delay times for a watershed. Sangrey et al. (1984) noted that monitoring wells in the same area had similar values for δ_{gw}, so once a delay time value for a geomorphic area is defined, similar delay times can be used in adjoining watersheds within the same geomorphic province.

2:4.2.2 PARTITIONING OF RECHARGE BETWEEN SHALLOW AND DEEP AQUIFER

A fraction of the total daily recharge can be routed to the deep aquifer. The amount of water than will be diverted from the shallow aquifer due to percolation to the deep aquifer on a given day is:

$$w_{deep} = \beta_{deep} \cdot w_{rchrg} \qquad 2:4.2.4$$

where w_{deep} is the amount of water moving into the deep aquifer on day i (mm H_2O), β_{deep} is the aquifer percolation coefficient, and w_{rchrg} is the amount of recharge entering both aquifers on day i (mm H_2O). The amount of recharge to the shallow aquifer is:

$$w_{rchrg,sh} = \cdot w_{rchrg} - w_{deep} \qquad 2:4.2.5$$

where $w_{rchrg,sh}$ is the amount of recharge entering the shallow aquifer on day i (mm H_2O).

2:4.2.3 GROUNDWATER/BASE FLOW

The shallow aquifer contributes base flow to the main channel or reach within the subbasin. Base flow is allowed to enter the reach only if the amount of water stored in the shallow aquifer exceeds a threshold value specified by the user, $aq_{shthr,q}$.

The steady-state response of groundwater flow to recharge is (Hooghoudt, 1940):

$$Q_{gw} = \frac{8000 \cdot K_{sat}}{L_{gw}^{\ 2}} \cdot h_{wtbl} \qquad 2:4.2.6$$

where Q_{gw} is the groundwater flow, or base flow, into the main channel on day i (mm H_2O), K_{sat} is the hydraulic conductivity of the aquifer (mm/day), L_{gw} is the distance from the ridge or subbasin divide for the groundwater system to the main channel (m), and h_{wtbl} is the water table height (m).

Water table fluctuations due to non-steady-state response of groundwater flow to periodic recharge is calculated (Smedema and Rycroft, 1983):

$$\frac{dh_{wtbl}}{dt} = \frac{w_{rchrg,sh} - Q_{gw}}{800 \cdot \mu} \qquad 2:4.2.7$$

where $\frac{dh_{wtbl}}{dt}$ is the change in water table height with time (mm/day), $w_{rchrg,sh}$ is the amount of recharge entering the shallow aquifer on day i (mm H_2O), Q_{gw} is the groundwater flow into the main channel on day i (mm H_2O), and μ is the specific yield of the shallow aquifer (m/m).

Assuming that variation in groundwater flow is linearly related to the rate of change in water table height, equations 2:4.2.7 and 2:4.2.6 can be combined to obtain:

$$\frac{dQ_{gw}}{dt} = 10 \cdot \frac{K_{sat}}{\mu \cdot L_{gw}^{2}} \cdot \left(w_{rchrg,sh} - Q_{gw}\right) = \alpha_{gw} \cdot \left(w_{rchrg,sh} - Q_{gw}\right) \qquad 2:4.2.8$$

where Q_{gw} is the groundwater flow into the main channel on day i (mm H_2O), K_{sat} is the hydraulic conductivity of the aquifer (mm/day), μ is the specific yield of the shallow aquifer (m/m), L_{gw} is the distance from the ridge or subbasin divide for the groundwater system to the main channel (m), $w_{rchrg,sh}$ is the amount of recharge entering the shallow aquifer on day i (mm H_2O) and α_{gw} is the baseflow recession constant or constant of proportionality. Integration of equation 2:4.2.8 and rearranging to solve for Q_{gw} yields:

$$Q_{gw,i} = Q_{gw,i-1} \cdot \exp\left[-\alpha_{gw} \cdot \Delta t\right] + w_{rchrg,sh} \cdot \left(1 - \exp\left[-\alpha_{gw} \cdot \Delta t\right]\right)$$

$$\text{if } aq_{sh} > aq_{shthr,q} \qquad 2:4.2.9$$

$$Q_{gw,i} = 0 \qquad \text{if } aq_{sh} \le aq_{shthr,q} \qquad 2:4.2.10$$

where $Q_{gw,i}$ is the groundwater flow into the main channel on day i (mm H_2O), $Q_{gw,i-1}$ is the groundwater flow into the main channel on day i-1 (mm H_2O), α_{gw} is the baseflow recession constant, Δt is the time step (1 day), $w_{rchrg,sh}$ is the amount of recharge entering the shallow aquifer on day i (mm H_2O), aq_{sh} is the amount of water stored in the shallow aquifer at the beginning of day i (mm H_2O) and

$aq_{shthr,q}$ is the threshold water level in the shallow aquifer for groundwater contribution to the main channel to occur (mm H_2O).

The baseflow recession constant, α_{gw}, is a direct index of groundwater flow response to changes in recharge (Smedema and Rycroft, 1983). Values vary from 0.1-0.3 for land with slow response to recharge to 0.9-1.0 for land with a rapid response. Although the baseflow recession constant may be calculated, the best estimates are obtained by analyzing measured streamflow during periods of no recharge in the watershed.

When the shallow aquifer receives no recharge, equation 2:4.2.9 simplifies to:

$$Q_{gw} = Q_{gw,0} \cdot \exp\left[-\alpha_{gw} \cdot t\right] \qquad \text{if } aq_{sh} > aq_{shthr,q} \qquad 2:4.2.11$$

$$Q_{gw,i} = 0 \qquad \text{if } aq_{sh} \leq aq_{shthr,q} \qquad 2:4.2.12$$

where Q_{gw} is the groundwater flow into the main channel at time t (mm H_2O), $Q_{gw,0}$ is the groundwater flow into the main channel at the beginning of the recession (time t=0) (mm H_2O), α_{gw} is the baseflow recession constant, and t is the time lapsed since the beginning of the recession (days), aq_{sh} is the amount of water stored in the shallow aquifer at the beginning of day i (mm H_2O) and $aq_{shthr,q}$ is the threshold water level in the shallow aquifer for groundwater contribution to the main channel to occur (mm H_2O). The baseflow recession constant is measured by rearranging equation 2:4.2.11.

$$\alpha_{gw} = \frac{1}{N} \cdot \ln\left[\frac{Q_{gw,N}}{Q_{gw,0}}\right] \qquad 2:4.2.13$$

where α_{gw} is the baseflow recession constant, N is the time lapsed since the start of the recession (days), $Q_{gw,N}$ is the groundwater flow on day N (mm H_2O), $Q_{gw,0}$ is the groundwater flow at the start of the recession (mm H_2O).

It is common to find the baseflow days reported for a stream gage or watershed. This is the number of days for base flow recession to decline through one log cycle. When baseflow days are used, equation 2:4.2.13 can be further simplified:

$$\alpha_{gw} = \frac{1}{N} \cdot \ln\left[\frac{Q_{gw,N}}{Q_{gw,0}}\right] = \frac{1}{BFD} \cdot \ln[10] = \frac{2.3}{BFD} \qquad 2:4.2.14$$

where α_{gw} is the baseflow recession constant, and *BFD* is the number of baseflow days for the watershed.

2:4.2.4 REVAP

Water may move from the shallow aquifer into the overlying unsaturated zone. In periods when the material overlying the aquifer is dry, water in the capillary fringe that separates the saturated and unsaturated zones will evaporate and diffuse upward. As water is removed from the capillary fringe by evaporation, it is replaced by water from the underlying aquifer. Water may also be removed from the aquifer by deep-rooted plants which are able to uptake water directly from the aquifer.

SWAT models the movement of water into overlying unsaturated layers as a function of water demand for evapotranspiration. To avoid confusion with soil evaporation and transpiration, this process has been termed „revap". This process is significant in watersheds where the saturated zone is not very far below the surface or where deep-rooted plants are growing. Because the type of plant cover will affect the importance of revap in the water balance, the parameters governing revap are usually varied by land use. Revap is allowed to occur only if the amount of water stored in the shallow aquifer exceeds a threshold value specified by the user, $aq_{shthr,rvp}$.

The maximum amount of water than will be removed from the aquifer via „revap" on a given day is:

$$w_{revap,mx} = \beta_{rev} \cdot E_o \qquad 2:4.2.15$$

where $w_{revap,mx}$ is the maximum amount of water moving into the soil zone in response to water deficiencies (mm H_2O), β_{rev} is the revap coefficient, and E_o is the potential evapotranspiration for the day (mm H_2O). The actual amount of revap that will occur on a given day is calculated:

$$w_{revap} = 0 \qquad \text{if } aq_{sh} \leq aq_{shthr,rvp} \qquad 2:4.2.16$$

$$w_{revap} = w_{revap,mx} - aq_{shthr,rvp} \qquad \text{if } aq_{shthr,rvp} < aq_{sh} < \left(aq_{shthr,rvp} + w_{revap,mx}\right) \qquad 2:4.2.17$$