SWAT

Soil and Water Assessment Tool

http://swatmodel.tamu.edu

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SWAT

Model Philosophy

- Readily available input – Physically based
- Comprehensive – Process Interactions
- Simulate Management

SWAT

Model Philosophy

- "Everything should be made as simple as possible. I have no interest in the laws of physics if they can't be made simple"

Albert Einstein

SWAT

ARS Modeling History Time Line

USLE	CREAMS (CLEAN WATER ACT)	EPIC	SWRRB	SWAT
1960's	1970's	1980's		1990's
		GLEAMS	WEPP AGNPS	ANN AGNPS

SWAT

Environmental Models Maintained at Temple, TX

- EPIC—Field Scale
- ALMANAC—Field Scale
- APEX—Farm Scale
- SWAT—Watershed Scale

SWAT

Global Applications

Hydrologic Unit Modeling for Global Eosystem/Environment

International SWAT Conferences

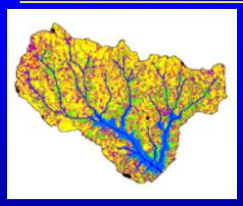
SWAT

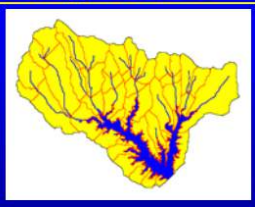
General Description

- Continuous Time
  - Daily Time Step
  - One Day ⟶ Hundreds of Years
- Distributed Parameter
  - Unlimited Number of Subwatersheds
- Comprehensive – Process Interactions
- Simulate Management

SWAT

Example Configuration





- Cells/Subwatersheds
- Hydrologic Response Units
- Output from other Models
- Point Sources - Treatment Plants

SWAT

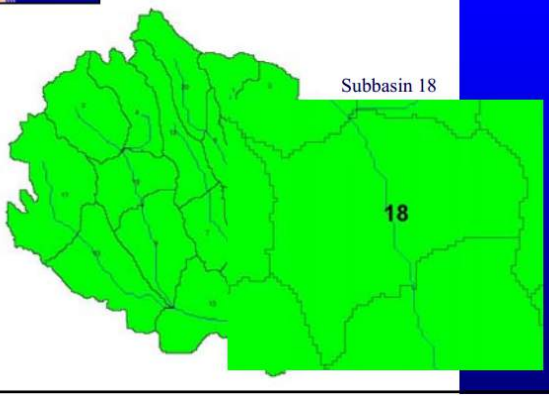
SWAT Watershed System

SWAT

Subbasins and Streams

SWAT

Subbasins and Streams



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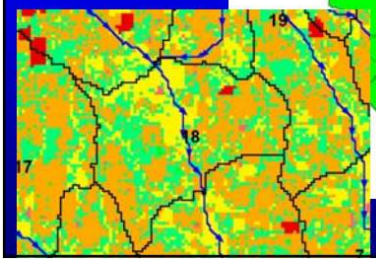
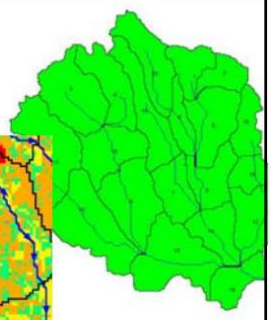
Subbasins and Streams

HRU's
28% Range-Sandy
51% Pasture – Silt
16% Forest – Sandy
4% - Agriculture - Silt





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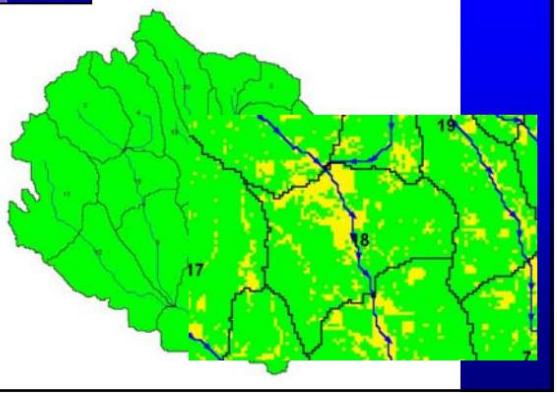
Subbasins and Streams



SWAT

Upland Processes

- Weather
- Hydrology
- Sedimentation
- Plant Growth
- Nutrient Cycling
- Pesticide Dynamics
- Management
- Bacteria

SWAT

Climate

- **Weather**
  - Precipitation
  - Air Temperature and Solar Radiation
  - Wind Speed
  - Relative Humidity
- **Snow**
  - Snow Cover
  - Snow Melt
  - Elevation Bands
- **Soil Temperature**

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Hydrology

- **Canopy Storage**
- **Infiltration**
- **Redistribution**
- **Evapotranspiration**
- **Lateral Subsurface Flow**
- **Surface Runoff**
  - Surface runoff volume
  - Peak runoff
- **Ponds**
- **Tributary Channels**
  - Transmission Losses

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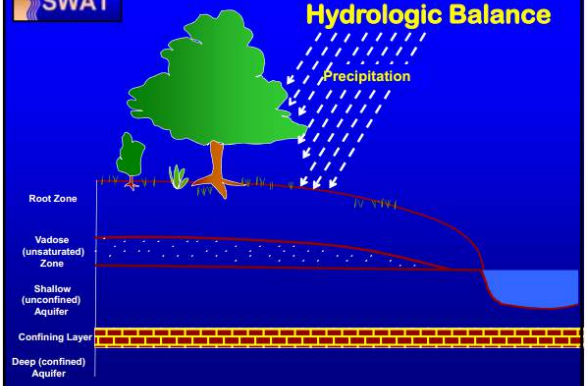
Hydrologic Balance



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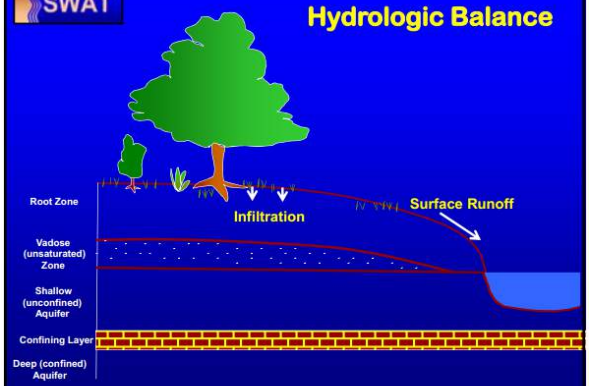
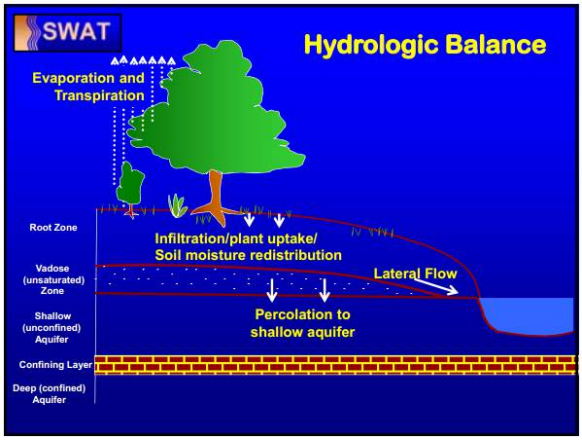
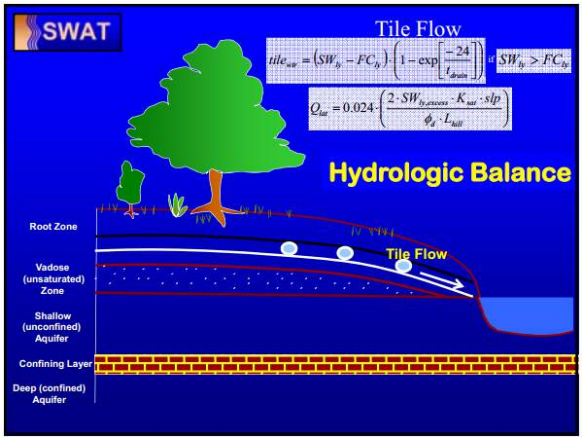
Hydrologic Balance




SWAT
Hydrologic Balance
Evaporation and Transpiration
Root Zone
Infiltration/plant uptake/ Soil moisture redistribution
Vadose (unsaturated) Zone
Lateral Flow
Shallow (unconfined) Aquifer
Percolation to shallow aquifer
Confining Layer
Deep (confined) Aquifer


SWAT
Tile Flow
$tile_{wtr} = (SW_{ly} - FC_{ly}) \cdot \left(1 - \exp\left[\frac{-24}{t_{drain}}\right]\right)$ if $SW_{ly} > FC_{ly}$
$Q_{lat} = 0.024 \cdot \left(\frac{2 \cdot SW_{ly,excess} \cdot K_{sat} \cdot slp}{\phi_d \cdot L_{hill}}\right)$
Hydrologic Balance
Root Zone
Tile Flow
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Confining Layer
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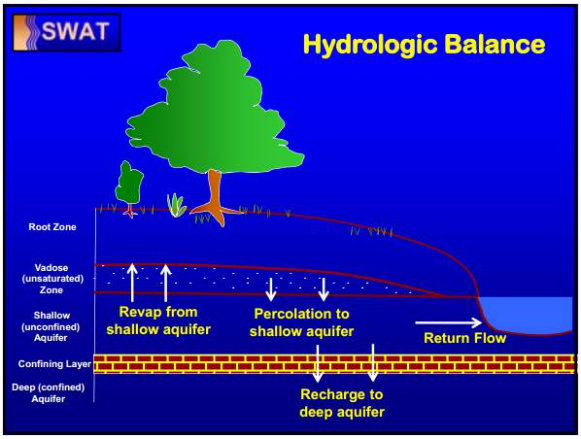
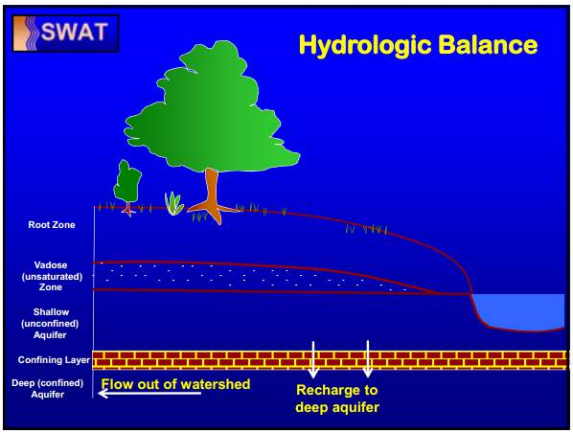
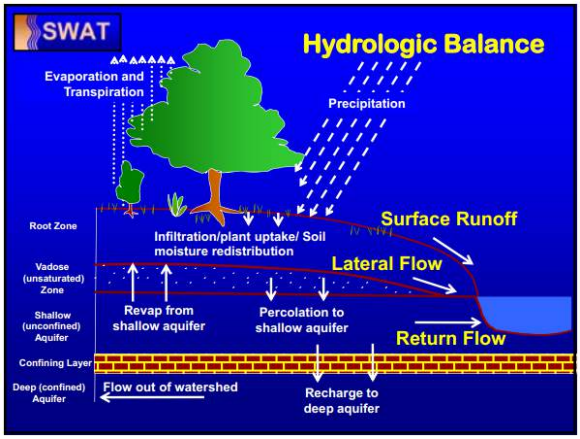

SWAT
Hydrologic Balance
Root Zone
Vadose (unsaturated) Zone
Revap from shallow aquifer
Percolation to shallow aquifer
Shallow (unconfined) Aquifer
Return Flow
Confining Layer
Deep (confined) Aquifer
Recharge to deep aquifer


SWAT
Hydrologic Balance
Root Zone
Vadose (unsaturated) Zone
Shallow (unconfined) Aquifer
Confining Layer
Deep (confined) Aquifer
Flow out of watershed
Recharge to deep aquifer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Evaporation and Transpiration
Precipitation
Root Zone
Surface Runoff
Infiltration/plant uptake/ Soil moisture redistribution
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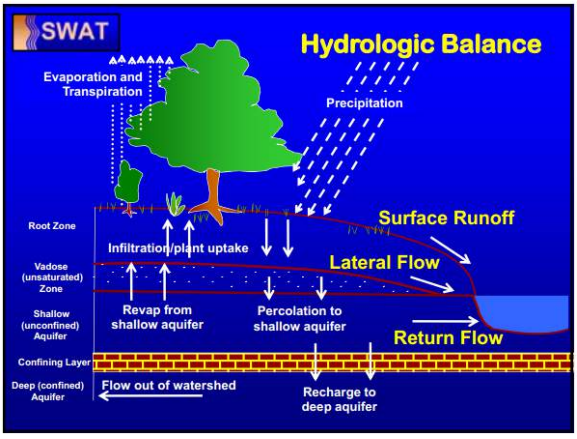
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SWAT

Plant Growth

SWAT

Plant Growth

Yield Prediction
- Harvest Index – Water Stress
- Residue – Cover and Nutrients

Optimum Growth
- Radiation Interception LAI
- Radiation Use Efficiency

Constraints
- Water, Temperature, Nitrogen, Phosphorus

Residue – Cover and Nutrients

Water, Nitrogen and Phosphorus Uptake

Root Growth

SWAT

Climate Change

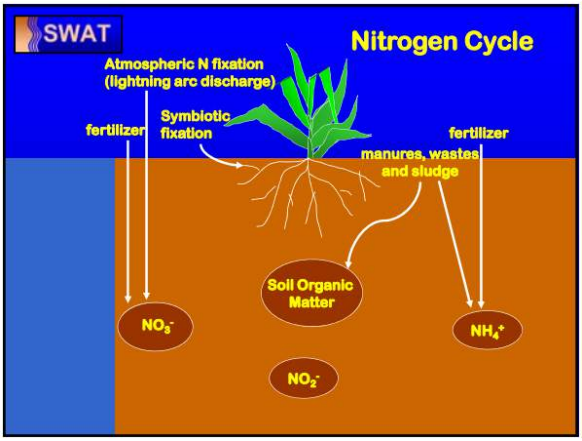
Radiation Use Efficiency Adjusted for CO_2

ET – Penman-Monteith
- Canopy Resistance Adjusted for CO_2
- Impact on Leaf Conductance

CGM Estimates of Precip, Temperature, Humidity, Solar Radiation, Wind Speed

SWAT

Nitrogen Cycle



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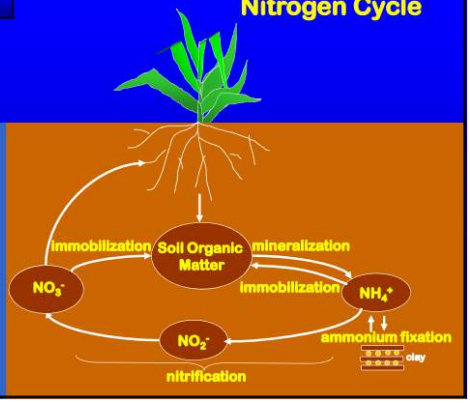
Nitrogen Cycle



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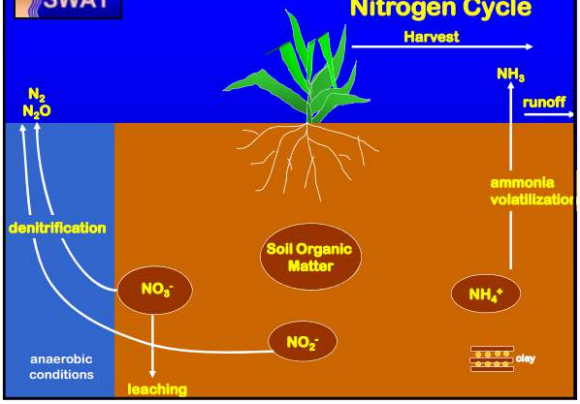
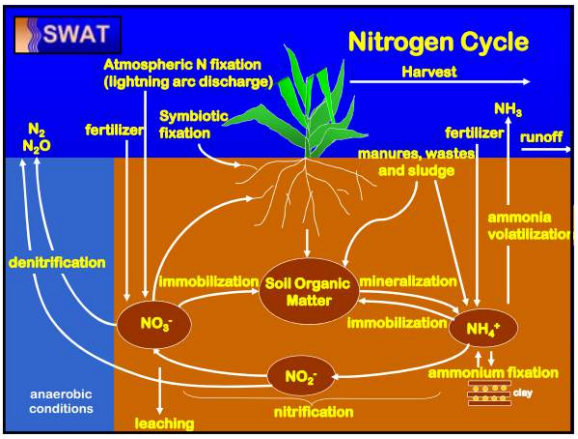
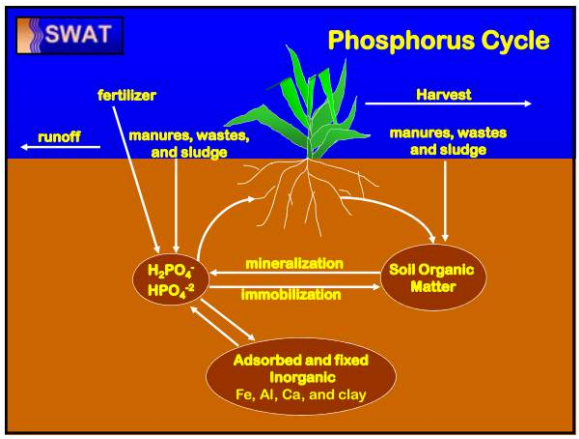
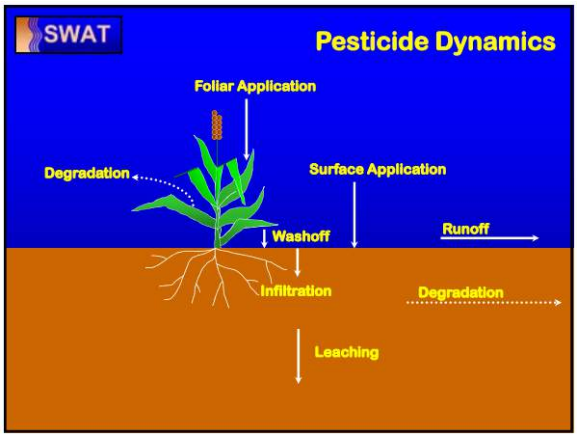
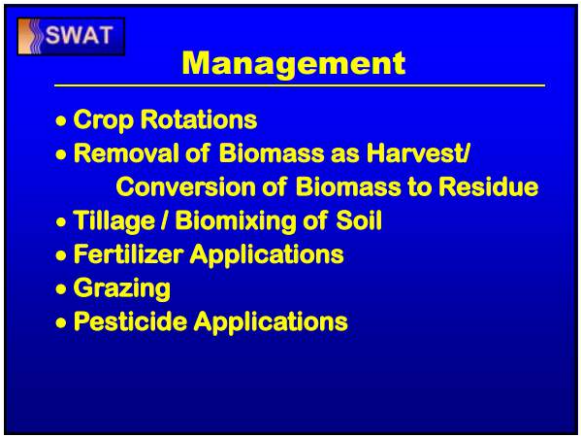
Nitrogen Cycle

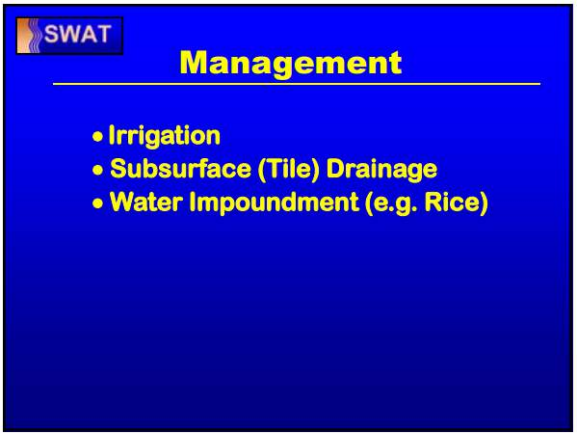



SWAT
Nitrogen Cycle
Atmospheric N fixation
(lightning arc discharge)
Harvest
Symbiotic
fixation
fertilizer
fertilizer
runoff
manures, wastes
and sludge
ammonia
volatilization
denitrification
immobilization
Soil Organic
Matter
mineralization
immobilization
ammonium fixation
clay
anaerobic
conditions
leaching
nitrification


SWAT
Phosphorus Cycle
fertilizer
Harvest
runoff
manures, wastes,
and sludge
manures, wastes
and sludge
mineralization
immobilization
Soil Organic
Matter
Adsorbed and fixed
Inorganic
Fe, Al, Ca, and clay


SWAT
Pesticide Dynamics
Foliar Application
Degradation
Surface Application
Washoff
Runoff
Infiltration
Degradation
Leaching

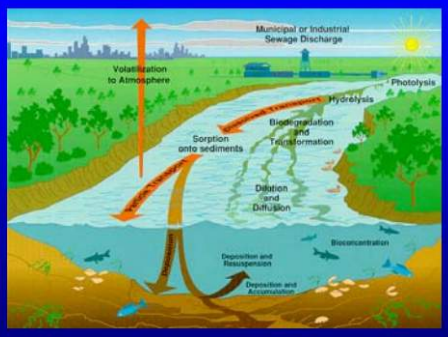

SWAT
Management
• Crop Rotations
• Removal of Biomass as Harvest/
Conversion of Biomass to Residue
• Tillage / Biomixing of Soil
• Fertilizer Applications
• Grazing
• Pesticide Applications


SWAT
Management
• Irrigation
• Subsurface (Tile) Drainage
• Water Impoundment (e.g. Rice)

SWAT
Management
• Urban Areas
Pervious/Impervious Areas
Street Sweeping
Lawn Chemicals
• Edge of Field Buffers

SWAT

Channel Processes



SWAT

Channel Processes

- Flood Routing
  - Variable Storage
  - Muskingum
- Transmission Losses, Evaporation
- Sediment Routing
  - Degradation and deposition computed simultaneously

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Channel Processes

- Nutrients
  - modified QUAL2E/WASP
- Pesticide
  - Toxic balance developed at University of Colorado

SWAT

In-stream Nutrient Processes

Atmospheric Aeration

Well-mixed Water Layer

Transport in → Org N, NH_4, NO_2, NO_3 | Dissolved Oxygen, Carbonaceous BOD | Org P, Dissolved P, Chlorophyll a, Algae → Transport out

Sediment Layer: Benthic Demand for Oxygen; Benthic Sink/Source for Nutrients

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In-stream Pesticide Processes

Volatilization

Well-mixed Water Layer

Transport in → Pesticide in Water → Transport out

Degradation

Settling

Resuspension

Well-mixed Sediment Layer: Pesticide in Sediment

Degradation; Burial

SWAT

Impoundments

- Water Balance
  - Inflow
  - Evaporation
  - Seepage
  - Withdrawals
  - Outflow
    - Spillway Control
    - Target Volume Approach
    - Missouri River Reservoir Operation

SWAT

Impoundments

- Nutrient Balance
  - Well-mixed System
  - Nitrogen & Phosphorus Loss Rates
  - 2 Settling Periods per Year
- Pesticide Balance
  - Well-mixed System
  - Toxic balance developed at University of Colorado

SWAT

User Options

- PET:
  - Penman-Monteith, Priestly-Taylor, or Hargreaves
- Runoff:
  - Curve Number or Green & Ampt
- Channel Flow:
  - Variable Storage Coefficient or Muskingham-Cunge
- Channel Water Quality:
  - QUAL2E On-Off Switch

More User Options

- ARC GIS 10.x
- Map Windows (Public Domain GIS)
- SWAT-CUP (Calibration and Uncertainty Program)
- VIZSWAT (Output Vizualization)
- Manuals in English, Spanish, Chinese, Korean
- SWAT 2003, 2005, 2009, 2012, (2015)

SWAT

SWAT Strengths

Upland Processes

- Comprehensive Hydrologic Balance
- Physically-Based Inputs
- Plant Growth – Rotations, Crop Yields
- Nutrient Cycling in Soil
- Land Management - BMP
  - Tillage, Irrigation, Fertilizer, Pesticides, Grazing, Rotations, Subsurface Drainage, Urban-Lawn Chemicals, Street Sweeping

SWAT

SWAT Strengths

Channel Processes

- Flexible Watershed Configuration
- Water Transfer—Irrigation Diversions
- Sediment Deposition/Scour
- Nutrient/Pesticide Transport
- Pond, Wetland and Reservoir Impacts

SWAT

Collaborators

- USDA Agricultural Research Service
- Texas A&M University
- USDA Natural Resources Conservation Service
- EPA Office of Science and Technology
- NOAA
- Universities

SWAT

The End

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