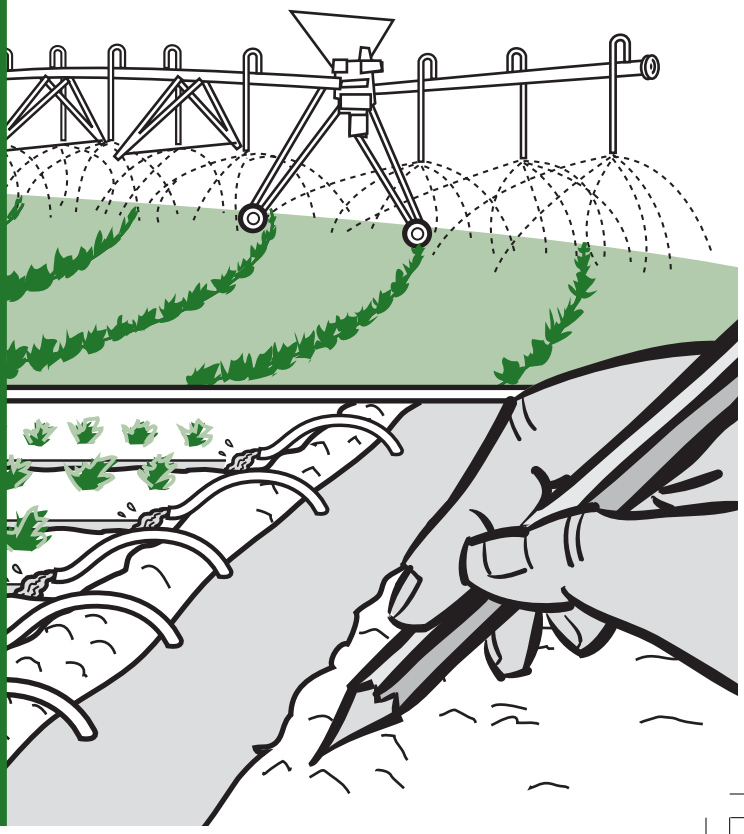
Irrigated Field Record Book



Irrigated Field Record Book

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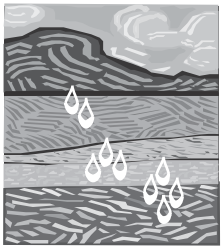

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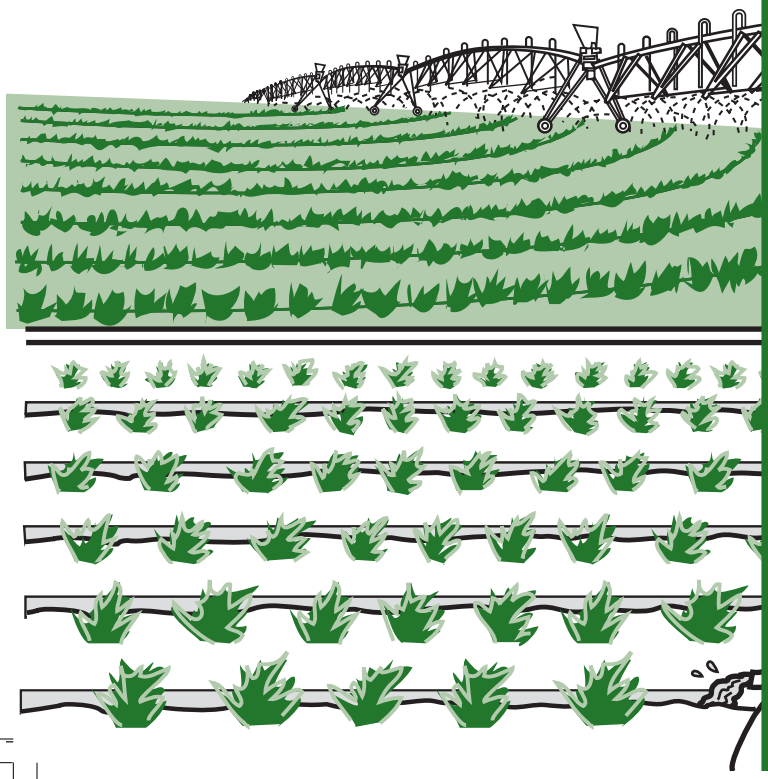

Purpose

The purpose of this book is to help you manage one of your operation's most valuable resources, water. This book includes tables for recording irrigation events, calculations to determine irrigation depth, descriptions to estimate soil moisture, irrigation system information, conversion factors, and a five-year calendar.

Keeping records of all aspects of your crop production system is essential for better management. This book provides tables for you to record irrigation information to help in your record keeping process.

Why keep irrigation records?

- To accurately track water use
- Improve irrigation scheduling
- To explain yield differences among fields
- Document crop insurance issues
- Help with water rights and well augmentation issues
- Improve fertilizer and pesticide application timing
- Reduce pumping costs

We encourage you to use this book for recording irrigation information and for keeping other field notes.

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Example irrigation records - surface

Field: Home NW Soil type: sandy clay loam

Crop: dry beans Water holding capacity*: 1.7”

Irrigation date(s)	Accumulated ET**	Rain	Target application depth
	---------- inches ----------		
6/3 to 6/7	2.5" since planting		2" net
6/18 to 6/20	2.6"	1"	2.5"
7/3 to 7/5	3.5"	2"	2"
7/8 to 7/10	1.5"	none	1.5"
7/13 to 7/15	1.75"	none	2"
7/20 to 7/21	2.2"	none	2.5"

Tips for record keeping

Each two-page irrigation record is intended for an individual field. There is room for 15 irrigations, but records can be continued onto subsequent pages if more irrigations are anticipated.

Tracking ET and rain is useful for scheduling irrigations and determining how much water to apply. Recording irrigation amounts is also helpful for scheduling and long-term records.

* See page 32 for soil water holding capacity.
** See pages 40 - 41 for ET information. ET rates are available at www.coagmet.com.

Irrigation system: siphon Acres: 40

System capacity: 2-2.5 cfs

Notes
2 cfs delivered; 10-1.5" tubes/set
2.5 cfs delivered, 45-1.5" tubes/set
2.5 cfs delivered, 75-1.5" tubes/set
2.0 cfs delivered, 60 tubes/set, V10 growth stage
2.0 cfs delivered, 60 tubes/set
2.5 cfs, 75 tubes/set, R1 growth stage

The second page is left open for notes concerning the wide variety of irrigated fields across Colorado. Examples of records that growers can keep here include:

- Soil moisture before or after irrigation
- Plant growth stage
- Observation of plant stress
- Cultivation
- Water delivery amounts
- Irrigated rows
- Weather

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Example irrigation records - sprinkler

Field: east circle Soil type: silt loam

Crop: corn Water holding capacity: 2.0

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		
6/15			1
6/15			
6/16 - 6/18	0.75		1
off on 6/21	0.6	0.75	
6/25	1.2		1
6/28 to 6/29	0.9		1
6/30			
7/1 to 7/1	1.1		1
off on 7/4	1.1	0.2	1

Examples of useful records for sprinkler irrigation include:

- Pivot settings
- Nozzle problems or other breakdowns
- Soil moisture before or after irrigation
- Chemigation events
- Plant growth stages
- Observation of plant stress

Irrigation system: pivot Acres: 120

System capacity: 750 gpm

Notes
soil moisture (S.M.) 60%, root depth (R.D.) 2 ft.
V7 to V9 growth stage
Continue irrigation, S.M. 65%, Fertigate-40lbs N
S.M. 90% Shut down 4 days
S.M. 60%, better corn color from fertigation
corn at V10 growth stage
Pivot out of alignment, down ~ 12 hrs
S.M. 60%, V12 to V14 growth stage

*S.M.=soil moisture, R.D.=root depth

Irrigation records

Field: Soil type:

Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Field: Soil type:

Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Field: Soil type:

Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

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	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

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Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

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Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Field: Soil type:

Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Field: Soil type:

Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Field: Soil type:

Crop: Water holding capacity:

Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Field: Soil type:

Crop: Water holding capacity:

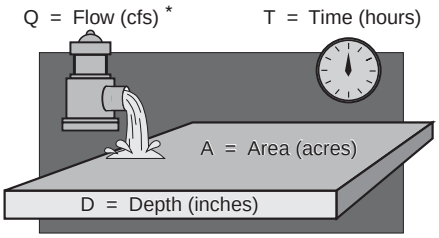
Irrigation date(s)	Accumulated ET	Rain	Target application depth
	---------- inches ----------		

Irrigation system: Acres:

System capacity:

Notes

Estimating application depths using the irrigator's equation



Area (A) x Depth (D) = Flow (Q) x Time (T)

Rearrange AD = QT to calculate the average irrigation depth:

$$D = \frac{QT}{A}$$

* 450 gallons per minute ≅ 1 cfs ≅ 1 acre inch/hr (see page 31).

Finding depth (D)

Example: Using the irrigator's equation to find depth.

Solve for depth: $D = \frac{QT}{A}$

Q - flow rate: 4 cfs
T - set time: 8 hours
A - area: 20 acres
D - depth for applied water: unknown inches

$$D = \frac{4 \text{ cfs x } 8 \text{ hours}}{20 \text{ acres}} = 1.6 \text{ inches}$$

Finding set time (T)

Example: Using the irrigator's equation to estimate irrigation time in hours.

$$\text{Time (hours)} = \frac{\text{D (inches) x acres}}{\text{flow (cfs)}}$$

$$\text{hours} = \frac{\text{2 inches (net) x 80 acres}}{\text{3 cfs}} = \text{53 hours}$$

Finding irrigated area (A)

Furrow system

Table 1. Use this table to find irrigated acres from irrigated 30 inch rows.

Run length	Number of Rows per Set-30-inch* rows								
	10	20	30	40	50	60	70	80	100
	Acres/set								
5200	3.0	6.0	9.0	11.9	14.9	17.9	20.9	23.9	29.8
2600	1.5	3.0	4.5	6.0	7.5	9.0	10.4	11.9	14.9
2000	1.15	2.3	3.4	4.6	5.7	6.9	8.0	9.2	11.5
1320	0.76	1.5	2.3	3.0	3.8	4.5	5.3	6.1	7.6
1000	0.57	1.1	1.7	2.3	2.9	3.4	4.0	4.6	5.7
750	0.43	0.86	1.3	1.7	2.2	2.6	3.0	3.4	4.3
600	0.34	0.69	1.0	1.4	1.7	2.1	2.4	2.8	3.4
300	0.17	0.34	0.52	0.69	0.86	1.03	1.21	1.38	1.72

* Set size (acres) is computed by the formula:

$$\frac{\text{\# of rows x row width (feet) x run length (feet)}}{\text{43,560 feet}^2\text{/acre}}$$

Table 2. Rows per acre at given row spacings and lengths*

	----- Row spacing (inches)-----			
row length	12	30	36	40
	-------- Rows per acre --------			
5280	8	3	3	2
3690	12	5	4	4
2600	17	7	6	5
1320	33	13	11	10
600	73	29	24	22
300	145	58	48	44
100	436	174	145	131

* To find row/acre with other spacings or lengths use this formula:

$$\text{Rows/acre} = \frac{43{,}560}{\text{row spacing (ft) x row length (ft)}}$$

Center pivot

Table 3. Irrigated area by pivot size

Radius* (ft)	Irrigated area (acres)
2600	487.3
1300	121.8
600	25.9
300	6.5

* Radius of wetted area

$$\frac{\text{Acres covered} = (\text{radius of wetted area})^2 \text{ x } 3.14}{43{,}560 \text{ feet}}$$

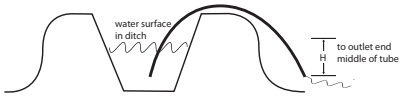
Finding flow (Q)

Approximate flow rates for various tube sizes

Table 4. Flow per tube in gpm at a given head

Tube diameter (inches)	Height difference (H)* ---------- inches ---------- 2	4	6	8
	---------- gpm ----------			
3/4	3.0	4.0	5.0	6.0
1	5.0	7.5	9.0	10.5
1 1/4	8.0	11.5	13.5	16.5
1 1/2	11.5	16.5	20.0	23.0
2	20.0	29.0	35.0	41.0
3		66.0	81.0	92.0
4		117.0	142.0	166.0
5		176.0	220.0	255.0
6		260.0	320.0	370.0

* Measure H by raising downstream end of tube alongside a measuring stick until flow just stops



Flow (Q) equations for flumes and weirs

Parshall flumes

Free flow discharge, height (H) of water is in feet

	cfs =
3”	$0.992H^{1.55}$
6”	$2.06H^{1.58}$
9”	$3.07H^{1.53}$
1’	$4H^{1.522}$
2’	$8H^{1.55}$
3’	$12H^{1.566}$
4’	$16H^{1.578}$

Weirs

V-Notch

	cfs =
22.5°	$0.497H^{2.5}$
30°	$0.676H^{2.5}$
45°	$1.035H^{2.5}$
60°	$1.443H^{2.5}$
90°	$2.500H^{2.5}$

Rectangular (with end contractions) (1’, 1.5’, 2’, 2.5’, 3’ weirs)

cfs =

$3.33(L-0.2H)H^{1.5}$

Without end contractions

	cfs =
1’	$3.33H^{1.5}$
1.5’	$4.995H^{1.5}$
2’	$6.66H^{1.5}$
2.5’	$8.325H^{1.5}$
3’	$9.99H^{1.5}$

Cipolletti (trapezoidal)

	cfs =
1’	$3.367H^{1.5}$
1.5’	$5.050H^{1.5}$
2’	$6.734H^{1.5}$
2.5’	$8.417H^{1.5}$
3’	$10.101H^{1.5}$

Table 5. Flow equivalents

Cubic feet/second (cfs)	Gallons/minute (gpm)*	Colorado Miner’s inches
1	449	38.5
2	898	76.9
4	1795	153.8
6	2693	230.8
8	3590	307.7
10	4488	384.6

* 1 acre-inch/hour ≅ 450 gallons per minute (gpm) ≅ 1 cubic foot per second (cfs)
1 cfs for 1 hour ≅ 1 acre-inch
1 cfs for 24 hours ≅ 2 acre-feet
1 cfs for 30 days ≅ 60 acre feet

Soil Moisture

Table 6. Soil texture and plant available water.

Although soil texture is the most important factor for soil moisture, it can also vary with organic matter content, coarse fragments (rocks, gravel) and salinity. Refer to a soil survey for more localized estimates of soil water holding capacity.

Soil Texture	Plant available water		
	low	high	average
	--- inches / foot soil ---		
Coarse sands	0.6	0.8	0.7
Fine sands	0.8	1.0	0.9
Loamy sands	0.8	1.2	1.0
Sandy loams	1.2	1.5	1.4
Fine sandy loams	1.5	2.0	1.8
Sandy clay loams	1.6	2.1	1.9
Loams	2.2	2.5	2.4
Silt loams	2.0	2.5	2.3
Silty clay loams	1.6	2.0	1.8
Clay loam	1.6	2.0	1.8
Silty clay	1.5	1.7	1.6
Clay	1.3	1.5	1.4

Estimating soil moisture by feel (see next two pages)

When estimating soil moisture by feel, use a handful of soil and form a ball by squeezing a handful of soil firmly with fingers. Take soil samples from plant rows or on the side of the beds in bedded fields.

Soil moisture is rarely uniform within fields, especially with surface irrigation. In surface irrigated fields, check soil moisture at distances of 1/3 and 2/3 down from the top of the field. With sprinkler irrigation take samples between sprinkler nozzles. Take samples in 1-foot increments from the active root zone.

Use Table 7 for guidelines on using the hand-feel method. The far right and left hand columns are inches of plant available soil moisture depleted from field capacity (Table 6) and the number in parenthesis beside each description is the percent of depleted plant available water.

Table 7. Estimating soil moisture by feel

Moisture deficit in/ft	Sand/Loamy sand	Sandy loam
	------(%) depleted plant available water------	
0 (field capacity)	Leaves wet outline on hand when squeezed (0)	Very dark, leaves wet outline on hand, makes a short ribbon (0)
0.3	Moist, forms weak ball (20-25)	
0.4		Very dark, makes a hard ball (30)
0.5	Slightly moist, slightly sticks together (40-45)	
0.6		Less dark, makes a good ball (40-50)
0.7		
0.8	Dry, loose, flows through fingers (80-100)	Slightly dark, forms weak ball (50-60)
0.9	(wilting point)	
1.0		Light, no ball forms (70-80)
1.1		
1.2		
1.3		Slight color (90-100)
1.4		(wilting point)
1.5		
1.7		
1.8		
1.9		

Soil moisture

(see instructions on page 33)

Loam	Clay loam	Moisture deficit in/ft
------(%) depleted plant available water------		
Very dark, leaves a wet outline on hand, will ribbon out about 1 inch (0)	Very dark, leaves slight moisture on hand when squeezed, will ribbon 2 inches (0)	0 (field capacity)
Dark, forms plastic ball, slicks when rubbed (10-15)		0.3
	Dark, will slick and ribbons easily (20-25)	0.4
		0.5
Very dark, forms a hard ball (25-30)		0.6
	Very dark, forms a thick ribbon, may slick when rubbed (30-40)	0.7
		0.8
Fairly dark, forms good ball (35-40)		0.9
	Fairly dark, good ball (40-60)	1.0
Slightly dark, forms weak ball (40-50)		1.1
	Balls, small clods will flatten, not crumble (50-75)	1.2
		1.3
Light, small clods, crumbles easily (60-70)		1.4
	Slight dark, crumbles (60-80)	1.5
Slight, hard small clods (80)		1.7
	Light - unavailable moisture, hard, cracked clods (80-95)	1.8
wilting point (100)		1.9

Soil moisture and tension - sandy soils

Table 8. Approximate soil moisture tension and available water for sandy soils. Tension readings can be used for tensiometers and WaterMark® sensors. Readings within the shaded areas are usual range for irrigation. Begin irrigation at a higher soil moisture for shallow or gravelly soils.

	---------- Soil Texture ----------			
Soil Moisture Tension	Fine sands	Loamy sand	Sandy loam	Fine sandy loam
cb	--- Inches of water per foot of soil ---			
0	1.00	1.10	1.40	1.80
5	1.00	1.10	1.40	1.80
10	1.00	1.10	1.40	1.80
15	0.90	1.10	1.40	1.80
20	0.80	0.90	1.20	1.80
25	0.70	0.80	1.10	1.60
30	0.60	0.70	1.00	1.50
35	0.50	0.70	0.90	1.30
40	0.40	0.60	0.90	1.20
45	0.40	0.60	0.80	1.10
50	0.40	0.50	0.80	1.00
55	0.30	0.50	0.70	1.00
60	0.30	0.40	0.70	0.90
65	0.30	0.40	0.60	0.80
70	0.20	0.40	0.60	0.80
75	0.20	0.30	0.60	0.70
80	0.20	0.30	0.50	0.70

Table 8 and Table 9 are modified from Nebraska Coop. Ext. Fact Sheet EC89-724

Soil moisture and tension - loam soils

Table 9. Approximate soil moisture tension and available water for silty, clay loam, and loam soils. Tension readings can be used for tensiometers and WaterMark® sensors. Readings within the shaded areas are usual range for irrigation.

	-------- Soil Texture --------				
	1*	2	3	4	5
cb	Available Soil Water				
	-------- Inches per foot of soil --------				
0	2.0	1.8	1.8	2.0	2.5
10	2.0	1.8	1.7	2.0	2.5
20	1.9	1.7	1.6	1.9	2.3
22.5	1.7	1.6	1.5	1.8	2.2
25	1.6	1.5	1.4	1.8	2.1
30	1.5	1.4	1.3	1.7	2
35	1.4	1.3	1.3	1.6	1.9
40	1.3	1.2	1.2	1.5	1.8
45	1.2	1.2	1.1	1.5	1.7
50	1.1	1.1	1.1	1.4	1.6
55	1.0	1.0	1.0	1.3	1.5
60	0.90	0.90	1.0	1.2	1.4
70	0.80	0.90	0.90	1.1	1.3
75	0.70	0.70	0.85	1.0	1.2
80	0.60	0.65	0.80	0.95	1.1

* 1 = Sandy Clay Loam (2.0)
2 = Silty clay loam, clay loam (1.8)
3 = Clay loams (1.8)
4 = Loams, very fine sandy loam, or silt loams with silty clay or clay loam subsoil (2.0)
5 = Loams, silt loams, very fine sandy loam with silt loam or sandy loam subsoil (2.5)

Table 10. Delmhorst® KSD1 meter reading vs. soil moisture tension for gypsum blocks.

Meter reading	Moisture tension bars	Meter reading	Moisture tension bars
99.0	0.1	59.0	1.8
98.0	0.2	53.0	2.0
96.0	0.3	43.0	3.0
94.0	0.4	37.0	4.0
91.5	0.5	32.0	5.0
89.0	0.6	28.0	6.0
87.0	0.7	21.0	8.0
84.5	0.8	15.0	10.0
80.5	0.9	10.0	12.0
77.5	1.0	4.0	15.0
63.0	1.5		

Source: Delmhorst Instruments

Table 11. General Delmhorst® meter reading guidelines

Soil type	No irrigation required	Irrigation to be applied	Danger zone, insufficient soil moisture
fine	80-100	60-80	below 60
medium	88-100	70-88	below 70
coarse	90-100	80-90	below 80

Source: Delmhorst Instruments

Scheduling irrigations

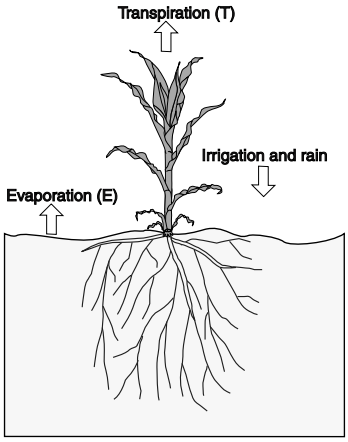
This booklet contains information that can be useful for estimating the next irrigation date. The following example shows how this information can be used.

		Example	
1.	Soil type:	sandy loam - 1.3" H_2O/ft	
2.	Corn growth stage:	V8	
3.	Rooting depth	2 ft	2' x 1.30" = 2.60"
4.	Current soil moisture (% of available):	80%	0.80 x 2.60" = 2.10"
5.	Maximum allowable depletion for growth stage (60% available) 40% remains:		0.40 x 2.60" = 1.00"
6.	Usable water (before stress):		2.10"-1.00" = 1.10"
7.	Estimated ET_r:	0.30"/day	
8.	Crop coefficient:	0.66	
9.	Crop ET (line 7 x line 8):		0.30" x 0.66 = 0.20"
10.	Days to next irrigation:	$\frac{\text{1.10" usable water}}{\text{0.20"/day}}$	= 5 days

Information on the lines is available in:
1. Table 6, page 32
3. Table 15, page 47
4. Tables 6, 7, 8, 9, 10, pages 32-38
5. Table 14, page 46
7. Table 12, pages 42-43
8. Table 13, pages 44-45

Using crop ET (evapotranspiration) information

Pages 42 and 43 contain average reference ET rates for various locations in Colorado. Reference ET (ET_r) is calculated from weather parameters using equations that are calibrated to well-watered alfalfa or grass. Multiply ET_r by a crop coefficient (see Table 13) to get actual crop ET for a given crop and growth stage.



ET information can help balance crop water use with irrigation and rain fall.

Since ET rates on Table 12 are average values, they are useful for estimating future crop water use. ET rates based on current weather are more accurate and can be obtained at www.coagmet.com, through local water districts, NRCS, Cooperative Extension offices or on the radio.

Using crop coefficients in Table 13

A crop coefficient is a multiplier that quantifies the fraction of ET_r that a crop uses according to its growth stage. The coefficients provided on pages 44 and 45 were established using normal crop development for the time after planting. These coefficients are intended for use with ET_r values from Penman alfalfa methods. Crops can be ahead or behind in development, depending on weather. Adjust the coefficients accordingly. As soil moisture becomes limiting, the crop ET rate will decrease. At 50 percent soil water depletion, the ET rate will decrease by approximately 15 percent.

Example of how ET information can be used:

Week of June 23 in Northeast Colorado:

- Average reference ET: 0.31" (Table 12)
- Crop: dry beans planted 30 days ago
- Crop coefficient: 0.60 (Table 13)

Estimated dry bean ET:
0.31" x 0.60 = 0.19" per day

Table 12. Average daily **reference** (multiply by coefficient in Table 13 to get actual crop ET) evapotranspiration, ET_r rates for various locations in Colorado by week.

Week ending	N. Front Range	North East	Central Plains	Ark Valley/SE	San Luis Valley	SW Colo	Grand Valley	Delta/ Olathe
	---------- Average Inches / Day ----------							
Apr 7	0.14	0.16	0.15	0.15	0.12	0.13	0.13	0.13
Apr 14	0.15	0.18	0.16	0.19	0.14	0.14	0.14	0.14
Apr 21	0.16	0.21	0.17	0.21	0.16	0.16	0.16	0.17
Apr 28	0.15	0.19	0.17	0.20	0.18	0.16	0.17	0.17
May 5	0.17	0.21	0.17	0.22	0.20	0.19	0.19	0.20
May 12	0.19	0.22	0.20	0.25	0.23	0.20	0.22	0.21
May 19	0.22	0.26	0.25	0.29	0.25	0.23	0.25	0.23
May 26	0.18	0.23	0.21	0.25	0.24	0.21	0.24	0.23
Jun 2	0.20	0.25	0.21	0.27	0.25	0.23	0.27	0.26
Jun 9	0.23	0.30	0.26	0.32	0.25	0.26	0.32	0.29
Jun 16	0.25	0.30	0.29	0.33	0.27	0.28	0.32	0.29
Jun 23	0.25	0.31	0.32	0.34	0.27	0.30	0.33	0.30
Jun 30	0.28	0.32	0.33	0.36	0.26	0.30	0.35	0.31
Jul 7	0.28	0.32	0.34	0.36	0.26	0.31	0.34	0.31

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Table 12 continued.

Week ending	N. Front Range	North East	Central Plains	Ark Valley/SE	San Luis Valley	SW Colo	Grand Valley	Delta/ Olathe
	---------- Average Inches / Day ----------							
Jul 14	0.27	0.28	0.31	0.34	0.23	0.27	0.33	0.28
Jul 21	0.25	0.27	0.30	0.34	0.22	0.26	0.31	0.28
Jul 27	0.25	0.25	0.28	0.30	0.22	0.25	0.30	0.27
Aug 3	0.23	0.23	0.28	0.30	0.20	0.25	0.28	0.26
Aug 10	0.21	0.22	0.26	0.28	0.19	0.23	0.26	0.24
Aug 17	0.21	0.23	0.26	0.27	0.20	0.22	0.26	0.22
Aug 24	0.20	0.21	0.25	0.26	0.18	0.21	0.23	0.20
Aug 31	0.20	0.22	0.25	0.24	0.19	0.19	0.22	0.19
Sep 7	0.19	0.21	0.25	0.22	0.19	0.18	0.20	0.17
Sep 14	0.17	0.20	0.24	0.19	0.17	0.16	0.18	0.16
Sep 20	0.16	0.17	0.20	0.17	0.16	0.15	0.17	0.14
Sep 27	0.12	0.14	0.17	0.14	0.16	0.16	0.14	0.15
Oct 4	0.13	0.15	0.17	0.15	0.15	0.14	0.13	0.13
Oct 11	0.11	0.14	0.15	0.14	0.13	0.12	0.12	0.11
Oct 18	0.11	0.14	0.16	0.13	0.13	0.11	0.10	0.11
Oct 25	0.09	0.11	0.11	0.09	0.09	0.13	0.07	0.08

Calculated using Kimberly-Penman method from a minimum of 7 years of CoAgMet data.

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Table 13. Crop coefficients of different crops as a function of days from planting or greenup.

Days from planting	Corn	Dry beans	Potatoes	Sorghum
5	0.15	0.15	0.15	0.15
10	0.20	0.24	0.20	0.25
15	0.23	0.30	0.23	0.34
20	0.28	0.38	0.26	0.46
25	0.34	0.49	0.31	0.59
30	0.41	0.60	0.37	0.73
35	0.49	0.72	0.43	0.86
40	0.57	0.84	0.50	0.93
45	0.66	0.92	0.58	0.93
50	0.74	0.92	0.65	0.93
55	0.81	0.92	0.72	0.93
60	0.87	0.92	0.78	0.93
65	0.92	0.92	0.84	0.93
70	0.93	0.92	0.88	0.93
75	0.93	0.92	0.90	0.93
80	0.93	0.91	0.90	0.93
85	0.93	0.85	0.90	0.93
90	0.93	0.79	0.90	0.93
95	0.92	0.73	0.90	0.93
100	0.91	0.66	0.90	0.93
105	0.89	0.59	0.90	0.93
110	0.83	0.52	0.90	0.93
115	0.77	0.45	0.90	0.93
120	0.70	0.38	0.90	0.90
125	0.67	0.31	0.90	0.88
130	0.63	0.25	0.90	0.87
135	0.55	0.20	0.90	0.87
140	0.48	0.15	0.90	0.87

Multiply crop coefficient by Penman reference ET (ET_r) to achieve actual crop ET for a given period.

Transplant onions	Small grains	Sugar beets	Alfalfa	Pasture
0.15	0.15	0.15	0.25	0.25
0.20	0.16	0.20	0.45	0.75
0.25	0.18	0.21	0.55	0.90
0.50	0.22	0.22	0.65	0.90
0.50	0.28	0.24	0.74	0.90
0.50	0.37	0.27	0.84	0.90
0.52	0.46	0.31	0.94	0.90
0.54	0.56	0.35	1.00	0.90
0.57	0.67	0.40	1.00	0.90
0.60	0.77	0.47	1.00	0.90
0.64	0.86	0.54	1.00	0.90
0.67	0.94	0.62	0.63*	0.90
0.71	1.00	0.71	0.75	
0.75	1.00	0.81	0.88	
0.79	1.00	0.91	1.00	
0.83	1.00	1.03	1.00	
0.87	1.00	1.00	1.00	
0.90	1.00	1.01	1.00	
0.93	0.94	1.01	1.00	
0.95	0.85	1.01	1.00	
0.97	0.74	1.00	1.00	
0.98	0.62	0.99	1.00	
0.98	0.49	0.98		
0.97	0.34	0.96		
0.97	0.19	0.94		
0.96	0.15	0.91		
0.95	0.15	0.89		
0.94	0.15	0.86		

Source: CSU Coop. Ext. Fact Sheet no. 4.707

*Cutting

Table 14. Maximum allowable depletion (MAD) of soil water in the root zone of selected crops at different growth stages. MAD is the percent of plant available water (Table 6) that can be depleted without yield-reducing stress.

Crop	Growth stages	MAD(%) in root zone	Critical water stress period
Alfalfa	emergence - 1st cut	65	Early spring and immediately after cuttings
	1st cut - 2nd cut	50	
	2nd cut - 3rd cut	40	
	3rd cut - 4th cut	60-70	
Pinto beans	emergence - aux, budding	60-70	Flowering and pod set
	flower - bud filling	55	
	bud filling - maturity	60-70	
Potatoes	early vegetation period	40-60	
	tuber bulking period	30-40	Tuber formation to harvest
	ripening period	65	
Corn	emergence - V4	50	Tasseling, silk stage until grain is fully formed
	V4 - V16	60-70	
	V16 - dough	50	
	dough-maturity	60-70	
Small grains	emergence - first node	65-70	Boot and bloom stages
	first node - flowering	40-60	
	mild ripe - maturity	50-70	

Source: CSU Coop. Ext. Fact Sheet No. 4.715

Table 15. Irrigation management depths for selected crops. Assumes rooting is not restricted by compaction or shallow soils.

	Irrigation management depths			
Annual crop	**Seedling**	**Vegetative**	**Flowering**	**Mature**
	---------- Soil depth (inches) ----------			
Corn	12	24	30	36 to 48
Potatoes	12	18	24	24 to 48
Small grain	12	18	24	36 to 48
Field beans	12	18	24	24 to 30
Sugarbeets	12	18	24	36 to 48
Vegetables	6 to 12	18	18	18 to 24

Perennial crop	**Seedling**	**Establishment**	**Mature**
Alfalfa	6 to 12	24 to 36	48 to 72
Turf and lawns	6	12	12
Grass and pasture	6	12	24

Irrigation systems information

Use Table 16 to estimate whether a water supply can meet crop ET demand for various field sizes and adjust irrigation schedules accordingly. Fields with more capacity per day can keep tighter irrigation schedules than those closer to, or below crop ET demand. For example, a 500 gpm well might irrigate a 140 acre pivot in three days. In one day it applies 0.57 inches over the area traveled, but the average application rate is only 0.19 inches per day over the whole field, which is not adequate to supply peak ET demand for most crops.

Table 16. Water supply (gpm or cfs) converted to average inches per day (gross*). Table assumes the water supply runs for 24 hours.

	Field size (acres)							
gpm	40	80	120	140	160	240	500	cfs
	average inches per day							
200	0.27	0.13	0.09	0.08	0.07	0.04	0.02	0.4
300	0.40	0.20	0.13	0.11	0.10	0.07	0.03	0.7
400	0.53	0.27	0.18	0.15	0.13	0.09	0.04	0.9
500	0.66	0.33	0.22	0.19	0.17	0.11	0.05	1.1
600	0.80	0.40	0.27	0.23	0.20	0.13	0.06	1.3
700	0.93	0.46	0.31	0.27	0.23	0.15	0.07	1.5
800	1.06	0.53	0.35	0.30	0.27	0.18	0.08	1.8
900	1.19	0.60	0.40	0.34	0.30	0.20	0.10	2.0
1000	1.33	0.66	0.44	0.38	0.33	0.22	0.11	2.2
1200	1.59	0.80	0.53	0.45	0.40	0.27	0.13	2.6
1400	1.86	0.93	0.62	0.53	0.46	0.31	0.15	3.1
1600	2.12	1.06	0.71	0.61	0.53	0.35	0.17	3.5
1800	2.39	1.19	0.80	0.68	0.60	0.40	0.19	4.0
2000	2.65	1.33	0.88	0.76	0.66	0.44	0.21	4.4

* Gross application rate. Multiply by irrigation efficiency to obtain net application amount.

Using cutoff ratios to improve irrigation efficiency in furrow irrigation:

The cutoff ratio is the ratio of set time to advance time that achieves maximum efficiency for a given soil type. Multiply the cutoff ratio for the soil type and reuse system in Table 17 by the irrigation set time. The result is the desired advance time for water to reach end of field.

Adjust flow rate with tube size, ditch water height, or number gates to achieve this advance time. Flow rates should not exceed the maximum non-erosive flow rate (Table 19).

Example:

- clay loam soil
- 12 hour set
- No reuse
- 12 hr x 0.90 = 10.8 hour

  Flow rates should be adjusted to achieve advance time of 10.8 hours.

Table 17. Recommended cutoff ratios to achieve maximum efficiency

	Clayey	Silty	Sandy
No reuse	0.90	0.70	0.50
Closed reuse system	0.90	0.40	0.20
Open reuse system	0.70	0.50	0.35
Blocked ends (low slope, 0.1%)	0.95	0.85	0.70
Blocked ends (moderate slope 0.5%)	0.95	0.80	0.65

Source: D. Eisenhauer, D. Martin, and G. Hoffman. Irrigation Systems Management, U of N, Lincoln

Table 18. Furrow irrigation recommendations for different soil types.

	Basic intake rate (in/hr)	Basic intake rate (gpm/100 ft)	Maximum furrow length (ft)	Stream size* (gpm/100 ft)
Loamy sand	2.0-5.0	2.4	600	4.8
Sandy loam	0.5-4.0	1.9	800	3.8
Fine sandy loam	0.2-2.0	1.7	1000	3.4
Silt loam	0.2-1.5	1.1	1100	2.2
Silty clay loam	0.05-0.25	0.1	1300	1.4

* Recommended stream size, actual stream size must be less than maximum nonerosive stream size.

Source: D. Eisenhauer, D. Martin, and G. Hoffman. Irrigation Systems Management, U of N, Lincoln

Table 19. General maximum furrow stream size for various slopes to prevent erosion. Use higher flow rates when using polyacrylamide (PAM).

Slope (%)	Stream size (gpm)
0.20	50
0.40	30
0.75	17
1.25	10

Source: NRCS Colorado Irrigation Guide
The general guideline for maximum furrow stream size is 10 divided by percent slope. Varies with soil type and condition.

Calibration for center-pivot chemigation

Only products specifically labeled for chemigation may be applied through any irrigation system. The label may also contain specific chemigation requirements that must be followed. The following calculations will help you determine the injection pump setting for the proper application rate.

a. Acres to be treated

$$\text{Acres} = \frac{(BR^2)}{43{,}560} \quad (B = 3.1416;\ R = \text{radius in feet})$$

b. Acres treated per hour or per minute

$$\text{Acres/hour} = \frac{\text{acres to be treated}}{\text{revolution time (hr) @ desired inches of water}}$$

or

$$\text{Acres/min} = \frac{\text{acres/hour}}{60}$$

c. Pump setting

Depending upon the manufacturer of your injection pump, you will initially need to set the pump in either gallons per hour (gal/hr) or percent. The following calculations will help you make the correct setting.

gal/hr = acres treated per hour x gallons per acre (labeled rate of product to be applied)

(continued on next page)

calibration continued

$$\text{\% dial setting on pump} = \frac{\text{gallons per hour}}{\text{max injection pump rating (GPH)}}$$

d. After initially setting the pump, it is a good idea to fine-tune the pump output. Systems should have a calibration tube (graduated in ounces or milliliters) located between the nurse tank and the pump. Adjust the pump while monitoring the sight tube until the proper rate is achieved. Use the following conversions to convert gallons per hour to ounces or milliliter per minute.

ounces (oz) per minute = (gallons per hour) x 2.13

milliliters (ml) per minute = (gallons per hour) x 63.1

The Colorado Chemigation Act requires a chemigation permit and the appropriate anti-siphoning and automatic injection pump shut off devices to be used when applying pesticides and fertilizers in closed irrigation systems. Chemigation units are subject to inspection by the Colorado Department of Agriculture (CDA). Contact the CDA at (303) 239-4149 for updated information on these requirements.

Equivalents

Volume equivalents

1 acre-foot covers 1 acre of land 1 foot deep;

1 acre-inch = 27,154 gallons

1 cubic foot
= 7.481 gallons
= 62.4 pounds water

1 acre-foot
= 43,560 cubic feet
= 325,851 gallons
= 12 acre-inches
= 2,718,000 pounds

1 cubic meter
= 1,000 liters
= 264.2 gallons

1 gallon
= 128 ounces
= 8.35 pounds
= 3.785 liters
= 3,785 milliliters

1 quart of water
= 0.947 liters

Flow equivalents

1 acre-inch/hour
≅ 450 gallons per minute (gpm)
≅ 1 cubic foot per second (cfs)
1 cfs for 1 hour ≅ 1 acre-inch
1 cfs for 24 hours
≅ 2 acre-feet
1 cfs for 30 days
≅ 60 acre feet

Table 20. Flow equivalents

Cubic feet/second (cfs)	Gallons/minute (gpm)*	Colorado Miner's inches
1	449	38.5
2	898	76.9
4	1795	153.8
6	2693	230.8
8	3590	307.7
10	4488	384.6

* Rounded to nearest gpm.

Table 21. Maximum flow capacities (full pipe) for coupled and gated pipe.

Pipe ID (inches)	Flow (gpm)
6	400
8	800
10	1,200
12	1,700

Conversions

Volume

Convert from:
Acre feet

Into:	**Multiply by:**
cubic feet	43,560
cubic meters	1,233
gallons	325,851
million gallons	0.326

Cubic feet

Into:	**Multiply by:**
acre feet	0.000023
cubic meters	0.02832
gallons	7.481

Gallons

Into:	**Multiply by:**
acre feet	0.000003069
cubic feet	0.1337
cubic meters	0.00379
liters	3.785
million gallons	0.000001

Volume

Convert from:
Million Gallons

Into:	**Multiply by:**
acre feet	3.068
cubic feet	133,680
cubic meters	3,785

Flow

Acre foot per day

Into:	**Multiply by:**
cubic foot per day	43,560
cubic foot per second	0.5042
cubic meters per second	0.014
gallons per second	3.771
gallons per minute	226.3

Cubic foot per day

Into:	**Multiply by:**
acre foot per day	0.00002296
cubic foot per second	0.00001157
gallons per second	0.00008656
gallons per minute	0.005195

Cubic foot per second

Into:	**Multiply by:**
acre foot per day	1.984
gallons per second	7.481
gallons per minute	448.8

Flow

Convert from:
Gallons per second

Into:	**Multiply by:**
acre foot per day	0.265
cubic foot per day	11,550
cubic foot per second	0.1337
gallons per minute	60
liters per second	3.785

Gallons per minute

Into:	**Multiply by:**
acre foot per day	0.00442
cubic foot per day	192.5
cubic foot per second	0.00223
cubic meters per day	5.451
cubic meters per second	0.00006309
gallons per second	0.01667

Other

Horse power

Into:	**Multiply by:**
Kilowatt	0.746

PSI

Into:	**Multiply by:**
foot of head	2.31*

*A column of water 2.31 feet deep exerts pressure of 1 psi

Use these charts to check-off rows where water has reached the bottom of the field.

	Irrigation number								
Furrow #	Example	1	2	3					
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Row check table

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Row check table

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Calendar

JANUARY 2007

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FEBRUARY 2007

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MARCH 2007

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APRIL 2007

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MAY 2007

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JULY 2007

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AUGUST 2007

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OCTOBER 2007

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NOVEMBER 2007

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2007

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FEBRUARY 2008

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MARCH 2008

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APRIL 2008

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MAY 2008

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JUNE 2008

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AUGUST 2008

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SEPTEMBER 2008

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OCTOBER 2008

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DECEMBER 2008

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FEBRUARY 2009

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MARCH 2009

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APRIL 2009

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MAY 2009

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JUNE 2009

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OCTOBER 2009

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NOVEMBER 2009

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2009

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MARCH 2010

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APRIL 2010

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MAY 2010

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JUNE 2010

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JULY 2010

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AUGUST 2010

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SEPTEMBER 2010

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OCTOBER 2010

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NOVEMBER 2010

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DECEMBER 2010

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JANUARY 2011

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FEBRUARY 2011

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MARCH 2011

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APRIL 2011

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MAY 2011

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JUNE 2011

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JULY 2011

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AUGUST 2011

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SEPTEMBER 2011

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OCTOBER 2011

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DECEMBER 2011

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2011

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