Irrigation Water Requirements in the Arkansas Valley

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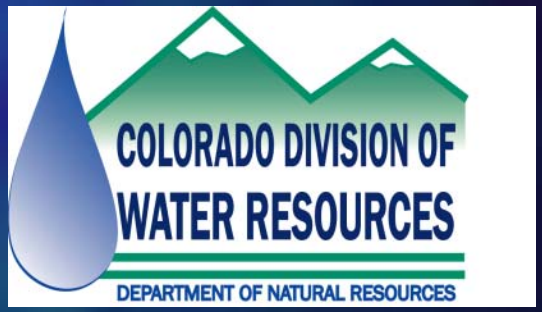


Objectives

- Define irrigation water requirements (IWR)
- Discuss each of the major components used to determine IWR
- Example

Irrigation Water Requirements

The quantity, or depth, of irrigation water, in addition to precipitation, required to produce the desired crop yield and quality and to maintain an acceptable salt balance in the root zone.

Irrigation Water Requirements

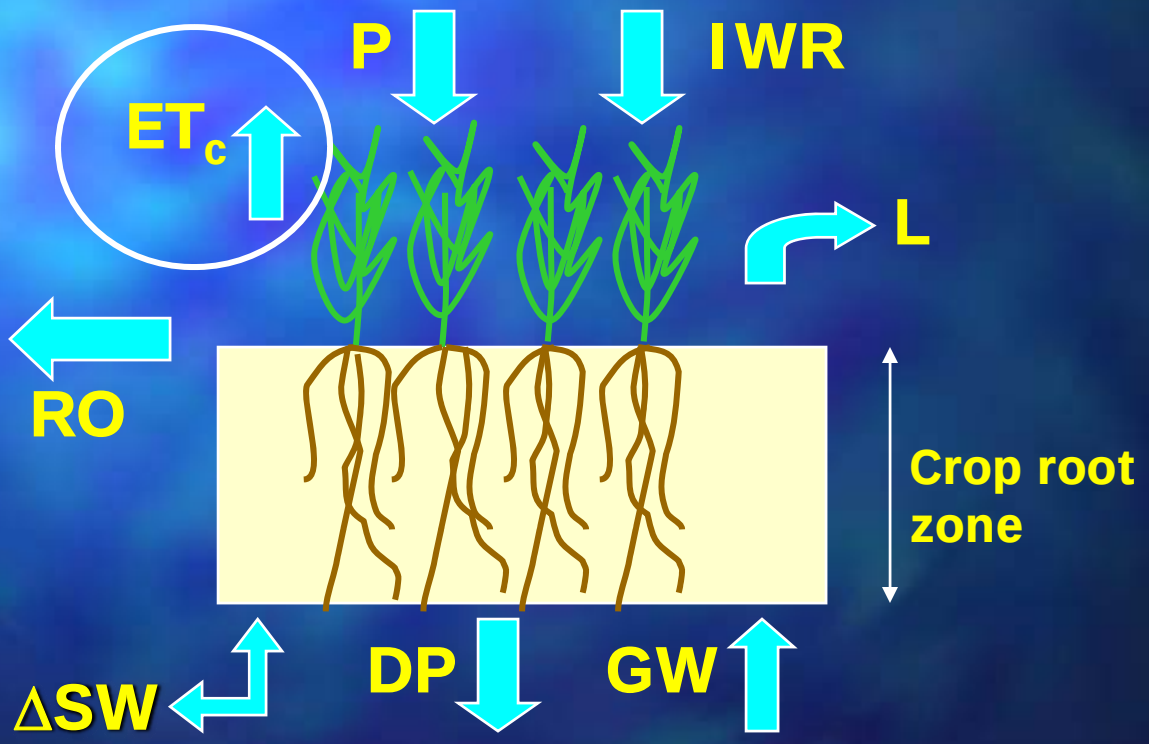
- Needed day-to-day
  - irrigation scheduling
  - other operational and management decisions
- Needed seasonally
  - sizing of irrigation system components (pipes, valves, ditches)
  - planning and development of irrigation projects
  - water rights issues
  - hydrologic studies

Factors Affecting IWR

- Crop type and growth characteristics
- Weather/climate
- Irrigation management
- Soil and field conditions

Soil-Water Balance

$$IWR = ET_c + DP + RO - P \pm \Delta SW - GW + L$$

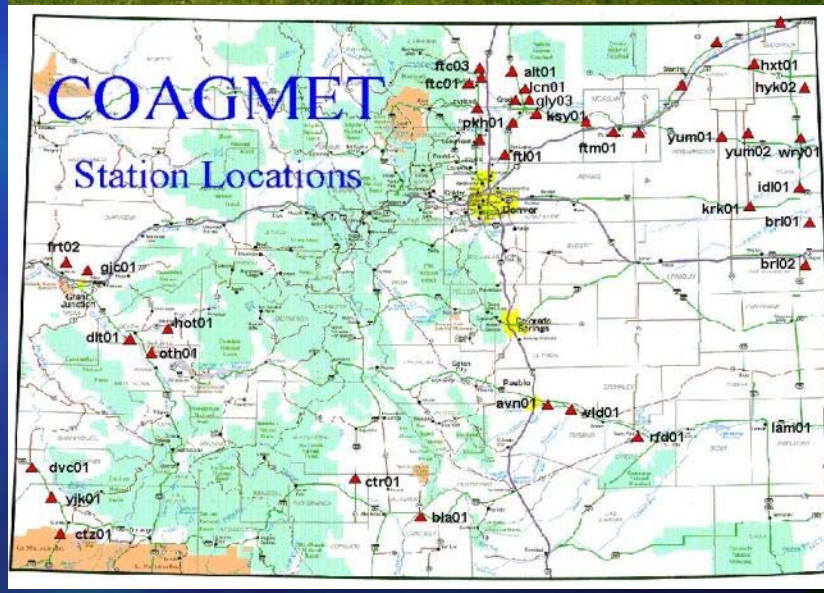


Crop Characteristics

- Crop type and variety
  - Height
  - Canopy characteristics (roughness, reflectivity, ground cover)
  - Stomatal control
  - Rooting characteristics (depth, density)
- Stage of development

Weather/Climate

- Solar radiation
- Air temperature
- Relative humidity
- Wind speed
- Exposure/sheltering



Management

- Irrigation method
- Irrigation management
- Cultivation practices
- Fertility management
- Disease and pest control

Soil and Field Conditions

- Soil type, texture, water-holding capacity
- Soil salinity
- Soil depth and layering
- Poor soil fertility
- Irrigation water quality
- Drainage

Determining/Estimating ET

- Direct measurement
- Compute ET using a wide variety of empirical, semi-empirical, and physically-based equations using climate and weather data

Direct Measurement of ET

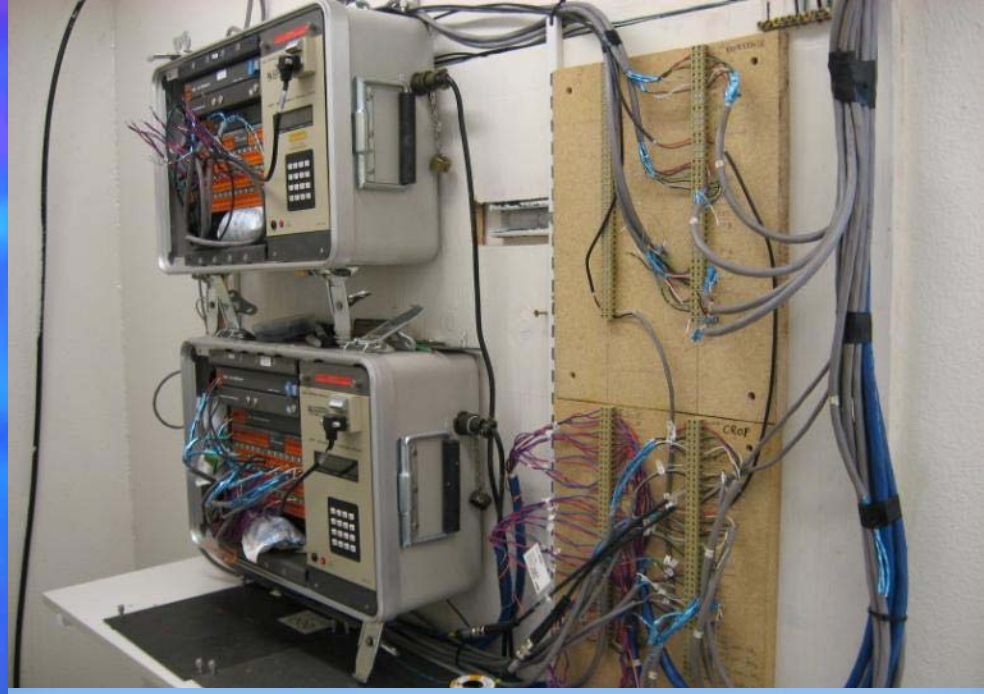
- Lysimetry
- Soil water depletion
- Energy balance and micro-meteorological methods—research applications only
- Remote sensing

Lysimetry

- Difficult and expensive to construct
- Require careful operation and maintenance
- Primarily research application
- Primary tool for evaluating weather effects on ET and evaluation of estimating methods

AVRC Lysimeter

- Direct measurement of ET
- Precision weighing lysimeter (resolution of 0.05 ET mm per hour or better)
- Soils inside and outside the tank must be similar
- Vegetation inside and outside the tank must perfectly match (height, leaf area, density, vigor)
- Terms in the soil water balance that are difficult to measure are carefully controlled and measured



Estimating ET

- Use weather/climate data
- Empirical, semi-empirical, and physically-based equations/models
  - Modified Blaney-Criddle Method
  - 1985 Hargreaves Method
  - 1982 Kimberly Penman Equation
  - Penman-Montieth Equation
  - ASCE Standardized Penman-Montieth Equation
- Crop coefficients

Wind direction
Wind speed
Solar radiation
Air temperature
Relative humidity
Rainfall
Holly CoAgMet Station
July 2005

ET Concepts

- Reference ET (ET_{ref})
  - ET rate from a reference vegetative surface, actively growing, not short of water
  - measure of evaporative demand under current climate conditions
- Crop ET under standard conditions
  - ET of disease-free, well-fertilized crop not short of water achieving full production.
  - Crop coefficients are determined experimentally as the ratio of measured crop ET (under optimal growing conditions) to reference crop ET
- Crop ET under non-standard conditions
  - ET of crop considering “real-world” growing conditions (diseases, pests, fertility problems, salinity effects, water stress, management, etc.)
  - water stress coefficient and adjusted crop coefficients

Crop Coefficients

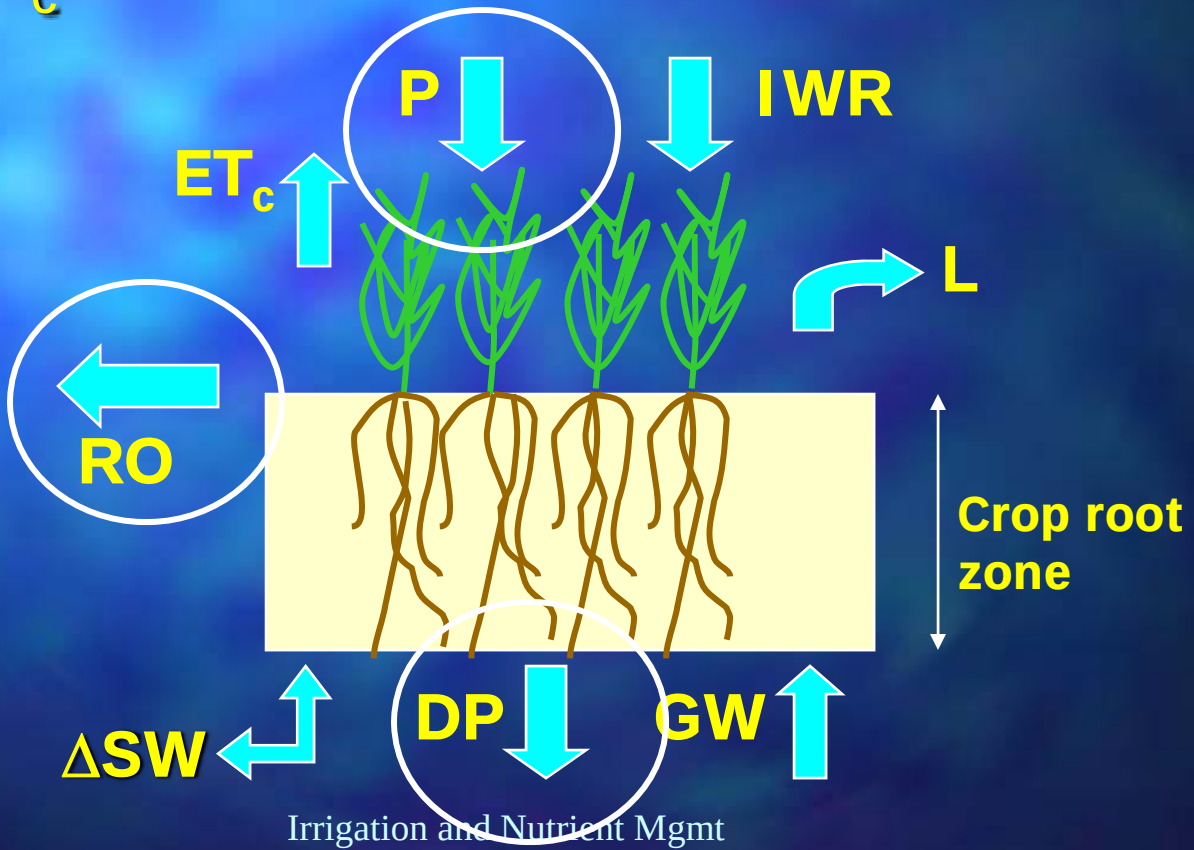
- Alfalfa or grass reference basis
- Method specific
- Geographical transferability (?)
  - H-I model for compact compliance currently using coefficients from Kimberly ID and Bushland TX
- ASCE Task Committee on crop coefficients is currently investigating these issues and compiling a world wide database of crop coefficients

Weather Data Considerations

- Detailed weather data requirements
  - solar radiation, air temperature, relative humidity, wind speed at 2 m
- Weather data quality
  - All data should be evaluated using available detailed QA/QC procedures
- Data collection environment
  - Weather station siting over clipped vegetated surface in open, irrigated settings with green, irrigated fetch in the primary wind direction
- Weather station location and density
  - weather station spacing of 20-40 miles, but highly dependent on topography, prevailing weather patterns, etc.

Soil-Water Balance

$$IWR = ET_c + DP + RO - P \pm \Delta SW - GW + L$$



Precipitation

- Precipitation is not 100% effective
  - Evaporation, runoff and deep percolation losses
- Effective precipitation (P_e) is the amount of rainfall that enters root zone soil water storage and is used in crop ET
- How much is effective?
  - Depends on rainfall characteristics, topography, slope, vegetative cover, soil characteristics
  - Generally 60-90%

Effective Precipitation

- SCS (USDA, 1970) procedure
- Monthly effective precipitation based on monthly total precipitation, crop ET and a soil water storage factor (SF) dependent on usable root zone soil water storage
- P_e limited to average monthly rainfall or crop ET

Net Irrigation Requirement

$$IWR_{net} = ET_c - P_e - \Delta SW - GW$$

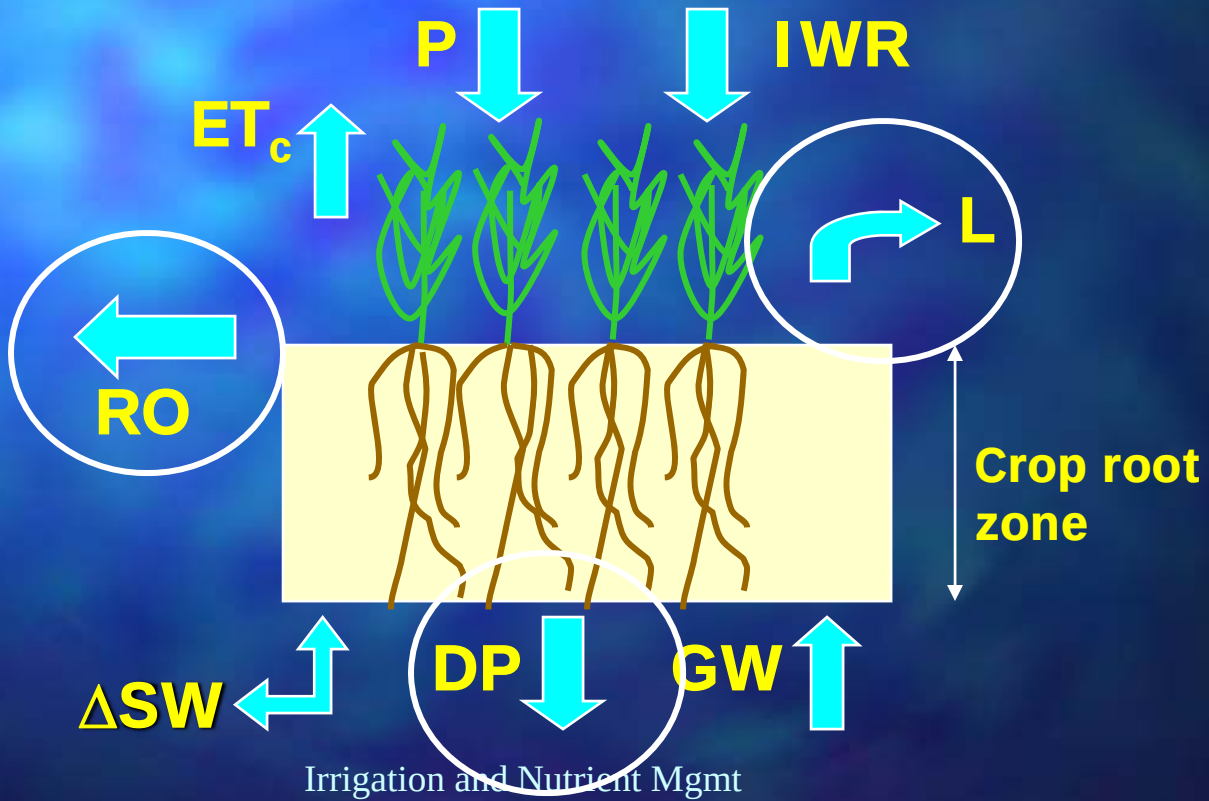
ΔSW – depleted soil water over the course of an irrigation season can be significant contribution to ET

(4 ft crop RZ x 2 in/ft AWHC x 50% MAD = 4 in)

GW – upward flow from a high water table dependent on soil water potential, pore pressure, and hydraulic conductivity

Soil-Water Balance

$$IWR = ET_c + DP + RO - P \pm \Delta SW - GW + L$$



Gross Irrigation Requirement

$$IWR_g = IWR_{net} / E_a$$

- E_a = irrigation application efficiency, the ratio of the average depth of water infiltrated and stored in root zone to the average depth of water applied
- Accounts for losses to deep percolation, surface runoff, evaporation, and spray/drift losses for sprinklers
- Dependent on irrigation method, environmental conditions at time of irrigation, management

Irrigation Application Efficiency

- Typical season average values
  - Surface irrigation—50-65%
  - Center pivot irrigation—80-85%
  - Wheel-line sprinkler—70-75%
  - Surface drip irrigation—80-90%
  - Subsurface drip irrigation—90%

Leaching Requirement

- The amount of applied water that infiltrates the soil and passes through the crop root zone to transport salts below the root zone to prevent yield reduction
- Depends on salinity of the applied irrigation water and specific crop salt tolerance level before yield is impacted

Leaching Requirement

$$LR = D_d / D_a = EC_{aw} / EC_d^*$$

- EC_d^* is the maximum salt content of the deep percolating drainage water before yields are reduced
- EC_d^* = a function of the crop threshold salt tolerance (EC_t) and the salinity of applied water

Table 2–34 Salt tolerance of selected crops [1/]

Common name	Botanical name	Salt tolerance threshold [2/] (EC_t)	Yield decline [3/] (Y_d)	Qua salt tole ratin
		mmho/cm	% per mmho/cm	
Field crops				
Barley	*Hordeum vulgare*	8.0	5.0	
Bean	*Phaseolus vulgaris*	1.0	19	
Broad bean	*Vicia faba*	1.6	9.6	
Corn	*Zea Mays*	1.7	12	
Cotton	*Gossypium hirsutum*	7.7	5.2	
Cowpea	*Vigna unguiculata*	4.9	12	
Flax	*Linum usitatissimum*	1.7	12	
Guar	*Cyamopsis tetragonoloba*	8.8	17.0	
Millet, foxtail	*Setaria italica*	—	—	
Oats	*Avena sativa*	—	—	
Peanut	*Arachis hypogaea*	3.2	29	
Rice, paddy [5/]	*Oryza sativa*	3.0	12	
Rye	*Secale cereale*	11.4	10.8	
Safflower	*Carthamus tinctorius*	—	—	
Sesame	*Sesamum indicum*	—	—	
Sorghum	*Sorghum bicolor*	6.8	16	

Irrigation Requirements for Salinity Control

- Arid areas:

$$IWR_{net} = ET_c / (1\text{-}LR)$$

$$IWR_g = IWR_{net} / E_a$$

- Areas where precipitation is significant part of growing season water balance, EC of applied water must include rainfall

Irrigation Requirements

- Which approach: traditional method to satisfy crop ET or salinity control?
- Compute by both methods
- Larger computed value governs
- In many cases with less efficient irrigation methods, the DP that occurs often satisfies the leaching requirement

Auxiliary Water Requirements

- Frost protection
- Crop cooling
- Wind erosion control
- Chemigation
- Germination
- Seedbed preparation/pre-irrigation

Example

- Location: La Junta CO
- Crop: grain corn (May 1 planting, October 1 harvest), 4 ft root zone, 50% MAD, 1.7 mmhos/cm threshold salt tolerance (EC_t)
- Soil: Sandy loam soil, 1.5 in/ft AWHC, well-drained, no water table
- Irrigation: 120 ac circle, 1.25 inch normal irrigation depth, 80% application efficiency, no runoff, irrigation water salinity of 2.3 mmhos/cm

Example

1950-2004 average ET_r, ET_c, and 30 yr Normal Precipitation at La Junta CO (11.0 in/year annual mean)

Month	ET_r (in/mo)	Mean K_c	ET_c (in/mo)	Precip (in/mo)
May	8.9	0.19	1.7	1.6
June	11.0	0.40	4.4	1.4
July	10.6	0.89	9.4	2.0
August	8.5	0.95	8.1	1.4
Sept	6.6	0.82	5.0	1.0
Total	45.6	---	28.6	7.4

Example

Month	ET_c (in/mo)	Precip (in/mo)	Eff. Precip (in/mo)
May	1.7	1.7	1.1
June	4.4	1.3	1.0
July	9.4	2.1	2.0
August	8.1	1.5	1.4
Sept	5.0	0.9	0.7
Total	28.6	7.5	6.2

From NEH Chap 2, Table 2-43 and a 3 inch usable soil water

Example

- Net Irrigation Requirement:

$$\Delta SW = 1.5 \times 4 \times 50\% = 3 \text{ inches}$$

$$GW = 0.0$$

$$IWR_{net} = ET_c - P_e - \Delta SW - GW$$

$$= 28.6 - 6.2 - 3$$

$$= 19.4 \text{ inches}$$

- Gross Irrigation Requirement:

$$IWR_g = IWR_{net} / E_a$$

$$= 19.4 / 0.80$$

$$= 24.2 \text{ inches}$$

Example

- Irrigation Requirements for Salinity Control:

$$LR = EC_{aw} / EC_d^*$$

$$EC_d^* = fct(EC_t \text{ and } EC_{aw})$$

$$LR=0.23 \text{ for } EC_t / EC_{aw} = 1.7/2.3 = 0.74$$

(from NEH Chap 2 Figure 2-33, curve 3)

$$IWR_{net} = (ET_c - P_e - \Delta SW) / (1-LR)$$
$$= (28.6 - 6.2 - 3) / (1 - 0.23)$$
$$= 19.4 / 0.77$$
$$= 25.2 \text{ inches}$$

$$IWR_g = IWR_{net} / E_a$$
$$= 25.2 / 0.80$$
$$= 31.5 \text{ inches}$$

Summary

- ET is key component to determining irrigation water requirements
  - Climate based ET estimation
  - Crop coefficients
- Net irrigation requirements
  - $ET_c – P_e - \Delta SW - GW$
- Gross irrigation requirement
  - Dependent on irrigation method, management, efficiency
- Leaching and salt balance
- Auxiliary requirements