SURFACE IRRIGATION
DESIGN TABLES

This chapter contains several tables for making surface irrigation determinations which will eliminate the need of performing many computations. A summary of which tables to use for the various methods of surface irrigation follows:

Border Irrigation

a. Level - Tables 6.1 and 6.2, Pages 6-3 and 6-4, are to be used to arrive at relationships for unit stream, length of level borders, and net irrigation application. The "n" values used, depending upon the crop, are indicated at the top of the page. Using a "q" or unit stream value greater than the minimum shown will decrease the application time proportionately.

After determining the desired "q" applicable to net application, adapted to the length of border encountered, Table 6.8, Page 6-9, may be used to compute the time required to apply the water to each border. Multiply the gross number of inches to be applied by the time in minutes from the chart for the applicable irrigation stream to obtain the time to apply the irrigation.

Tables 6.3, Page 6-5, gives the flow depths of water for various crops as related to size of irrigation stream and border length. The ratio Q/W or irrigation stream per foot width of border is determined by dividing the stream (cfs) turned into the border by the width of the border being watered by that stream. It can also be determined by multiplying the unit stream from Tables 6.1 or 6.2 by the border length in 100-foot units. (That is, 2,600 ft. = 26 units each 100 feet long.) This information is useful in determining the height for the field borders. A minimum freeboard of 0.2 foot should also be provided.

b. Graded - Tables 6.4 and 6.5, Pages 6-6 and 6-7, can be used to determine the relationships for unit stream and length of run for graded borders. In addition, Table 6.4 gives the time required to apply the water and the efficiency which is possible to attain for various amounts of net application.

Table 6.6, Page 6-8, shows unit stream sizes with respect to their limitations with graded borders. Using stream sizes smaller than the minimum will result in inadequate spreading. Using streams larger than the maximum may cause erosion.

Table 6.7, Page 6-8, giving flow depths for various sized streams, may be used to determine required height of border dikes. (A minimum freeboard of 0.2 foot should also be provided.) The ratio of Q/W is found as for level borders.

Table 6.8, Page 6-9, can also be used for graded borders. It gives time required to apply 1.0 inch of water using different size unit streams.

Furrow Irrigation

Tables 6.9 and 6.10, Pages 6-10 and 6-11, may be used to determine the design length and spacing for furrow irrigation. Combinations of various stream sizes "q" can be matched with various net depths of applications "f" to arrive at the most satisfactory design.

The needed opportunity time (T_O) is also given. Acceptable operating schedules for various values of T_O and T_A are given in Table 6.11, Page 6-12.

Table 6.12, Page 6-13, lists clock times which work well with the operating schedules.

Table 6.13, Page 6-14, gives a conversion table to change intake rates or application rates from gpm for 100 feet to inches per hour, or to change inches per hour to gpm per 100 feet.

Contour Ditch

Table 6.14, Page 6-15, gives relationship for slope, soil group, net application, expected efficiency and time of application for contour ditch irrigation.

TABLE 6.1

MAXIMUM LENGTH-MINIMUM "q" RELATIONSHIP FOR LEVEL BORDERS APPLYING VARIOUS NET APPLICATIONS

Alfalfa and Grass -- n = .15

Design Efficiency -- 80%

Irrigation Groups IIA, IIB, IIC

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.0048	500	.0031	800	.0023	1100	.0019	1400
.0055	600	.0036	1000	.0025	1300	.0020	1500
.0063	700	.0039	1100	.0028	1500	.0021	1600
.0071	800	.0042	1200	.0031	1700	.0022	1700
.0079	900	.0048	1400	.0033	1800	.0024	1800

Irrigation Groups IIIA, IIIB, IIIC, IIID

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.0095	400	.0060	600	.0049	900	.0040	1100
.0105	500	.0070	750	.0052	1000	.0042	1250
.0130	600	.0083	900	.0058	1150	.0045	1400

Irrigation Groups IVA, IVB, VA, VB, VIA, VIB, VIC

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.016	200	.011	350	.009	500	.0079	650
.021	300	.013	450	.010	600	.0085	750
.028	400	.016	550	.011	700	.0092	850

Irrigation Groups VIIA, VIIB, VIIIA, VIIIB

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.028	200	.018	300	.014	400	.012	500
.034	250	.022	400	.017	500	.013	600
.042	300	.025	450	.019	575	.014	675

Maximum length based on maximum flow depth of 0.5 and distance water will travel during 0.5 design opportunity time.

EXAMPLE OF USE: Irrigation Group IIIA. Net application 4.0 inches, then maximum border length is 1150 feet and minimum unit stream for this length is .0058 cfs.

TABLE 6.2
MAXIMUM LENGTH-MINIMUM "q" RELATIONSHIP FOR LEVEL BORDERS
APPLYING VARIOUS NET APPLICATIONS

Small Grain -- n = .10

Design Efficiency -- 80%

Irrigation Groups IIA, IIB, IIC

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.0045	600	.0030	900	.0022	1200	.0017	1500
.0056	800	.0035	1200	.0023	1400	.0018	1700
.0067	1000	.0040	1500	.0025	1600	.0019	1800
.0078	1200	.0045	1700	.0027	1800	--	--

Irrigation Groups IIIA, IIIB, IIIC, IIID

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.0075	400	.0055	700	.0043	1000	.0036	1300
.0102	600	.0065	900	.0047	1200	.0039	1500
.0118	700	.0076	1100	.0052	1400	.0042	1700
.0140	800	.0083	1200	.0056	1500	.0044	1800

Irrigation Groups IVA, IVB, VA, VB, VIA, VIB, VIC

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min. q	Max. L	Min. q	Max. L	Min. q	Max. L
.017	300	.011	500	.0104	800	.0086	1000
.022	400	.012	600	.0118	900	.0093	1100
.028	500	.014	700	.0130	950	.0098	1150

Irrigation Groups VIIA, VIIB, VIIIA, VIIIB

2.0 In.		3.0 In.		4.0 In.		5.0 In.	
Min. q	Max. L	Min q	Max. L	Min. q	Max. L	Min. q	Max. L
.022	200	.017	350	.014	500	.012	650
.030	300	.020	450	.016	600	.013	750
.040	400	.024	550	.018	700	.014	850

Maximum length based on maximum flow depth of 0.5 ft. and distance water will travel during 0.5 design opportunity time.

TABLE 6.3
LEVEL BORDER FLOW DEPTHS "d_1" IN FEET FOR VARIOUS IRRIGATION STREAMS Q/W, AND BORDER LENGTHS

$$d_1 = 0.833(N)^{.462}(Q/W)^{.462}L^{.231}$$

Border Length	Irrigation Streams Q/W												
	.03	.04	.05	.06	.07	.08	.09	.10	.12	.14	.16	.18	.20
Small Grain -- n = .10													
200	.19	.22	.24	.27	.28	.30	.32	.33	.36	.39	.42	.44	.46
300	.21	.24	.27	.29	.32	.33	.35	.37	.40	.43	.46	.48	.51
400	.22	.26	.29	.32	.34	.36	.38	.40	.44	.47	.50	.52	.55
600	.25	.28	.31	.34	.37	.39	.41	.43	.47	.51	.54	.57	.60
800	.27	.30	.33	.36	.39	.42	.44	.46	.50	.54	.58	.61	.64
1000	.28	.32	.36	.39	.41	.44	.47	.49	.53	.57	.61	.64	
1200	.30	.34	.37	.41	.43	.46	.49	.51	.55	.59	.63		
1400	.31	.35	.38	.42	.45	.48	.51	.53	.57	.61	.65		
1600	.31	.36	.40	.43	.47	.50	.53	.55	.60	.64			
1800	.32	.37	.41	.45	.48	.51	.54	.56	.61				
2000	.33	.37	.42	.46	.49	.52	.55	.57	.62				
Alfalfa and Grass -- n = .15													
200	.23	.26	.29	.32	.34	.36	.38	.40	.44	.47	.50	.53	.56
300	.25	.29	.32	.35	.38	.40	.42	.44	.48	.52	.55	.58	.61
400	.27	.31	.35	.38	.41	.43	.45	.48	.52	.56	.59	.62	.65
600	.30	.34	.38	.41	.44	.47	.49	.52	.57	.61	.65	.69	.72
800	.32	.36	.40	.44	.47	.50	.53	.56	.61	.65	.69	.73	
1000	.34	.39	.43	.47	.50	.53	.56	.59	.64	.69	.73		
1200	.36	.41	.45	.49	.52	.55	.58	.61	.66	.71			
1400	.37	.42	.46	.50	.54	.57	.60	.63	.69	.74			
1600	.38	.43	.48	.52	.56	.59	.62	.65	.71				
1800	.39	.44	.49	.53	.57	.61	.64	.67	.73				
2000	.40	.45	.50	.55	.59	.63	.66	.69	.75				

EXAMPLE OF USE:

Crop alfalfa. From Table 6.1
Length was 1150 feet. q = .0058 cfs per foot width per 100' length
The "Q" per foot width of Q/W = $.0058 \left(\frac{1150}{100}\right) = .0058\ (11.5) = .067$.

From table above, Q/W of .06 for 1150 feet length gives flow depth of approximately .49 foot, and Q/W of .07 for 1150 feet gives flow depth of approximately .52 foot. Therefore, Q/W of .067 would give flow depth of approximately .50 foot.

TABLE 6.4
UNIT STREAMS, TIME OF APPLICATION
AND DESIGN EFFICIENCIES FOR GRADED BORDER IRRIGATION

Irrigation Group	Grade Ft/Ft	2.0" Net Application			3.0" Net Application			4.0" Net Application			5.0" Net Application		
		Unit q	T_A	Eff.	Unit q	T_A	Eff.	Unit q	T_A	Eff.	Unit q	T_A	Eff.
IIA, IIB, IIC	.0010	.0023	190	65	.0017	380	65	.00145	590	65	.0013	830	65
	.0020	.0023	200	60	.0018	390	60	.00180	600	50			
	.0040	.0025	205	55									
IIIA, IIIB, IIIC, IIID	.0010	.0040	105	65	.0030	200	70	.0026	310	70	.0023	430	70
	.0020	.0039	110	65	.0030	210	65	.0026	330	65	.0022	450	70
	.0040	.0038	120	60	.0029	220	65	.0026	330	65	.0025	450	60
	.0075	.0038	120	60	.0035	220	55	.0035	330	50			
	.0125	.0044	120	55									
IVA, IVB, VA, VB, VIA, VIB, VIC	.0010	.0082	49	70	.0063	90	75	.0054	140	75	.0048	195	75
	.0020	.0079	54	65	.0062	95	70	.0053	150	70	.0048	200	75
	.0040	.0076	60	60	.0062	105	65	.0053	160	65	.0047	210	70
	.0075	.0076	60	60	.0062	105	65	.0053	160	65	.0047	210	70
	.0125	.0076	65	55	.0062	110	60	.0053	170	60	.0047	220	65
	.0200	.0076	65	55	.0062	110	60	.0057	170	55			
VIIA, VIIB, VIIIA, VIIIB	.0010	.0121	33	70	.0095	60	75	.0079	90	80	.0072	120	80
	.0020	.0121	35	65	.0094	64	70	.0078	95	75	.0071	130	75
	.0040	.0119	39	60	.0093	69	65	.0077	105	70	.0071	140	70
	.0075	.0117	41	60	.0093	69	65	.0077	105	70	.0070	145	70
	.0125	.0117	43	55	.0093	73	60	.0077	110	65	.0070	150	65
	.0200	.0117	43	55	.0093	73	60	.0077	110	65	.0070	150	65
IX, X	.0010	.0160	26	65	.0130	46	70	.0107	70	75	.0095	92	80
	.0020	.0155	29	60	.0126	50	65	.0106	75	70	.0094	100	75
	.0040	.0150	31	60	.0122	53	65	.0105	75	70	.0094	105	70
	.0075	.0150	31	60	.0121	54	65	.0104	77	70	.0093	108	70
	.0125	.0150	33	55	.0121	57	60	.0104	82	65	.0093	112	65
	.0200	.0150	33	55	.0121	57	60	.0104	85	65	.0093	115	60

EXAMPLES OF USE: Irrigation Group IIIA
Net application 4.0"
Border grade .0020 or .20 feet per 100'
Then q = .0026 cfs and
T_A = 330 minutes and eff. = 65%

T_A = Minutes to apply water
Unit q = stream size per foot width for 100'
Border length in cfs
Eff. = design efficiency

TABLE 6.5
MAXIMUM LENGTH OF RUN FOR GRADED BORDER IRRIGATION
FOR CLOSE GROWN CROPS

Slope Groups	0.05-0.15	0.16-0.25	0.26-0.54	0.55-0.95	1.0-1.5	1.6-2.5
Design Slope	0.1%	0.20%	0.40%	0.75%	1.25%	2.0%
Stream Q/W	.085	.085	.085	.075*	.051*	.036
Unit Stream "q"						
0.013	650	650	650	580	390	280
0.012	710	710	710	620	420	300
0.011	770	770	770	680	460	330
0.010	850	850	850	750	510	360
0.009	940	940	940	830	570	400
0.008	1060	1060	1060	940	640	450
0.007	1210	1210	1210	1070	730	520
0.006	1420	1420	1420	1250	850	600
0.005	1700	1700	1700	1500	1020	
0.0045	1890	1890	1890	1670	1130	
0.0040	2110	2110	2110	1870	1270	
0.0035	2420	2420		2140		
0.0030	2640	2640	2640	Unit stream too small to provide adequate spread.		

*Maximum nonerrosive Stream Q/W = $0.06(100S_o) - .75$

Table stops at .085 Q/W because of practical stream sizes

$$\text{Depth of Flow "}d_1\text{"} = \frac{(Q/W)^{0.6}}{\left(\frac{1.486}{n}\right)^{0.6} (S_o)^{0.3}}$$

EXAMPLE OF USE: Unit stream from example on previous page q = .0026
Grade of border .0020 or .20 percent
Then maximum length = 2640 feet

TABLE 6.6
MINIMUM AND MAXIMUM STREAM SIZES
FOR GRADED BORDERS

Minimum Unit Stream "q" = c.f.s.		Grade of Border Ft./100 Ft.	Maximum Stream Q/W = c.f.s. per ft. width
n = 0.10	n = 0.15		
.0019	.0013	0.10	0.085
.0027	.0018	0.20	0.085
.0038	.0026	0.40	0.085
.0052	.0035	0.75	0.075
.0067	.0044	1.25	0.051
.0085	.0057	2.00	0.036

Maximum stream limited to 0.085 for practical operation of border systems.

$$\text{Minimum Unit Stream "q"} = \frac{0.006(S^{0.5})}{n}$$

$$\text{Maximum stream per foot width } Q/W = 0.06(100S_o)^{-0.75}$$

TABLE 6.7
FLOW DEPTHS FOR VARIOUS IRRIGATION STREAMS

Irrigation Stream "Q/W"	Grade - Feet per 100 ft. and (n) values										
	0.10		0.20		0.40		0.75		1.25		2.00
	.15	.10	.15	.10	.15	.10	.15	.10	.15	.10	.15
.01	.13	.10	.10	.08	.08	.07	.07	.05	.06	.04	.15
.02	.19	.15	.16	.12	.13	.10	.10	.08	.09	.07	.08
.03	.24	.19	.20	.15	.16	.13	.13	.11	.11	.10	.10
.04	.29	.23	.24	.18	.19	.15	.16	.13	.14	.12	
.05	.33	.26	.27	.21	.22	.17	.18	.15	.16		
.06	.37	.29	.30	.24	.24	.19	.20	.16			
.07	.40	.32	.33	.26	.27	.21	.22	.17			
.08	.43	.35	.36	.28	.29	.23	.24	.19			
.09	.47	.38	.38	.30	.31	.25					
.10	.50	.40	.41	.33	.33	.27					
.12		.45	.46	.37							

Erosive Irrigation Streams

$$\text{Flow depth "d"} = \frac{(Q/W)^{0.6}}{\frac{1.486}{n}^{06}(S_o)^{0.3}}$$

EXAMPLE: Crop is alfalfa with "n" value of .15
From previous page, maximum length = 2640 feet
q = .0026, grade = .20 feet/100 feet
Then Q/W = (.0026) 26.4 =.069
Read from above table. Flow depth approximately .33 foot

TABLE 6.8
TIME IN MINUTES REQUIRED TO APPLY
1.0" OF WATER USING VARIOUS SIZE UNIT STREAMS

Unit Streams	.000	.0001	.0002	.0003	.0004	.0005	.0006	.0007	.0008	.0009
.001	138.9	126.2	115.7	106.8	99.3	92.7	86.9	81.8	77.2	73.2
.002	69.4	66.2	63.2	60.4	57.9	55.6	53.4	51.5	49.7	47.9
.003	46.3	44.8	43.4	42.1	40.9	39.7	38.6	37.5	36.5	35.6
.004	34.7	33.9	33.1	32.3	31.6	30.9	30.2	29.6	29.0	28.4
.005	27.8	27.3	26.8	26.3	25.8	25.3	24.8	24.4	24.0	23.6
.006	23.2	22.8	22.4	22.0	21.7	21.4	21.1	20.8	20.4	20.1
.007	19.8	19.6	19.3	19.1	18.8	18.5	18.3	18.1	17.8	17.6
.008	17.4	17.2	17.0	16.8	16.6	16.4	16.2	16.0	15.8	15.6
.009	15.4	15.3	15.1	14.9	14.8	14.6	14.5	14.3	14.2	14.0
.010	13.9	13.8	13.6	13.5	13.4	13.2	13.1	13.0	12.8	12.7
.011	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7
.012	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.8
.013	10.7	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	10.0
.014	9.9	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3
.015	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7
.016	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2
.017	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8
.018	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.4
.019	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.0
.020	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6

$$T = \frac{.1389d}{q}$$

EXAMPLE OF USE: Unit stream ·0043. Gross depth of application is 4.8". Then time to apply = 4.8 x 32.3 = 155 minutes.

From previous example:

Unit stream = .0026
Net application is 4.0"
Efficiency = 65%
Then gross application = $\frac{4.0}{.65}$ = 6.15

From table, minutes to apply 1.0" with unit stream of .0026 is 53.4 minutes. 53.4 minutes per inch and 6.15 inches = 53.4 (6.15) = 328 minutes.

TABLE 6.9
GENERALIZED DESIGN GUIDE FOR FURROW IRRIGATION

q = Furrow stream--gpm/100' T_o = Needed opportunity time for cut-back operation 36" Furrows

Irrigation Groups	Irrig. Grade Ft./100'	Net Application f_n - Inches											
		1.8 to 2.2		2.3 to 2.7		2.8 to 3.2		3.3 to 3.7		3.8 to 4.2		4.3 to 4.7	
		q	T_o	q	T_o	q	T_o	q	T_o	q	T_o	q	T_o
IIA, IIB, IIC	0.1	2.1	4.8	1.9	6.6	1.7	8.8	1.6	11.0	1.5	13.3	1.4	16.0
	0.2	1.8	5.6	1.6	7.8	1.5	10.0	1.4	12.6	1.3	15.3	1.2	18.7
	0.4	1.6	6.3	1.4	9.0	1.3	11.5	1.2	14.6	1.1	18.2	1.0	22.5
	0.75	1.3	7.7	1.2	10.5	1.1	13.6	1.0	17.5	0.9	22.2	0.85	28.4
	1.25	1.1	9.1	1.0	12.5	0.9	16.7	0.85	20.6	0.8	25.0	0.75	30.0
IIIA, IIIB, IIIC, IIID	0.1	3.2	3.1	2.9	4.3	2.7	5.6	2.5	7.0	2.3	8.7	2.2	10.2
	0.2	2.8	3.6	2.5	5.0	2.3	6.5	2.2	8.0	2.1	9.6	2.0	11.3
	0.4	2.4	4.2	2.2	5.7	2.0	7.6	1.9	9.2	1.8	11.1	1.7	13.2
	0.75	2.1	4.8	1.9	6.6	1.7	8.8	1.6	11.0	1.5	13.3	1.4	16.0
	1.25	1.7	5.9	1.5	8.3	1.4	10.6	1.3	13.4	1.2	16.6	1.1	20.4
IVA, IVB, VA, VB, VIA, VIB, VIC	0.1	5.8	1.7	5.4	2.3	5.0	3.0	4.7	3.7	4.4	4.5	4.1	5.5
	0.2	5.1	1.9	4.7	2.7	4.4	3.4	4.1	4.3	3.8	5.3	3.6	6.3
	0.4	4.4	2.3	4.0	3.1	3.7	4.1	3.5	5.0	3.3	6.1	3.1	7.3
	0.75	3.6	2.8	3.3	3.8	3.1	4.8	2.9	6.0	2.7	7.4	2.5	9.0
	1.25	2.8	3.6	2.6	4.8	2.4	6.2	2.2	7.9	2.0	10.0	1.9	11.8
VIIA, VIIB, VIIIA, VIIIB	0.1	7.6	1.3	7.0	1.8	6.5	2.3	6.1	2.9	5.8	3.5	5.6	4.0
	0.2	6.8	1.5	6.1	2.1	5.7	2.7	5.3	3.3	5.1	3.9	4.9	4.6
	0.4	5.8	1.7	5.2	2.4	4.9	3.1	4.6	3.8	4.4	4.5	4.2	5.4
	0.75	4.5	2.2	4.4	2.9	4.1	3.7	3.8	4.6	3.6	5.6	3.4	6.6
	1.25	3.9	2.5	3.5	3.6	3.2	4.7	3.0	5.8	2.8	7.1	2.6	8.9
IX, X	0.1	10.2	1.0	9.6	1.3	8.5	1.8	7.9	2.2	7.4	2.7	7.0	3.2
	0.2	9.1	1.1	8.5	1.5	7.4	2.0	6.9	2.5	6.5	3.1	6.1	3.7
	0.4	7.8	1.3	7.4	1.7	6.2	2.4	5.9	3.0	5.5	3.7	5.2	4.3
	0.75	5.7	1.7	5.7	2.2	5.1	2.9	4.8	3.6	4.5	4.4	4.3	5.2

EXAMPLE OF USE: Furrow spacing - 36"; soil in Group IIIA; net application = 3.5"; furrow grade = 0.4'/100'. Then from table above, furrow stream = 1.9 gallons per minute per 100 feet; needed time to obtain intake rate = 9.2 hours.

TABLE 6.10
DESIGN TABLES FOR OTHER THAN 36" FURROWS
PERCENT OF VALUES FROM DESIGN TABLES

	T_o or T_A Limited to Needed Time for 36" Spacings (1)			Net Application Same as for 36" Spacings (2)		
Furrow Spacing	I_{af} or q	T_o or T_A	f_n	I_{af} or q	T_o or T_A	f_n
18	77	65	100	77	65	100
20	80	69	100	80	69	100
22	83	73	100	83	73	100
24	86	77	100	86	77	100
26	89	81	100	89	81	100
28	91	84	100	91	84	100
30	94	88	100	94	88	100
32	96	92	100	96	92	100
34	98	96	100	98	96	100
36	100	100	100	100	100	100
38	102	100	97	102	104	100
40	104	100	94	104	108	100
44	108	100	90	106	116	100
48	112	100	86	108	124	100
52	116	100	82	110	132	100
56	120	100	79	112	139	100
60	123	100	76	114	146	100
64	127	100	73	116	153	100
68	130	100	70	118	160	100
72	133	100	67	120	167	100
76	136	100	64	122	174	100

I_{af} = average furrow intake rate, or
q = furrow stream in gpm per 100 feet
T_o = needed intake time
T_A = time to apply water
f_n = net irrigation application

EXAMPLE OF USE: Assume furrow spacing is 30 inches instead of 36 inches as in example in Table 6.9. Then, furrow stream q = 94 percent of stream for 36-inch furrows or 0.94 (1.9) = 1.8 gpm/100 ft. and T_o = 88 percent of T_o for 36-inch furrows or 0.88 (9.2) = 8.1 hours.

Table 6.11

Selection of Schedules for Furrow Irrigation

Re-Use Procedure		Cut-back Procedure	
1/ T_A (Hrs)	Operating Schedule	Needed T_o Hrs	Operating Schedule
1.75 to 2.25	2.0	4.25 to 5.00	2-2-4
2.50 to 3.25	3.0	2/ 5.25 to 6.25	2.5-2.5-5
3.50 to 4.75	4.0	6.50 to 8.00	3-3-6
5.00 to 6.75	6.0	8.25 to 10.50	4-4-8
7.00 to 8.75	8.0	2/10.75 to 12.25	5-5-10
9.00 to 10.75	10.0	12.50 to 15.50	6-6-12
11.00 to 13.75	12.0	16.00 to 19.00	8-8-16
14.00 to 17.50	16.0	19.50 to 22.50	9-9-18
18.00 to 21.50	20.0	23.00 or over	12-12-24
22.00 or over	24.0		

1/ $T_A = 1.2\ T_o$ (approximately)

2/ These schedules require automatic pump cut off. Where supply is continuous so that cut off is impractical the net application should be increased or decreased as necessary to give a time schedule compatible with the next longer or shorter schedule. In these cases depth of application and stream sizes should be adjusted accordingly.

EXAMPLE: From example on previous page T_o = 9.2 hours; T_A would be (1.2)(9.2) = 11.0 hrs.

Then from above table, time to apply water for Re-Use system is 12.0 hours and for cutback system, 4-4-8 hour schedule.

TABLE 6.12

CLOCK TIME FOR CHANGE OF FURROW STREAMS

Operation Schedules--Time to Change--Days to Complete Cycle - Number Sets per Cycle								
12-12-24	9-9-18	8-8-16	6-6-12**	5-5-10	4-4-8	3-3-6	2.5-2.5-5	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 a.m.
6:00 p.m.	3:00 p.m.	2:00 p.m.	12:00 p.m.	11:00 a.m.	10:00 a.m.	9:00 a.m.	8:30 a.m.	8:00 a.m.
6:00 a.m.	12:00 a.m.*	10:00 p.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.
Repeat	6:00 p.m.	2:00 p.m.	Repeat	Repeat	10:00 p.m.*	6:00 p.m.	4:00 p.m.	2:00 p.m.
2 days	3:00 a.m.*	10:00 p.m.*	1 day	(Automatic	2:00 a.m.*	9:00 p.m.*	6:30 p.m.	4:00 p.m.
1 set	12:00 p.m.	6:00 a.m.	1 set	pump shut-	6:00 a.m.	12:00 p.m.*	9:00 p.m.*	6:00 p.m.
	6:00 a.m.	10:00 p.m.*		off at	2:00 p.m.	Repeat	Repeat	10:00 p.m.*
		6:00 a.m.		2:00 a.m.)	6:00 p.m.	1 day	(Automatic	12:00 p.m.*
		2:00 p.m.		1 day	10:00 p.m.*	2 sets	pump shut-	2:00 a.m.*
	Repeat	Repeat		1 set	Repeat		off at	Repeat
	3 days	4 days			2 days		2:00 a.m.)	1 day
	2 sets	3 sets			3 sets		1 day	3 sets
							2 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 6.13
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 g.p.m.	Intake Rate - Inches per Hour for Following Furrow Spacings								
	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	0.87	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	1.69	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	1.28

Intake rate = gpm per 100' row x $\frac{11.55}{\text{Furrow spacing (in.)}}$

EXAMPLE OF USE: Application rate = 1.9 gpm per 100'. 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 6.14
CONTOUR DITCH IRRIGATION

Unit width stream = .01 cfs/ft.

Irr. Group	Net Irrigation Application (Inches)	Approx. Irrigation Time (Hrs.)	Maximum Length of Run and Efficiency							
			Design Slope							
			0.75		1.25		2.00		3.00	
			Mod. Smooth	Very Smooth	Mod. Smooth	Very Smooth	Mod. Smooth	Very Smooth	Mod. Smooth	Very Smooth
IIA, IIB, IIC	2	5.0	300 (50)	400 (55)	275 (45)	350 (50)	250 (40)	300 (45)	200 (35)	275 (40)
	3	8.0	325 (50)	425 (55)	300 (45)	375 (50)	250 (40)	325 (45)	200 (35)	300 (40)
	4	12.0	350 (50)	475 (55)	300 (45)	400 (50)	250 (40)	350 (45)	200 (35)	300 (40)
	5	16.0	350 (50)	500 (55)	300 (45)	400 (50)	250 (40)	350 (45)		
IIIA, IIIB, IIIC, IIID	2	3.5	250 (50)	325 (60)	225 (50)	300 (55)	200 (45)	275 (55)	175 (40)	250 (50)
	3	5.0	250 (55)	350 (65)	250 (50)	300 (60)	200 (50)	275 (55)	175 (40)	275 (50)
	4	7.0	275 (55)	375 (65)	250 (50)	325 (60)	225 (50)	300 (55)	200 (40)	275 (50)
	5	10.0	300 (55)	400 (65)	275 (50)	350 (60)	225 (50)	325 (55)	200 (40)	275 (50)
IVA, IVB, VA, VB, VIA, VIB, VIC	2	2.5	200 (55)	250 (60)	200 (55)	225 (55)	175 (50)	200 (55)	150 (45)	200 (55)
	3	3.5	225 (55)	275 (65)	200 (55)	250 (60)	175 (50)	225 (55)	150 (45)	200 (55)
	4	5.0	225 (55)	300 (65)	225 (55)	275 (60)	200 (50)	250 (60)	175 (45)	225 (55)
	5	7.0	250 (55)	325 (65)	250 (55)	300 (60)	200 (50)	275 (60)	175 (45)	250 (55)
VIIA, VIIB, VIIIA, VIIIB	2	1.5	150 (60)	175 (65)	150 (60)	175 (65)	125 (55)	150 (60)	125 (50)	150 (60)
	3	2.5	150 (60)	200 (65)	150 (60)	200 (65)	125 (55)	175 (60)	125 (50)	175 (60)
	4	3.5	175 (60)	225 (65)	175 (60)	225 (65)	150 (55)	200 (60)	150 (50)	200 (60)
	5	5.0	200 (60)	250 (65)	200 (60)	250 (65)	175 (55)	225 (60)	150 (50)	225 (60)

Mod. Smooth: Contours essentially parallel, cross slope not more than 1/4 general downfield slope. No rills, dikes or furrows.

Very Smooth: Contours are very smooth and nearly parallel, cross slope does not exceed 0.1 percent. All minor irregularities have been removed.

Contour ditch based on:

1. Distance water will travel in 50 percent application time.

2. Length restricted by:
   L max. = 500 $S^{\frac{1}{2}}$ for very smooth topography
   L max. = 300 $S^{\frac{1}{2}}$ for moderately smooth topography

3. Length limited so that unit stream will meet border irrigation criteria for minimum size stream.

4. Runoff recoverable: Irrigation Group II, 60%; Group III, 55%; Groups IV, V, and VI, 50%; Groups VII and VIII, 45%.

5. Application time based on time that gives percolation loss about equal to nonrecoverable runoff loss.

TABLE 6.16
APPROXIMATE DISCHARGE OF SIPHON TUBES FOR 1" HEAD

Diameter Inches	Length of Siphon Ft.				
	4	5	7-1/2	8	10
1/2 ID	1.2	1.0			
1/1 OD	0.8	0.6			
3/4 ID	2.3	2.0			
3/4 OD	1.7	1.4			
1" ID	4.0	3.6	3.0		
1" OD	3.1	2.7	2.2		
1 1/4 ID	6.2	5.8	5.3		
1 1/4 OD	5.1	4.7	4.2		
1 1/2 ID	8.7	8.3	7.7		
1 1/2 OD	7.3	6.9	6.3		
1 3/4 ID	11.9	11.5	10.9		
1 3/4 OD	10.5	10.1	9.5		
2 ID	16.4	15.8	14.9		
2 OD	14.4	13.8	13.0		
2 1/2 ID	26.8	26.0	24.8		
2 1/2 OD	24.4	23.6	22.5		
3 ID		43.0	41.0		
3 OD		35.0	33.0		
4 ID				64.0	62.0
4 OD				58.0	56.0
5 ID				100.0	98.0
5 OD				92.0	90.0
6 ID				140.0	135.0
6 OD				135.0	130.0

TABLE 6.17

Multiply capacity for 1" head from table 6.16 by following factor for measured head to obtain discharge of siphon tube.

Head in Inches	Multiplying Factor	Head in Inches	Multiplying Factor
0.5	0.7	5.5	2.3
1.0	1.0	6.0	2.4
1.5	1.2	6.5	2.5
2.0	1.4	7.0	2.6
2.5	1.6	7.5	2.7
3.0	1.7	8.0	2.8
3.5	1.9	8.5	2.9
4.0	2.0	9.0	3.0
4.5	2.1	10.0	3.2
5.0	2.2		

TABLE 6.18
ACRE FEET OF WATER PUMPED IN T. HOURS

T. Hours Pumping	PUMP DISCHARGE - GALLONS PER MINUTE										
	200	300	400	500	600	700	800	900	1000	1100	1200
10	0.37	0.56	0.74	0.93	1.11	1.30	1.48	1.67	1.85	2.04	2.22
12	0.44	0.67	0.89	1.11	1.33	1.56	1.78	2.00	2.22	2.44	2.67
14	0.52	0.78	1.04	1.30	1.56	1.81	2.07	2.33	2.59	2.85	3.11
16	0.59	0.89	1.19	1.48	1.78	2.07	2.37	2.67	2.96	3.26	3.56
18	0.67	1.00	1.33	1.67	2.00	2.33	2.67	3.00	3.33	3.67	4.00
20	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33	3.70	4.07	4.44
22	0.81	1.22	1.63	2.04	2.44	2.85	3.26	3.67	4.07	4.48	4.89
24	0.89	1.33	1.78	2.22	2.67	3.11	3.56	4.00	4.44	4.89	5.33
26	0.96	1.44	1.93	2.41	2.89	3.37	3.85	4.33	4.81	5.30	5.78
28	1.04	1.56	2.07	2.59	3.11	3.63	4.15	4.67	5.19	5.70	6.22
30	1.11	1.67	2.22	2.78	3.33	3.89	4.44	5.00	5.56	6.11	6.67
32	1.19	1.78	2.37	2.96	3.56	4.15	4.74	5.33	5.93	6.52	7.11
34	1.26	1.89	2.52	3.15	3.78	4.41	5.04	5.67	6.30	6.93	7.56
36	1.33	2.00	2.67	3.33	4.00	4.67	5.33	6.00	6.67	7.33	8.00
38	1.41	2.11	2.81	3.52	4.22	4.93	5.63	6.33	7.04	7.74	8.44
40	1.48	2.22	2.96	3.70	4.44	5.19	5.93	6.67	7.41	8.15	8.89
42	1.56	2.33	3.11	3.89	4.67	5.44	6.22	7.00	7.78	8.56	9.33
44	1.63	2.44	3.26	4.07	4.89	5.70	6.52	7.33	8.15	8.96	9.78
46	1.70	2.56	3.41	4.26	5.11	5.96	6.81	7.67	8.52	9.37	10.22
48	1.78	2.67	3.56	4.44	5.33	6.22	7.11	8.00	8.89	9.78	10.67
50	1.85	2.78	3.70	4.63	5.56	6.48	7.41	8.33	9.26	10.19	11.11

TABLE 6.19
WATER PRESSURE

(Pounds Per Square Inch and Head Feet Equivalents)

Head (Feet)	Lbs. Per Sq. In.	Head (Feet)	Lbs. Per Sq. In.	Head (Feet)	Lbs. Per Sq. In.
1	.43	30	12.99	140	60.63
2	.87	40	17.32	150	64.96
3	1.30	50	21.65	160	69.29
4	1.73	60	25.99	170	73.63
5	2.17	70	30.32	180	77.96
6	2.60	80	34.65	190	82.29
7	3.03	90	38.98	200	86.62
8	3.46	100	43.31	250	108.27
9	3.90	110	47.64	300	129.93
10	4.33	120	51.97	400	173.24
20	8.66	130	56.30	500	216.55