Overview of WEPP Model Science
WEPP Model Components

- Climate Simulation
- Irrigation
- Winter Processes
- Surface Hydrology
- Water Balance & Percolation
- Subsurface Hydrology
- Soil Component
- Plant Growth
- Residue Decomposition and Management
- Overland Flow Hydraulics
- Hillslope Erosion Component
Additional WEPP Model Watershed Components

- Channel Flow Hydraulics
- Channel Erosion
- Surface Impoundment Element
HOW WEPP WORKS
Daily Simulation Model

- Every day – computes status of land – biomass & soil
- If we have precipitation (rain, snowmelt, irrigation), computes runoff
- If runoff is computed, computes sediment detachment, transport and deposition
HILLSLOPES AND OVERLAND FLOW ELEMENTS (OFE)
Climate Simulation

- Stochastic weather generator using long-term station statistics
- 2-stage Markov chain used to predict the occurrence of rainfall
- Predicts storm depth, duration, peak intensity & time of peak occurrence, air temperatures, solar radiation, wind information.
- Parameters for over 2600 stations in US.
INPUT RAINFALL VARIABLES

- Total precipitation—rain or snow
- Duration of precipitation
  - One storm a day
- Time of peak
  - Fraction of duration where peak intensity occurs
- Ratio peak intensity to average intensity

- OR – alternative break point inputs
Irrigation Component

- Stationary Sprinkler Irrigation is simulated in a manner identical to natural rainfall.
- Furrow irrigation uses a special two-dimensional infiltration function.
- Depletion-level scheduling option allows water applications based on dry soil conditions.
- Fixed-date scheduling allows sprinkler or furrow irrigation on any date.
Winter Processes

- Predicts snow accumulation, snow density increases, and snow melting.
- Predicts frost and thaw development in the soil, and impact on infiltration and erosion parameters.
- Hourly calculations
- Snow melt runoff can cause rill detachment.
Surface Hydrology

- Modified Green and Ampt equation for unsteady rainfall
- Solution to Kinematic Wave equation to predict peak runoff rates
- Estimation of depressional storage based on slope & random roughness
- Use of an equivalent plane procedure that allows simulation of nonuniform hydrology on multiple OFEs
Ip  Peak intensity/avg intensity

Time of peak intensity - Tp

Time varying intensity - exponentially increases from time zero to peak, and decreases from peak to end of duration

Average rainfall intensity = Total precipitation / duration

Duration
Infiltration rate

Average rainfall intensity

Instantaneous rainfall intensity

Time varying infiltration: Green-Ampt, based on capillary potential, soil moisture deficit, and saturated hydraulic conductivity
Instantaneous rainfall intensity

Runoff rate—difference between rainfall intensity and infiltration rate

Runoff rate

Infiltration rate

Tp
Erosion and sediment transport at this runoff rate and over this time.
Water Balance & Percolation

- Evapotranspiration (ET) component is a modified Ritchie’s (1972) model
- When wind information is available, WEPP uses the Penman (1963) equation to compute potential ET
- If no wind information available, WEPP uses Priestly–Taylor (1972) ET method
- Soil water balance is updated daily
- Water in soil layers in excess of field capacity is percolated to lower layers
Subsurface Hydrology

- Simple subsurface lateral flow model
- Subsurface Drainage using drain tubes
- Root zone soil water redistribution
- Soil water content effects:
  - infiltration & runoff in subsequent events
  - irrigation scheduling
  - plant growth
  - residue decomposition
Tillage Impacts on:
- Roughness
- Ridge Height
- Bulk Density
- Hydraulic Conductivity
- Erodibility Parameters

Soil Consolidation
Freeze–Thaw Adjustments
Cropland Plant Growth Component

- Based on EPIC crop model (Williams et al., 1989)
- Plant growth is based on daily heat unit accumulation
- Potential growth is a function of PAR – Photosynthetic Active Radiation
- Water & Temperature Stresses limit growth
- Harvest Index to partition biomass
Rangeland Plant Growth Component

- Rangeland Plant Communities modeled instead of individuals
- Unimodal or bimodal potential growth curves user-defined
- Management Options
  - No plant growth
  - Plant growth
  - Grazing with supplemental feed
  - Burning
  - Herbicides
Residue Decomposition and Management

- Cropland Simulations
  - Based on Decomposition Day theory
  - Maximum Decomposition Rate limited by Temperature and Moisture stresses
  - Management options include removal, shredding, and burning

- Rangeland Simulations
  - function of antecedent rainfall, average daily temperature, and C–N ratio of residue
Overland Flow Hydraulics

- Determination of Darcy–Weisbach Hydraulic Roughness Coefficients for:
  - Peak runoff calculations
  - Flow depth calculations
  - Flow shear stress acting on soil
  - Flow shear stress acting on soil
  - Used to estimate Sediment Transport Capacity
  - Used to predict Rill Detachment

- Roughness from Soil Grains, Random Roughness, Plant Residues, Living Plants
Hillslope Erosion Component

- Steady-State Sediment Continuity Equation
- Hillslope is divided into Rill Channels and Interrill Areas
- Interrill Detachment is driven by Rainfall Intensity & Runoff
- Rill Detachment a function of Excess Flow Shear Stress
RILL & INTERRILL EROSION

Diagram showing the flow of water through interrill and rill areas.
RILL DETACHMENT

\[ \tau = \text{Hydraulic Shear} \sim g \ R \ S \qquad R = \frac{A}{WP} = \sim D \]

\( K_r = \text{Rill erodibility, } \tau_c = \text{Critical hydraulic shear stress, } G = \text{Sediment load, } T_c = \text{Sediment transport capacity} \)
RILL DETACHMENT

- Rill Detachment
- Freshly tilled
- Consolidated
- No Till

Hydraulic Shear

$\tau_c$
When sediment load \((G)\) > transport capacity \((T_c)\), deposition occurs. Based on size distribution and fall velocity of sediment being transported.
**RILLS – CHANNELS**

Rill width - Can be set to constant (Furrow irrigation?) Generally computed based on flow rate at lower end of OFE.

Channel width - computed based on flow rate, when depth = last tillage depth, widens till hydraulic shear = critical hydraulic shear
D_i = K_i \cdot I \cdot q \cdot S_f \cdot \text{ADJ} \cdot \text{SDR}_{RR} \cdot F_{\text{nozzle}}

D_i - Interrill detachment, K_i - Interrill erodibility, I - rainfall intensity, q - runoff rate, S_f - slope factor, ADJ - adjustment factors for K_i, SDR_{RR} – sediment delivery ratio, F_{\text{nozzle}} – irrigation nozzle energy adjustment.
Channel Hydrology & Hydraulics

- channel runon and runoff situations
Channel Erosion

- Detachment Capacity: \( D_c = K_{ch}(\cdot \text{ave} - \cdot \text{cr}) \)
- When Sediment Load is below Transport Capacity and average channel flow shear stress exceeds critical shear stress, active Channel Erosion occurs (before the depth of the channel reaches nonerodible layer):
  \( E_{ch} = w_{ch} K_{ch}(\cdot \text{ave} - \cdot \text{cr}) \)
- Once a nonerodible layer is reached, the channel widens and erosion decreases.
Surface Impoundments

- Can simulate various types:
  - farm ponds
  - culverts
  - filter fences
  - check dams
- Based upon more complete CSTRS model (Wilson and Barfield, 1984)
- Assumes a single continuously stirred reactor
Types of Structures to Input

- Drop spillway
- Perforated riser
- Two sets of identical culverts
- Emergency spillway
- Rock-fill check dam
- Filter fence
- Straw bale check dam
- or Discrete stage-discharge values
Surface Impoundments

- The hydraulic simulation section
  - performs a direct numerical integration of an expression of continuity.
  - An adaptive time step is utilized which increases the time step when the inflow and outflow rates are relatively constant.
  - A temporary file of the predicted outflow hydrograph is created.
Surface Impoundments

- The sedimentation section
  - determines the amount of sediment deposited and the outflow concentration for each time step.
  - Conservation of mass and overflow rate concepts are utilized.
  - Two calibration coefficients are used to account for impoundment geometry, hydraulic response, and stratification.