friction losses are related to the velocity of water in the pipe, the pipe inside diameter and roughness, and the overall length. The Hazen-Williams friction coefficient used for the tubing is C=130 or 140 (depending on the manufacturer).

The drip tubing manufacturers are using computer programs to calculate the friction loss (pressure drop) per 100 feet along the drip tubing for their designs. The programs are using the Darcy-Weisbach equation for computing friction loss. The equation is based on a Reynolds number for pipe roughness. (This number ranges between 2,000 and 100,000, according to a manufacturer's representative from Roberts Irrigation.) The final equation is head loss $h_L = (k) \times (Q^x)$; with k = 0.5256, x = 1.75, and Q in gal/min (gpm). The equation then becomes:

$$\text{Head loss } h_L \text{ (psi/100 ft.)} = (0.52567) \times (Q^{1.75})$$

Using this value and the ID, the pressure loss can be calculated in the same manner that PVC and PE headloss is figured for mainline, submains, etc.

The emitter flow rate (Q) can generally be characterized by a simple power equation:

$$Q = k\ H^x$$

Where: k is a constant depending upon the units of Q and H
H is the pressure
x is the emitter exponent

The value of x is typically between 0 and 1, although values outside the range are possible. For an ideal product, x equals 0, meaning that the flowrate of the emitter is independent of the pressure. This would allow for high uniformity on very long driplines, which would minimize cost. An emission product with an x of 0 is said to be fully pressure compensating. An x value of 1 is noncompensating, meaning any percentage change in pressure results in an equal percentage change in flowrate. Many lay-flat drip tape products have an emitter exponent of approximately 0.5. A 20 percent change in pressure along the dripline would result in a 10 percent change in flowrate if the exponent were 0.5. As a rule of thumb, flowrates should not change more than 10 percent along the dripline in a properly designed system. Most manufacturers can provide the emitter exponent for their product. (Lamm et al, 1998).

(v) Dripline hydraulic designs--In the majority of states where SDI is being installed at this time, the actual designs are drawn up by the drip tubing manufacturers (or dealers) who use the computer programs for pipe design that the manufacturers supply them. A copy of the design hydraulics, including friction loss in the individual line, can be made available. It is also possible to obtain a copy of the hydraulics computer programs from some of the manufacturers. For this reason, there is no section with an example hydraulic design in this document. For a copy of the steps and an example, refer to KS652.0605(d)(vi) where there are design procedures for a regular SDI system.

There is an excel spreadsheet that has been developed at one of the area offices for computing friction loss for SDI systems. The area office staff also has access to a couple of manufacturers' design programs, but they are specific to the particular manufacturer's drip tap products.

(vi) SDI design example--Figure KS6-8 is a form that can be used for the general design of an SDI system and was taken from the example at the NRCS 2001 Netafim SDI training sessions.

Given:

Emitter flow rate	=	0.16 gph
Pump flow rate	=	900 gpm
Emitter spacing	=	2.0 feet (24 inches)
Dripline spacing	=	5.0 feet
Lateral length	=	2580 feet
Field width	=	2580 feet

Using the information given above, the following steps correspond to those given on Figure KS6-8:

1) To determine the area irrigated by the SDI system, multiply the lateral length in feet (average lateral length by the field width, also measured in feet. If the shape is irregular, then it will need to be calculated in segments and added together.

$$\frac{2580\text{ ft.} \times 2580\text{ ft.}}{43560\text{ ft}^2/\text{ac.}} = 152.8\text{ ac.}$$

2) The number of driplines for the field is obtained by dividing the field width (measured in feet) by the dripline (lateral) spacing (feet distance).

$$\frac{2580\text{ ft.}}{5.0\text{ ft.}} = 516\text{ driplines (laterals)}$$

3) The number of emitters per lateral is determined by dividing the lateral length

(feet length) by the emitter spacing (distance between emitters measured in feet).

$$\frac{2580 \text{ ft.}}{2.0 \text{ ft.}} = 1290 \text{ emitters/lateral}$$

4) The flow rate per lateral can be obtained by multiplying the number of emitters in the lateral by the emitter flow rate (gph) and dividing the resultant product by 60 minutes per hour.

$$\frac{1290 \text{ emitters x } 0.16 \text{ gph/emitter}}{60 \text{ min./hr.}} = 3.44 \text{ gpm/lateral}$$

5) Total flow for system is calculated by taking the number of laterals [found in Item 2)] and multiplying it by the flow rate per lateral--computed in Item 4).

516 laterals x 3.44 gpm per lateral = 1775 gpm

6) If the maximum pump flow rate is less than the total flow needed to irrigate all the laterals at one time, then the system will need to be split into sets or zones. The minimum number of zones that would be required can be determined by dividing the "Total flow for the system [from Item 5) above] by the maximum pump flow rate. The number should be rounded up to the next whole number in order to maintain uniformity between zones, and to compensate for possible reduction of pump flow as the system ages and/or the water source changes (for example less water in the aquifer or ditch). It may desirable to increase the number of zones, perhaps double them if there is a significant fluctuation (or anticipated fluctuation) in flow rate during the season. Additional zones will increase the initial cost of the system and affect the efficiency of the pump if the flow rate does not change.

$$\frac{1775 \text{ gpm}}{900 \text{ gpm}} = 1.97 \simeq 2 \text{ zones}$$

6a) The flow rate per zone is obtained by taking the actual system flow rate divided by the number of zones operating at one time.

If the system can support the needs of both zones in this example, then

$$\frac{1775 \text{ gpm}}{2 \text{ zones}} = 887.5 \text{ gpm/zone}$$

7a) The number of laterals per zone is determined by dividing the total number of laterals in the field by the minimum number of zones (whole number) just computed.

$$\frac{516 \text{ laterals}}{2 \text{ zones}} = 258 \text{ laterals per zone}$$

7b) Hydraulic middle of zone is calculated to set the valve station for the zone. This minimizes the flow to the laterals, and minimizes the friction loss and pipe size needed to convey water to the individual driplines. In a square or rectangular field, distance is one-half the number of laterals in the zone. It may be measured from the edge of the field or the middle of the field, depending on the location of the beginning of the mainline.

$$\frac{258 \text{ laterals}}{2} = 129 \text{ laterals from field edge}$$

Note: For an irregularly shaped field, it would be where there is an equal number of emitters on each side of the valve (or approximately equal numbers so valve is between 2 rows).

7c) Additional zone centers are obtained by adding the number of laterals in the first zone (previous zone(s)) to the hydraulic middle of the next zone.

129 + 258 = 387 laterals from field edge (Zone 2)

8) Mainline needed along laterals is used to determine the length of pipe needed. It is figured from the edge of the field or from the center, based on the location of the mainline. From the edge of the field it would be the number of laterals from the edge of the field to the zone center times the spacing between laterals. If the mainline splits the field in two, then it is the distance from the middle of the field to the zone center (number of laterals from the center of the field to the zone center times the spacing between laterals).

Mainline starting at edge of field:
387 laterals x 5 ft. spacing = 1935 ft.

If mainline splits in middle of field:
2 x 129 laterals x 5 ft. spacing = 1290 ft.

9a) Daily flow provides the water pumped per day. It consists of the pump flow rate (gpm) times the number of minutes in a day and converting this volume from gallons per day to acre-feet per day.

$$900 \text{ gpm} \times 1320 \text{ minutes/day} = 1{,}188{,}000 \text{ gal./day}$$

$$\frac{1{,}188{,}000 \text{ gal./day}}{325{,}850 \text{ gal./ac.-ft.}} = 3.65 \text{ ac.-ft./day}$$

9b) Maximum application depth for field is needed to determine if the water requirements can be met for the crop (either maximum estimated daily evapotranspiration rate or the maximum average daily evapotranspiration rate for the critical month(s).) The value is obtained by taking the daily flow rate (converted from acre-feet to acre-inches) and dividing it by the field size being irrigated (measured in acres).

$$\frac{3.65 \text{ ac.-ft./day} \times 12 \text{ in./ft.}}{153 \text{ acres}} = 0.29 \text{ in./day}$$

Note: This example assumes 92 percent application efficiency (as used in Table KS6-1).

Manufacturers' computer programs can be used for detailed analysis of lateral lines and uniformity or emitter variations.

(vii) Application of agricultural waste with SDI--There has been very little experience using SDI for the application of agricultural waste liquid. Because of the discharge rate through the emitters, the liquid that is utilized in the irrigation system must first pass, as a minimum, through a 200-mesh filter. The emitters must be large enough so that they are not significantly affected by plugging and clogging (less than 10 percent flow reduction).

The soil and water need to be tested for nutrients at the beginning of the irrigation season to insure that water quality criteria can be met. It may not be possible to irrigate exclusively with the wastewater. If the amount of phosphorus (P), nitrogen (N), or other nutrients in the liquid applied during the season would exceed the amount that the plant can utilize, then the excess would have the potential of migrating into the ground water or downslope, outletting into surface waters.

Another potential limitation of this irrigation method would be the capability of applying a given volume of water within a set time period because of drawdown requirements in the agricultural waste pond or pit resulting from runoff due to a state agency designated design storm. Keeping the aforementioned items in mind, the information that follows will address what is needed for a successful system.

SDI has a number of advantages over other methods of wastewater utilization or disposal. These include (Trooien et al. 1999) the following:

- Limited human contact with the wastewater
- No aerial sprinkler application resulting in less odor and no pathogen drift
- Fewer climatic application constraints (e.g. high winds or frozen soils)
- No runoff of wastewater into surface waters
- No soil surface application of phosphorous-rich wastewater
- Greater uniformity of application resulting in better control of water
- Nutrients and salts, less irrigation system corrosion
- Greater flexibility in matching field and irrigation system sizes
- Better environmental aesthetics due to lower visibility of wastewater irrigation application

Figure KS6-8 SDI General Worksheet

Emitter flow rate = [   ] gpm (gallons per minute)

Emitter flow rate = [   ] gph (gallons per hour)

Pump flow rate = [   ] gpm

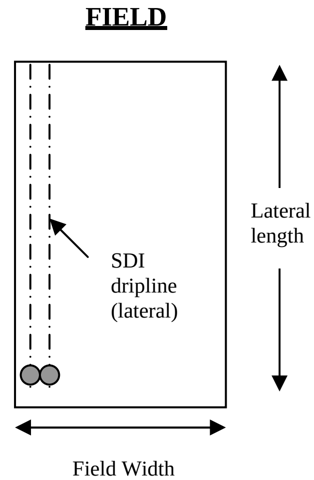
Emitter spacing = [   ] ft.

Dripline spacing = [   ] ft.

1 dripline = 1 lateral

Lateral length = [   ] ft.

Field Width = [   ] ft.



Area

(1) Total Area Irrigated = $\dfrac{\_\_\_\_\_\_\ \text{ft. } \textit{(lateral length)} \times \_\_\_\_\_\ \text{ft. } \textit{(field width)}}{43{,}560\ \text{ft.}^2/\text{ac.}}$ = [   ] acres

Flow Rate Needed for Laterals

(2) Number of driplines = $\dfrac{\_\_\_\_\_\_\ \text{ft. } \textit{(field width)}}{\_\_\_\_\_\_\ \text{ft. } \textit{(lateral spacing)}}$ = [   ] # driplines (laterals)

(3) Emitters per lateral = $\dfrac{\_\_\_\_\_\_\ \text{ft. } \textit{(lateral length)}}{\_\_\_\_\_\_\ \text{ft. } \textit{(emitter spacing)}}$ = [   ] # emitters/lateral

(4) Flow rate / lateral = $\dfrac{\_\_\_\_\_\_\ \text{\# emitters/lateral } \textit{(3)} \times \_\_\_\_\_\ \text{gph } \textit{(emitter flow rate)}}{60\ \text{min/hr}}$ = [   ] gpm/lateral

(5) Flow for total system = _____ gpm/lateral *(4)* x ______ # laterals *(2)* = [   ] gpm/system

Figure KS6-8 SDI General Worksheet (continued)

Zones

(6) Zones (sets) needed = _______ gpm/system *(5)* / _______ gpm (*pump flow rate*) = [ ] zones (round up to whole #)

(6a) Flow rate per zone = _______ gpm/system *(5)* / _____ # zones *(6)* = [ ] actual flow rate

(7a) Laterals per zone = ______ # laterals *(2)* / ______ # zones *(6)* = [ ] laterals

(7b) Hydraulic middle of zone* = ______ # laterals *(7a)* / 2 = [ ] laterals

(7c) Additional valve stations = _____ # laterals *(7b)* x _____ # laterals in zone *(7a)* = [ ] laterals

For additional zone centers, add total laterals per zone to previous zone station

(8) Mainline length (along field) = ___ # laterals to final zone center *(7c)* x ___ ft.*(lateral spacing)* = [ ] ft.
or
Main length (center of field) = _____ # zone center laterals *(7b)* x _____ ft. (*lateral spacing*) x 2 = [ ] ft.

Maximum Daily Application Rate per Acre

(9a) Flow per day** = ______ gpm/system *(5)* x 1320 min./day = [ ] gpm/day

= ______ gpm/day *(9a)* / 325,850 gal./ac.-ft. = [ ] ac.-ft./day

(9b) Volume per acre = ______ ac.-ft./day *(9a)* x 12 in./ft. / ______ area irrigated *(1)* = [ ] ac.-in./ac./day

*The hydraulic middle is the middle of the zone where there is an equal number of emitters on each side of the valve (total length of lateral line is equal for both sides of the valve). If the field irrigated by the zone is not square or rectangular (different row lengths, i.e. corner of center pivot field) the hydraulic middle of the corner triangle will be approximately 2/3 of the distance from the shortest row to the longest row (other end of line).

**Conservation Practice Standard 441, Irrigation System, Microirrigation, only allows a maximum flow of 22 hours per day (60 minutes x 22 hours = 1320 minutes per day) to allow for 10 percent down time for back flushing.