

CWEMF IWFM v4.0 Workshop

January 7-8, 2014
West Yost Associates, Davis, CA

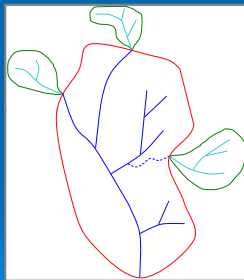
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Session 8: Small Watershed Boundary Condition and Simulation of Multiple Aquifer Layers



Small Watershed Boundary Condition

- Subsurface and surface flows into modeled area from adjacent small watersheds are simulated approximately
- Surface flows from small watersheds can contribute to groundwater as well as stream flows



Small Watershed Boundary Condition

- Subsurface flow from small watersheds contribute to groundwater at nodes specified by the user:

$$Q_{wg} = C_{wg} S_{wg}$$

Q_{wg} = subsurface outflow component, (L^3/T);

C_{wg} = subsurface flow recession coefficient, ($1/T$);

S_{wg} = groundwater storage within the small watershed boundary, (L^3).



Small Watershed Boundary Condition

- Surface flow from small watersheds contribute to stream flow at nodes specified by the user:

$$Q_{ws} = C_{ws}(S_{wg} - S_{wgt}) \quad \text{if } S_{wg} > S_{wgt}$$

- Q_{ws} = surface outflow component, (L³/T);
- C_{ws} = surface runoff recession coefficient, (1/T);
- S_{wg} = groundwater storage within small watershed boundary, (L³);
- S_{wgt} = threshold value for groundwater storage within the small watershed, (L³).



Small Watershed Boundary Condition

- Groundwater storage in small watershed:

$$S_{wg}^{t+1} = S_{wg}^t + D_{sw} - (Q_{ws} + Q_{wg})\Delta t$$

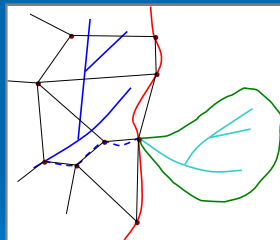
- Deep percolation in small watersheds, D_{sw} is simulated the same way as in the root zone component using either Campbell's or van Genuchten-Mualem equation
- Routing of soil moisture in small watersheds is the same as in the root zone component:

$$Z_{sw}^{0,t+1} = Z_{sw}^{0,t} + \Delta t (P_{sw} - R_{Psw} - D_{sw} - ET_{sw})$$



Small Watershed Boundary Condition

- Surface flows from small watersheds may contribute to groundwater as percolation from creeks that are not modeled
- User defined percolation rates at specified groundwater nodes



Groundwater Flow in Multiple Aquifer Layers

$$\frac{\partial S_s h}{\partial t} - \nabla (T \nabla h) - I_u q_u - I_d q_d - Q = 0$$

- S_s = Storativity, (dimensionless);
- h = Groundwater head, (L);
- T = Transmissivity = Kh_s , (L^2/T);
- K = Hydraulic conductivity, (L/T);
- h_s = Saturated thickness of aquifer, (L);
- t = Time (T);
- q_u, q_d = Flow from adjacent upper and lower aquifer layers, (L/T);
- I_u, I_d = Indicator functions for top and bottom aquifer, (dimensionless);
- Q = Source/sink term, (L/T).



Groundwater Flow in Multiple Aquifer Layers

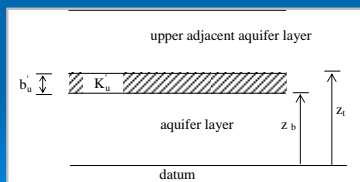
$$\frac{\partial S_s h}{\partial t} - \nabla (T \nabla h) - I_u q_u - I_d q_d - Q = 0$$

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- Q = Source/sink term, (L/T).



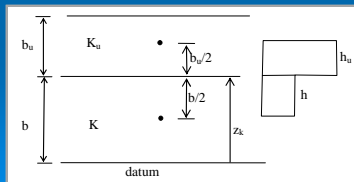
Vertical Flow (Aquifer Layers Separated by an Aquitard)

$$q_u = -L_u(h - h_u) = -\frac{K'_u}{b_u}(h - h_u)$$



Vertical Flow (Aquifer Layers not Separated by an Aquitard)

$$q_u = -L_u(h - h_u) = -\left[\frac{1}{0.5\left(\frac{b_u}{K_u} + \frac{b}{K}\right)}\right](h - h_u)$$

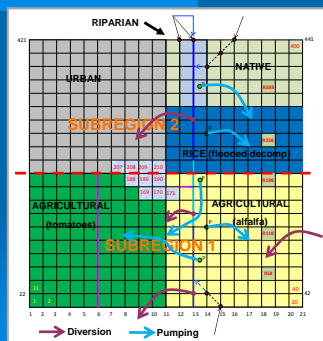


Groundwater Flow in Multiple Aquifer Layers (after substitution)

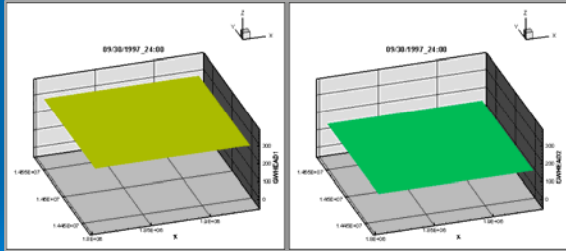
$$\frac{\partial S_s h}{\partial t} - \nabla \cdot (T \nabla h) + I_u L_u (h - h_u) + I_d L_d (h - h_d) - Q = 0$$

- S_s = Storativity, (dimensionless);
- h = Groundwater head, (L);
- T = Transmissivity = Kh_s , (L^2/T);
- K = Hydraulic conductivity, (L/T);
- h_s = Saturated thickness of aquifer, (L);
- t = Time (T);
- I_u, I_d = Indicator functions for top and bottom aquifer, (dimensionless);
- h_u, h_d = Groundwater head at adjacent upper and lower aquifer layers, (L/T);
- L_u, L_d = Leakage coefficients of adjacent upper and lower aquifer layers, ($1/T$);
- Q = Source/sink term, (L/T).

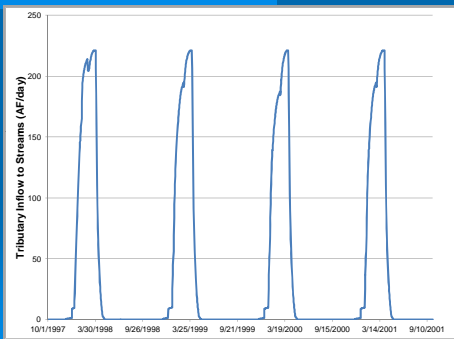
Example 8



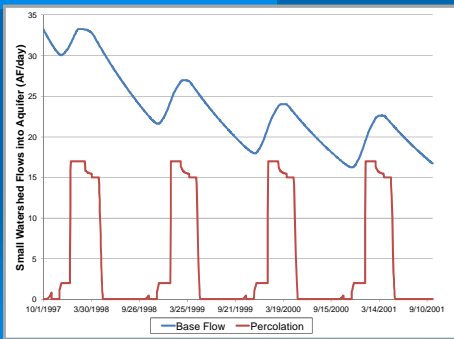
Example 8: Groundwater Heads



Example 8: Contribution of Small Watersheds to Streams



Example 8: Contribution of Small Watersheds to Groundwater



Example 8: Vertical Flow

