

# CalSimHydro v2.0 Updates

## Hydrology and Climate Change Session

### 2025 CWEMF Annual Meeting

#### Session 33

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Date: May 14, 2025

James Polsinelli (DWR)



# Outline

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- Summary of CalSimHydro v1.0
- Summary of differences between v1.0 and v2.0
- V2.0 Rainfall Runoff Method
- Applied water differences
- Percolation method
- Small Watersheds
- Domain expansion



# CalSimHydro v2.0 Background

- Started with the 2023 CalSim-C2VSimCG alignment and streamlining efforts.
  - Can Dogrul, Malinda Wimalaratne, Shalamu Abudu, and Jim Polsinelli went off to modernize this interaction;
  - New CS3 groundwater DLL, updates to C2VSim (r374 to v1.0), updates to CalSim3 stream-groundwater connectivity, and CSHydro v2 are the main outcomes (so far).



# CalSimHydro v1.0

- Developed in late 2000s
- Automated running of and data exchange between several components
  - Daily rainfall runoff simulator (NRCS curve number method)
  - Customized version of IWFM IDC (v3.0)
  - Rice water use models
  - Refuge water use model
  - Hydrologic water balance diagnosis utility
  - CalSimHydro EE and Small Watershed Module
- IDC has matured significantly since CalSimHydro v1.0

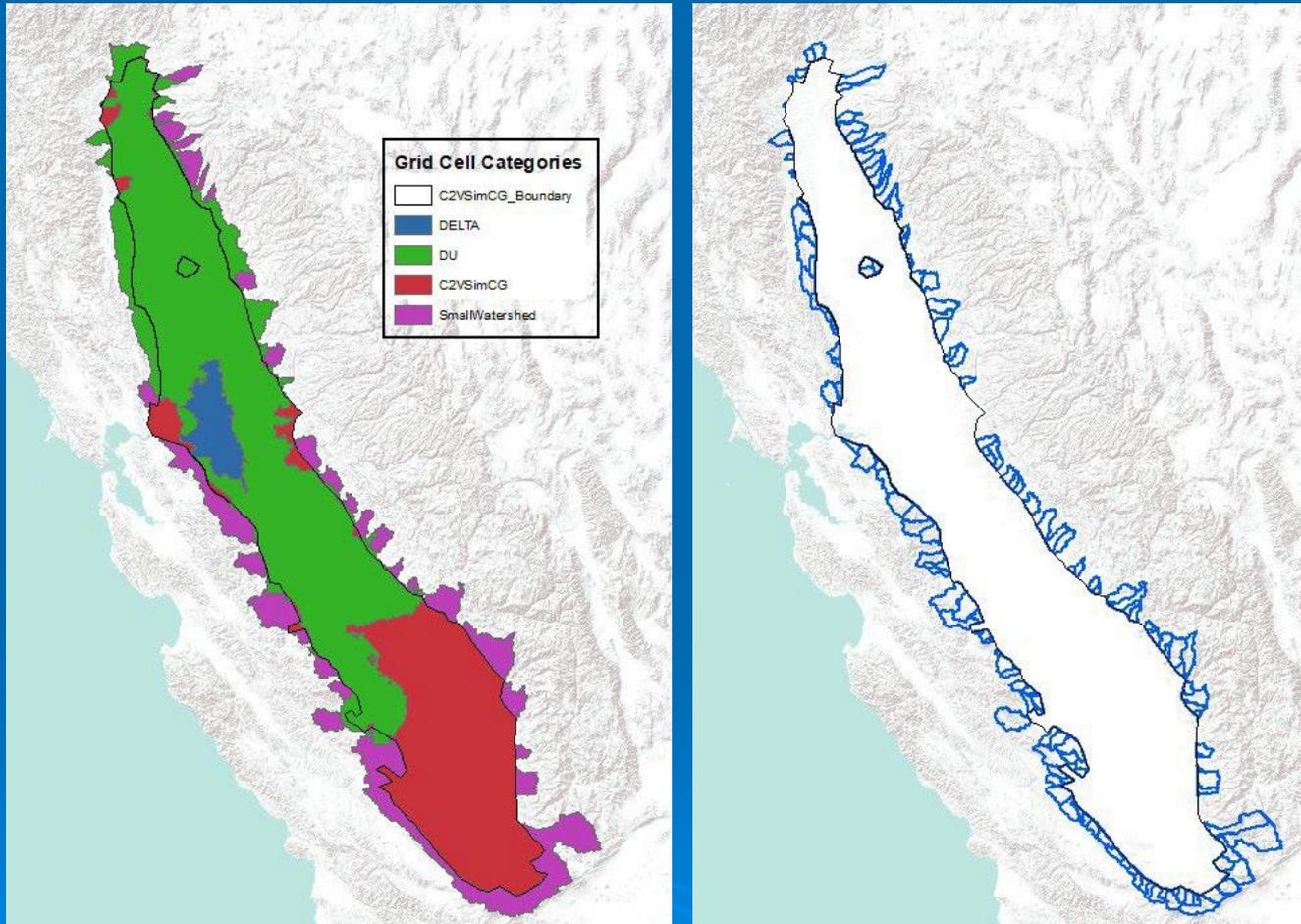


# CalSimHydro v2.0

- Uses the latest IDC to simulate all four processes.
- No need for the separate water balance diagnosis tool.
- Simulates recharge and boundary inflows into the Central Valley groundwater system.
  - Includes small watersheds,
  - Includes the C2VSimCG v1.0 domain (CSHydroEE).
- Rainfall runoff is simulated using a different method.
- Percolation is simulated using one of two physically-based groundwater flow approximations.
- Uses methods described in UN FAO Paper 56 to compute irrigation water demand



# CalSimHydro v2.0 Domain



# Extended Domain

- CalSimHydro v2.0 domain extended to encompass:
  - DUs,
  - C2VSimGC v1.0 grid cells that are outside of DU boundaries,
  - Small watersheds
- 921 grid cells grouped in 66 categories:
  - 238 DU in 42 WBA
  - All small watersheds in 1 category
  - C2VSimCG v1.0 grid cells in 23 categories.

**Table 1.** Number of WBAs, DUs, small watersheds and C2VSimCG v1.0 grid cells in CalSimHydro v2.0 domain

Hydrologic Region	WBAs	DUs	Small Watersheds	C2VSimCG Grid Cells
Sacramento	30	145	61	72
San Joaquin	10	87	23	19
Tulare	2	6	67	475
<i>TOTAL</i>	42	238	151	566



# Input/Output

**Table 4.** Time series input data (WBA=water budget area; DU=demand unit; SW=small watershed; GC=C2VSimCG v1.0 grid cell)

Data Type	Computational Unit	Time Interval
<i>General</i>		
Precipitation	WBA, SW, GC	Daily
Reference ET (ET <sub>0</sub> )	WBA, SW, GC	Monthly
Land use area	DU, SW, GC	Constant
Irrigation period flag	DU, GC	Daily
<i>Non-ponded crops</i>		
Irrigation trigger minimum moisture	DU, GC	Constant
Irrigation target moisture	DU, GC	Constant
<i>Ponded crops</i>		
Ponding depth	DU	Daily
Pond operations	DU	Daily
<i>Urban</i>		
Population	DU, GC	Constant
Water use specifications	DU, GC	Monthly
Per capita water use	DU, GC	Monthly

- Crop and habitat coefficients are also input under the “General” category.

**Table 3.** Flow terms printed by CalSimHydro v2.0 to be used by CalSim 3.0

Acronym	DSS Data	Spatial Resolution
AWO	Applied water for non-ponded crops	DU
AWR	Applied water for rice	DU
AWW	Applied water for managed wetland (refuge)	DU
PC	Percolation	WBA
SR	Rainfall runoff	WBA
TW	Tailwater (agricultural return flow)	DU
UD	Urban Demand	DU
WW	Wastewater (urban return flow)	DU



# Rainfall Runoff

$$R_p = \frac{1 (P\Delta t - 0.2S)^2}{\Delta t P\Delta t + 0.8S} \quad (5)$$

$$S = \begin{cases} S_{\max} \left[ 1 - \frac{\theta^t - \frac{\theta_f}{2}}{\theta_T - \frac{\theta_f}{2}} \right] & \text{for } \theta^t > \frac{\theta_f}{2} \\ S_{\max} & \text{for } \theta^t \leq \frac{\theta_f}{2} \end{cases} \quad (6)$$

$$S_{\max} = \frac{1000}{CN} - 10 \quad (7)$$

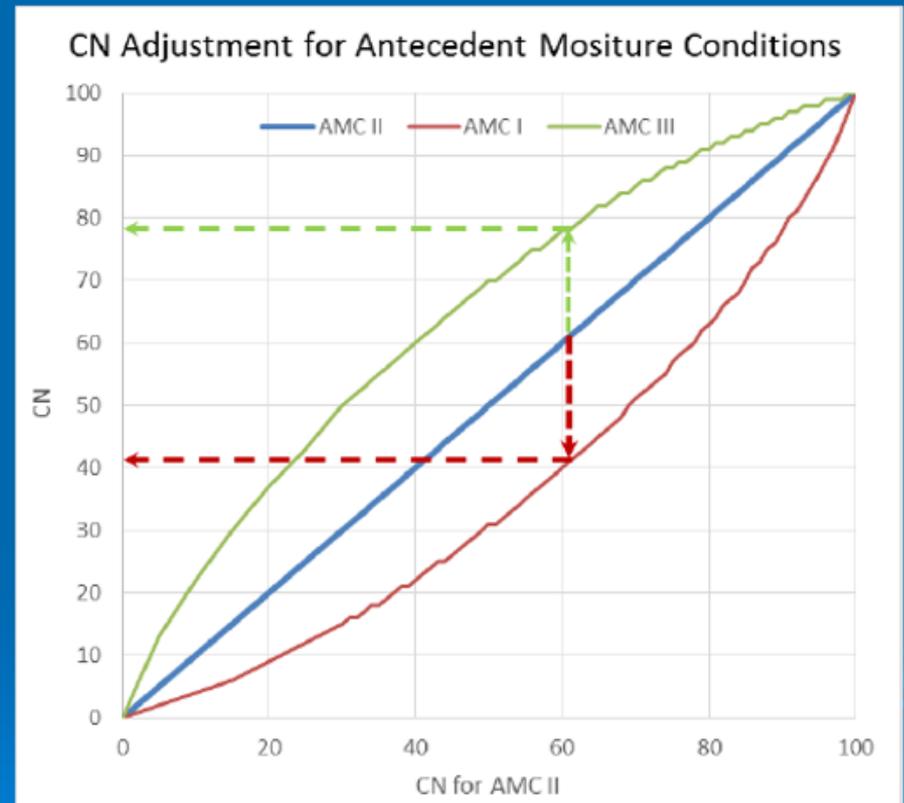
- Modified version of SCS curve number method.
- $\theta$ : total soil moisture content
- $\theta_f$ : soil field capacity
- $\theta_T$ : soil total porosity
- $S$ : soil retention parameter
- $S_{\max}$ :  $S$  for dry antecedent moisture condition
- $CN$ : curve number for a combination of land use, soil type, and management practice.



# CalSimHydro v1.0 Rainfall Runoff

- Curve Number Adjustment for Antecedent Moisture Conditions

Antecedent Moisture Condition		Total Previous 5-Day Precipitation for Given AMC Condition (inches)	
		Dormant Season	Growing Season
AMC I	Dry	< 0.5	< 1.4
AMC II	Average	0.5 – 1.1	1.4 – 2.1
AMC III	Wet	> 1.1	> 2.1



# Percolation

- Amount of vertical moisture flow that leaves the root zone through lower boundary.
- One dimensional approximation through the equation:
  - $P_C^{t+1} = K(\theta^{t+1}Z^{t+1}) \frac{dh(\theta^{t+1}Z^{t+1})}{dz}$
  - K is the unsaturated hydraulic conductivity,
  - h is the pressure head,
  - Z is the vertical distance from the land surface
- Percolation in CalSimHydro v1.0 is computed as the amount of soil moisture above the field capacity.



# Percolation Approximations

- Two approximations available. Van Genuchten-Mualem:

- $$P_C^{t+1} = P_{Crdc}^{t+1} + K_s \sqrt{\frac{\theta^{t+1}}{\theta^T}} \left\{ 1 - \left[ 1 - \sqrt[m]{\frac{\theta^{t+1}}{\theta^T}} \right]^m \right\}^2$$
 where  $m = \frac{\lambda}{\lambda+1}$

$$P_{Crdc}^{t+1} = \begin{cases} \theta^t (Z^t - Z^{t+1}) & \text{if } Z^t > Z^{t+1} \\ 0 & \text{otherwise} \end{cases}$$

- $K_s$  is the saturated hydraulic conductivity and  $\lambda$  is the pore size distribution index.

- Campbell:

- $$P_C^{t+1} = P_{Crdc}^{t+1} + K_s \left( \frac{\theta^{t+1}}{\theta^T} \right)^{3 + \frac{2}{\lambda}}$$



# Small Watersheds

- Adjacent regions to the CalSim3 domain.
- Contribute boundary inflows into the groundwater basin.
- Assumed that flow is one-way.
- Percolation simulated as the inflow to the groundwater storage at the small watershed.
- $\frac{\partial S_{wg}}{\partial t} = D_{wp} - Q_{wg} - Q_{wgs}$
- $S_{wg}$  is groundwater storage in the small watershed boundary
- $D_{wp}$  is recharge to groundwater storage
- $Q_{wg}$  is subsurface outflow that contributes to groundwater storage in modeled area
- $Q_{wgs}$  is contribution of groundwater storage to the surface flow in the modeled area.



# Small Watersheds

- The subsurface flow terms are approximated as:
  - $Q_{wg} = C_{wg}S_{wg}$  where  $C_{wg}$  is the subsurface flow recession coefficient.
  - $Q_{wgs} = C_{ws}(S_{wg} - S_{wgt})$  where  $C_{ws}$  is a surface runoff recession coefficient, and  $S_{wgt}$  is a threshold value for groundwater storage within the small watershed above which the small watershed contributes to surface flow.



# Solving the Root Zone Equation

- Iterative method that combines Newton's method and the bisection method.
- Newton's method used when the soil moisture is less than 90% of total porosity.
- Bisection used otherwise (mostly for Rice and Refuges)
- CalSimHydro v2.0 is able to solve the full water balance equation simultaneously, including the rainfall runoff and ponded crops.
- V1.0 solves a much simpler system of equations, but is broken up into many different modules. An extra utility is needed to ensure water balance.



# Applied Water & Streamlining

- May be calculated by IDC or
- May be specified in part or total
  - Useful for historical simulation.
  - Useful if applied water is dictated by contractual agreement.
  - Urban applied water is specified.
  - Native vegetation applied water always taken to be zero.
- Run times for v2 shorter!
- Now, v2 combines eight separate processes into IDC, removes the need for one process, and may eliminate two other processes:
  - SJR Adjustment
  - (Possibly) SV Composer



# Status and Documentation

- Migration of the model parameters finished.
- Some parameters have been adjusted from the CalSimHydro v1.0 values in order to keep the results of the v1.0 and v2.0 simulations comparable.
- Full documentation of the v2.0 model finished.
- QA/QC underway by DWR, USBR and partners.



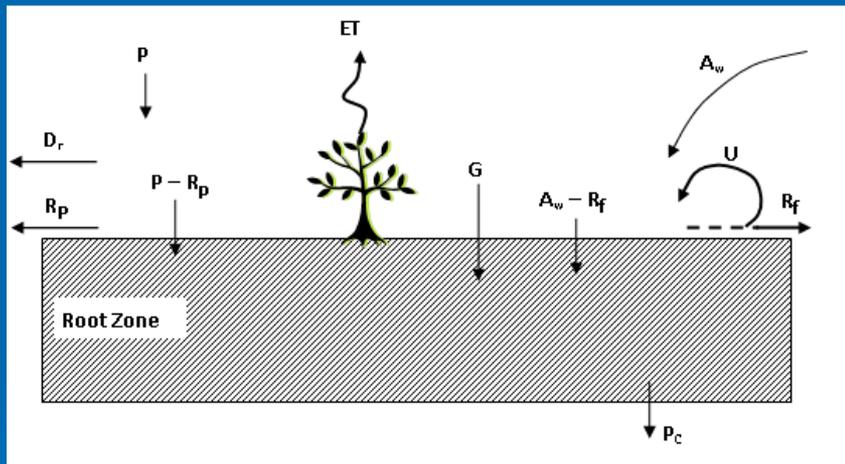
# Question?

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# Root Zone Water Balance



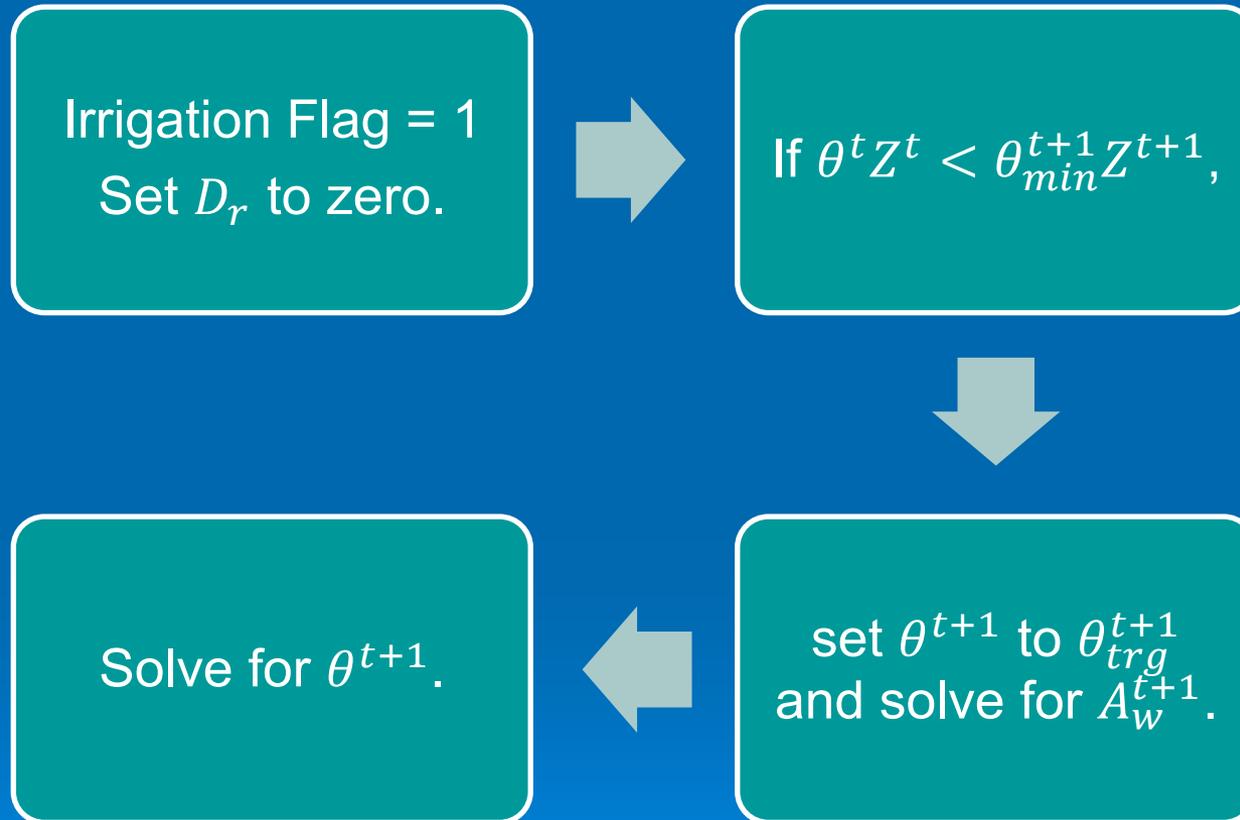
- Inflows:
  - Precipitation (P)
  - Applied water (A<sub>w</sub>)
  - Reused portion of initial return flow (U)
  - Other (user defined) inflows (G)
- Outflows:
  - Rainfall runoff (R<sub>p</sub>)
  - Rice/refuge pond drainage (D<sub>r</sub>)
  - Evapotranspiration (ET)
  - Net return flow after reuse (R<sub>f</sub>)
  - Percolation to groundwater (P<sub>c</sub>)

# Water Demand for Non-Ponded Crops

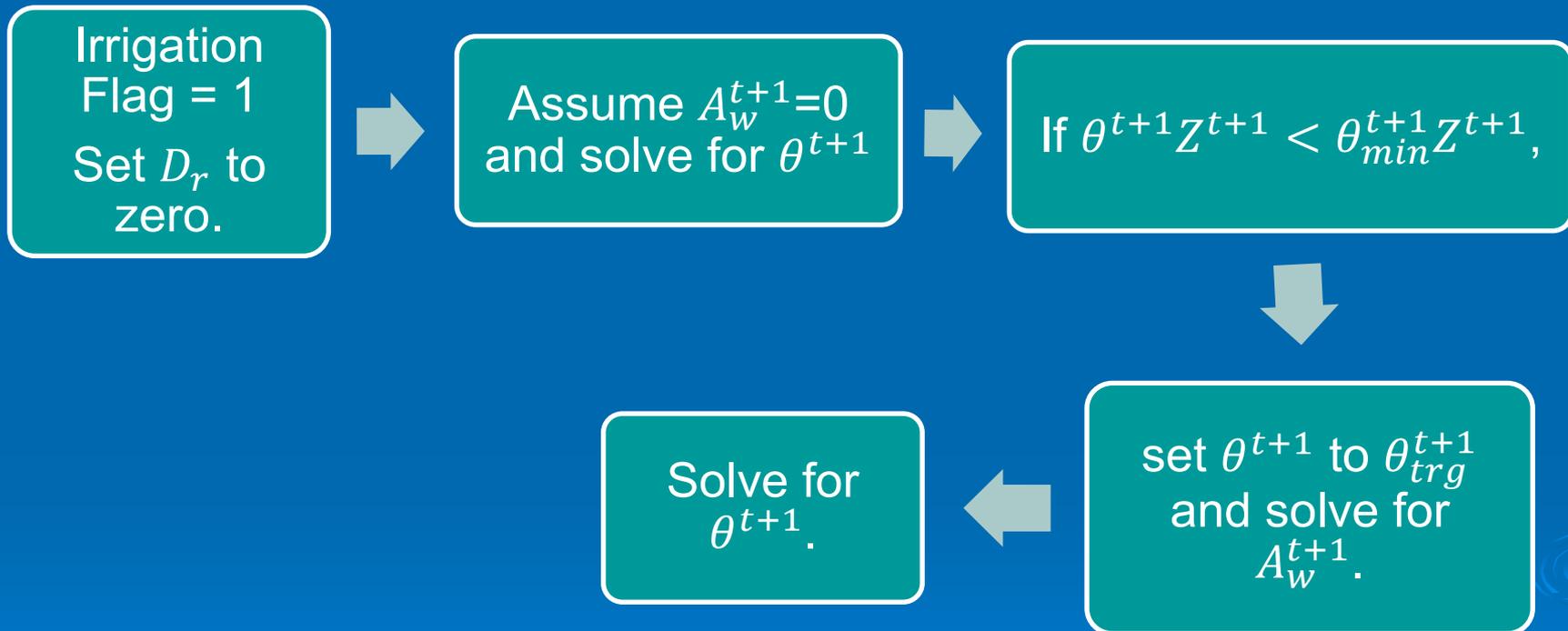
- At each grid cell, the following time series data is needed:
  - Irrigation period flag
  - Irrigation trigger min soil moisture
  - Irrigation target soil moisture
  - Min. percolation requirement as a fraction of infiltrated applied water (uncommon)
  - Return flow and re-use fractions
- User specifies if the soil moisture at the beginning or end of a timestep is used.
  - For day timestep, beginning
  - For month, end

$$A_w^{t+1} = \begin{cases} \frac{\theta_{\text{trg}}^{t+1} Z^{t+1} - \theta^t Z^t - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} - G^{t+1} Z^{t+1} + P_{\text{Ctrg}}^{t+1} + ET_{\text{trg}}^{t+1} & \text{if } \theta^t Z^t < \theta_{\text{min}}^{t+1} Z^{t+1} \\ 1 - \left( f_{R_f, \text{ini}}^{t+1} - f_U^{t+1} \right) & \\ 0 & \text{if } \theta^t Z^t \geq \theta_{\text{min}}^{t+1} Z^{t+1} \end{cases} \quad (23)$$

# Non-Ponded Crops – Short Timestep



# Non-Ponded Crops – Long Timestep



# Root Zone Water Balance Equation

$$\theta^{t+1}Z^{t+1} = \theta^t Z^t$$

$$+\Delta t(P^{t+1} - R_p^{t+1} + A_w^{t+1} - R_f^{t+1} + G^{t+1}Z^{t+1} - D_r^{t+1} - P_C^{t+1} - ET^{t+1})$$

$$+\Delta\theta_a^{t+1}$$

and

$$\theta^{t+1} = \theta_p^{t+1} + \theta_{A_w}^{t+1} + \theta_G^{t+1} \quad (2)$$

$$\theta^t = \theta_p^t + \theta_{A_w}^t + \theta_G^t \quad (3)$$

$$R_f^{t+1} = R_{f,ini}^{t+1} - U^{t+1} \quad (4)$$

$$R_f = A_w (f_{R_{f,ini}} - f_U)$$

$$R_{f,ini} = A_w f_{R_{f,ini}}$$

$$U = A_w f_U$$

where

$\theta_p$  = soil moisture content due to precipitation (L/L),

$\theta_{A_w}$  = soil moisture content due to applied water (L/L),

$\theta_G$  = soil moisture content due to a generic, user-defined moisture inflow (L/L),

$\theta$  = total soil moisture content (L/L),

$Z$  = rooting depth (L);

$P$  = rate of precipitation (L/T),

$R_p$  = rainfall runoff (L/T),



$A_w$  = applied water, i.e. irrigation (L/T),  
 $R_{f,ini}$  = initial return flow (L/T),  
 $U$  = re-used portion of the initial return flow (L/T),  
 $R_f$  = net return flow after re-use takes place (L/T),  
 $G$  = a generic, user-defined moisture inflow to represent any source of moisture other than precipitation or irrigation (L/L/T),  
 $D_r$  = outflow due to the draining of rice and refuge ponds (L/T),  
 $P_C$  = percolation (L/T),  
 $ET$  = evapotranspiration (L/T),  
 $\Delta\theta_a$  = change in soil moisture due to change in land use area (L),  
 $t$  = the time step index (dimensionless),



# Drainage of Rice and Refuge Ponds

- Rice and Refuge ponds are drained periodically.
- A timeseries of pond depths may be input.
- Drainage is defined as:

$$D_r^{t+1} = \frac{P_D^t - P_D^{t+1}}{\Delta t} \geq 0$$



# Evapotranspiration

- Calculations based on potential ET,  $ET_{pot}$ , taken to be crop ET under standard conditions,  $ET_c$ .

- $$ET^{t+1} = \begin{cases} ET_{pot}^{t+1} & \text{if } \theta^{t+1} > \frac{\theta_f + \theta_{wp}}{2} \\ 2 \frac{\theta^{t+1} - \theta_{wp}}{\theta_f - \theta_{wp}} ET_{pot}^{t+1} & \text{if } \theta_{wp} \leq \theta^{t+1} \leq \frac{\theta_f + \theta_{wp}}{2} \\ 0 & \text{if } \theta^{t+1} < \theta_{wp} \end{cases}$$

- $\theta_f$  is the field capacity,  $\theta_{wp}$  is the wilting point.
- CalSimHydro v1.0 uses the same equation but assumes  $\theta_{wp}$  is negligible.



# Ponded Crops

If  $P_D^{t+1} > 0$

Set  $D_r, R_f = 0, P_c = K_s, ET = ET_{pot}, \theta^{t+1}Z^{t+1} = \theta_T Z + P_D^{t+1}$

$$A_{w,ini}^{t+1} = \frac{\theta_T Z + P_D^{t+1} - \theta^t Z}{\Delta t} - P^{t+1} + R_p^{t+1} + K_s + ET_{pot}^{t+1} + D_R^{t+1}$$

$$A_w^{t+1} = A_{w,ini}^{t+1} + R_{f,ini}^{t+1} - U^{t+1}$$

If  $A_{w,ini}^{t+1} > 0$ ,  
compute  $D_r, R_f$

