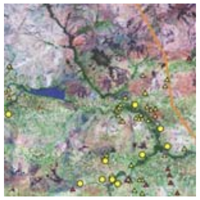
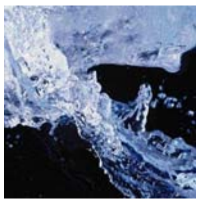


Modeling BMPs to Reduce Pesticide Runoff at the Watershed Scale Using APEX



Michael Winchell, Raghavan Srinivasan, Jimmy Williams

EMPM Meeting / EPA

12/09/08

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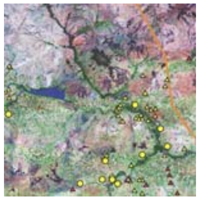
Contents



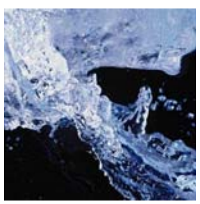
1 APEX Model Background

2 Pesticide Processes in APEX

3 Modeling BMPs in APEX

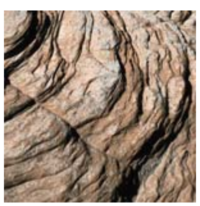
4 ArcAPEX Interface

5 Grass Waterway Example



6 Vegetated Buffer Strips Example

7 Integrating APEX with SWAT



8 Next Steps

The Agricultural Policy / Environmental Extender Model (APEX)

- Whole farm/watershed scale
- Subarea component (EPIC)
- Pesticide component (GLEAMS)
- Routing (water, sediment, nutrients, pesticides)
- Groundwater, water table
- Daily time step
- Capable of simulating 100's of years
- Economics

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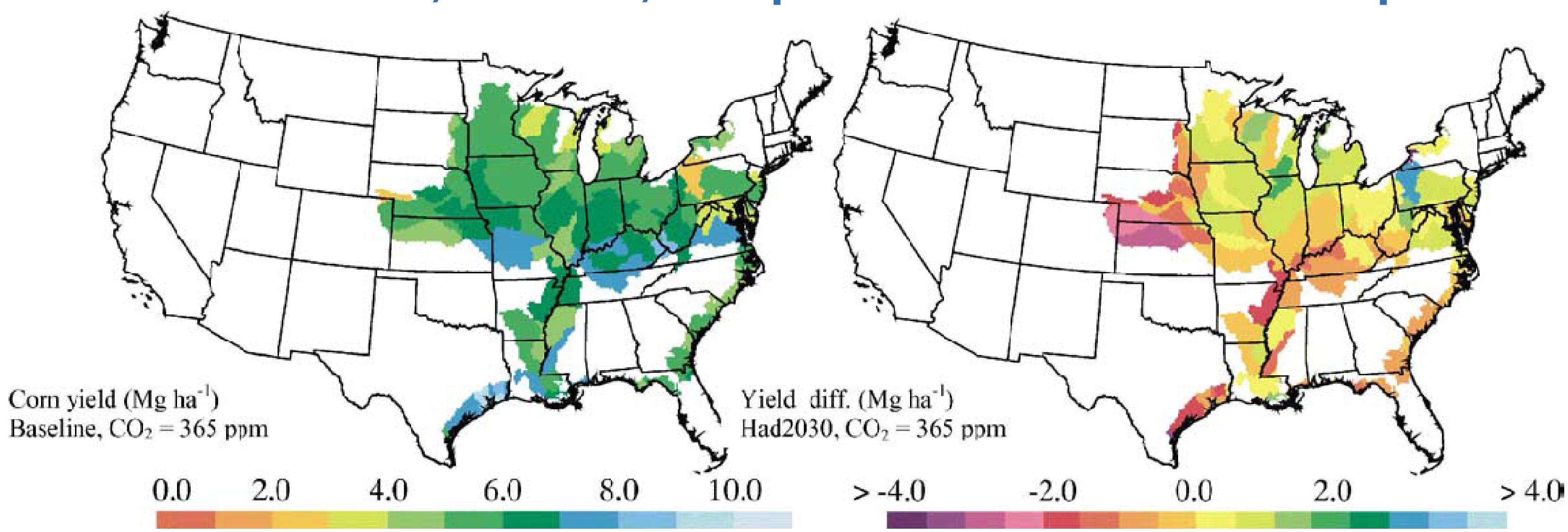
The Agricultural Policy / Environmental Extender Model (APEX)

- Management capabilities
  - Irrigation
  - Drainage
  - Furrow dikes
  - **Buffer strips**
  - Terracing
  - **Grass Waterways**
  - Fertilization
  - Manure management
  - Lagoons
  - Reservoirs
  - Crop rotation and selection
  - **Pesticide application**
  - Grazing
  - Tillage

The Agricultural Policy / Environmental Extender Model (APEX)

- Applications
  - Evaluate effects of global climate/CO_2 changes
  - Design biomass production systems for energy
  - Livestock farm and nutrient management (manure and fertilizer)
  - Forest management
  - **Evaluate effects of buffer strips nationally**
  - **Simulate runoff, erosion, and pesticide losses from cropland**

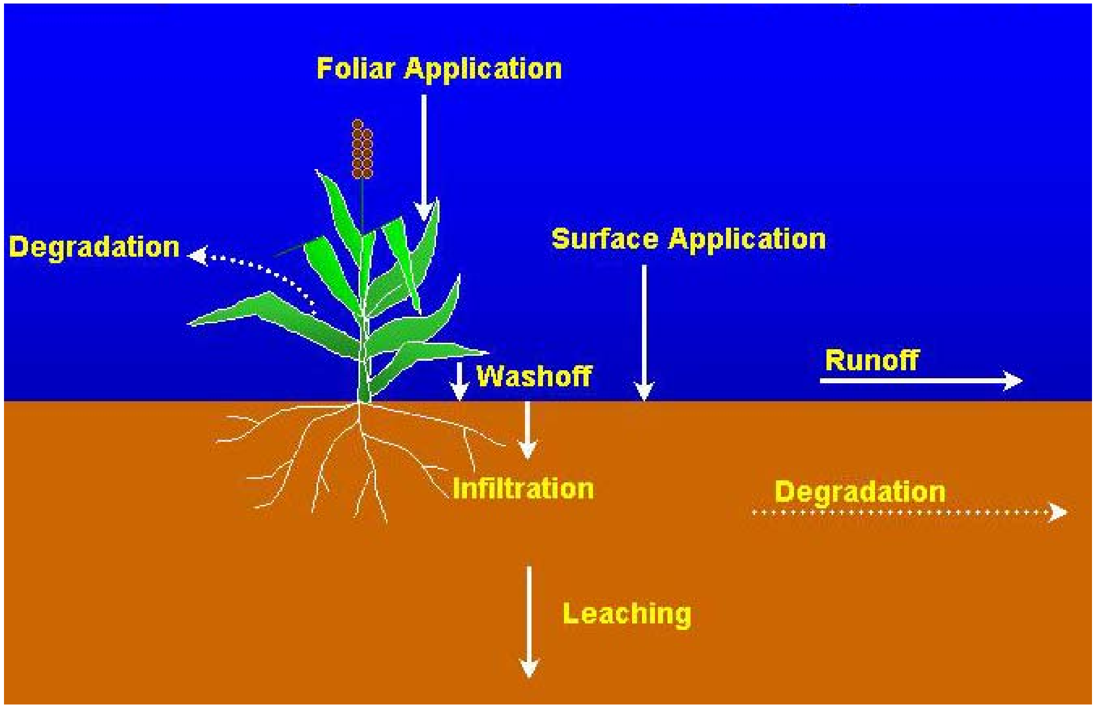


Pesticide Processes in APEX: GLEAMS Model

- Simulation of pesticide transport by:
  - Runoff
  - Percolation
  - Soil evaporation
  - Sediment
- Pesticides applied:
  - Any time and rate
  - To plant foliage
  - Soil surface or at any depth
- Some pesticide lost to atmosphere during application

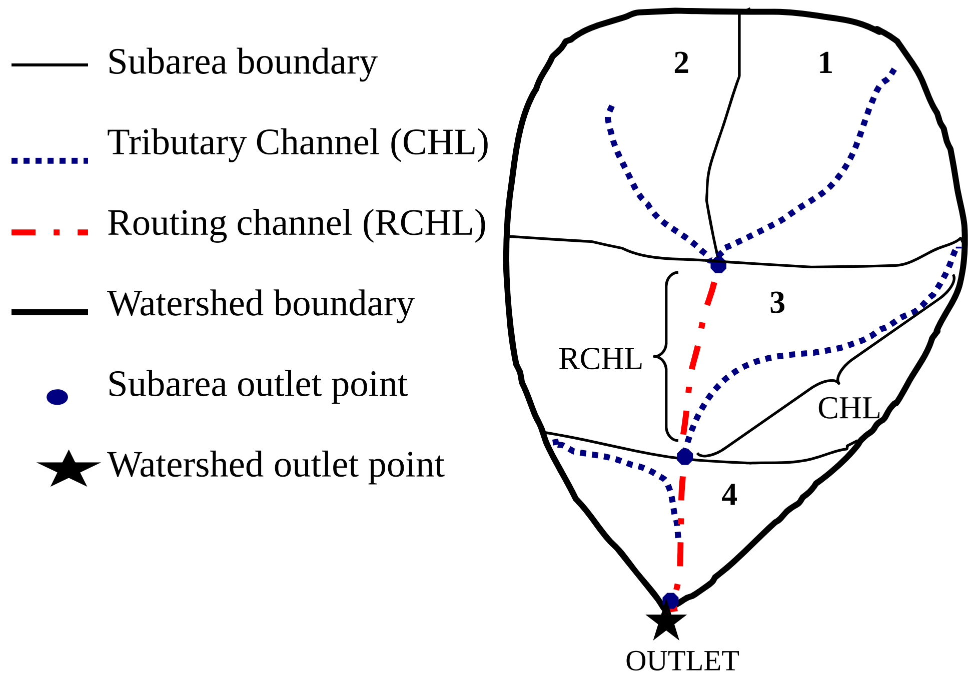
Pesticide Processes in APEX: Pesticide Fate

- Washoff from vegetation
  - Rainfall
  - Irrigation
- Surface runoff
  - Soluble
  - Adsorbed
- Leaching
  - Lateral flow in soil
  - Vertical flow to groundwater
- Degradation
  - Foliar degradation
  - Soil degradation



Modeling BMPs in APEX: APEX Model Structure

- An APEX watershed is divided into subareas
  - Single crop or land cover
  - Homogenous climate, soils, and management
  - A hybrid of a SWAT subbasin and HRU
- Subarea routing
  - Routing via channel flow
  - Routing via overland flow (key process for BMP simulation)



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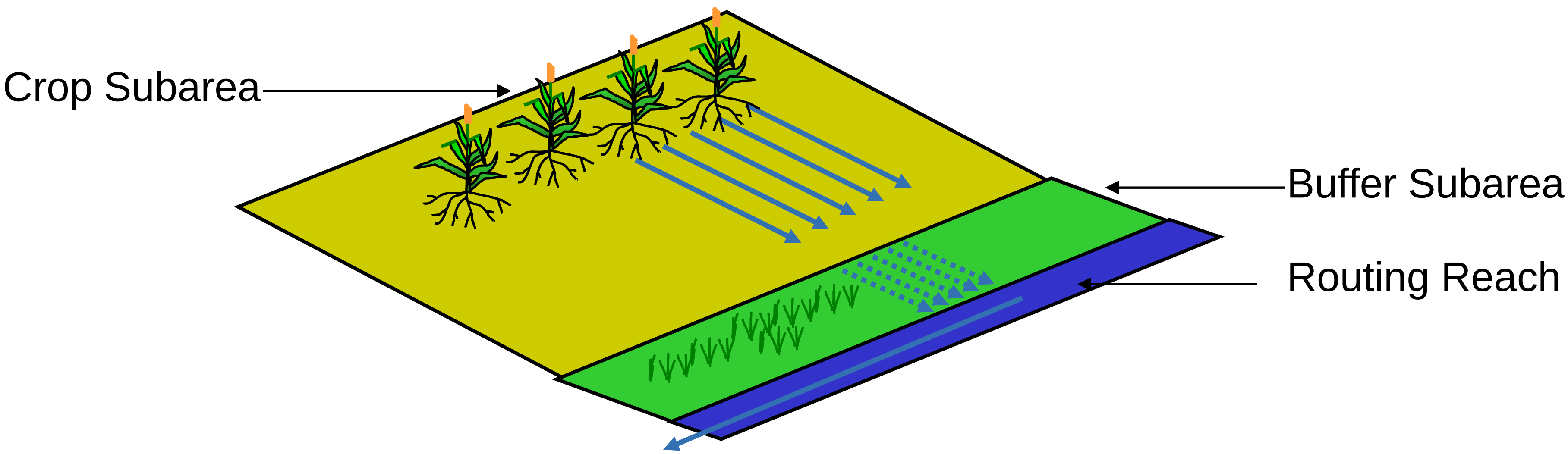
Modeling BMPs in APEX: Vegetated Buffer Strips

- Modeled as two separate subareas
  - First subarea, growing crop, produces surface runoff and sediment
  - A downstream subarea, with grass filter strip cover, traps sediment and increases infiltration of overland flow
  - Pesticide sorbed to sediment is trapped in buffer and soluble pesticide infiltrates, resulting in a lower runoff peak

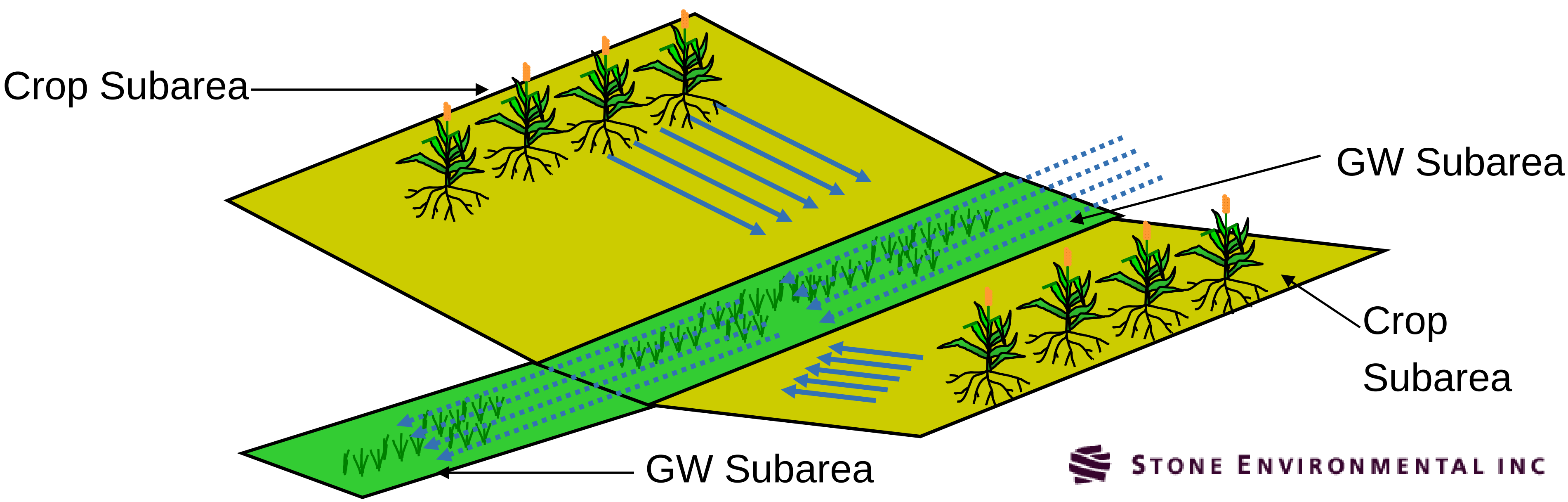


Modeling BMPs in APEX: Vegetated Buffer Strips, Two Approaches

- Explicit subarea definition:
  - Define and parameterize both crop and buffer strip areas independently
  - Advantages: Allows more detailed customization of buffer characteristics and management (vegetation type, roughness, slope, maintenance, etc.)
  - Drawbacks: Cumbersome to implement over a watershed with numerous subareas, each requiring a buffer strip
- Virtual subarea definition:
  - In parameterization of crop subarea, set the fraction of subarea controlled by buffer, and set the buffer width
  - Advantages: Can be applied to multiple subareas at once, much easier to test effectiveness of varying buffer width, and occurrence
  - Drawbacks: Less flexibility in defining specific buffer characteristics

Modeling BMPs in APEX: Grass Waterways

- Modeled as crop subareas and grass waterway (GW) subareas
  - Crop subareas produce surface runoff and sediment
  - Crop subarea(s) flow into GW subareas, where sediment is trapped and infiltration of overland flow occurs
  - Upstream GW subareas can flow into downstream GW subareas
  - GW subareas parameterized for ~100% floodplain flow



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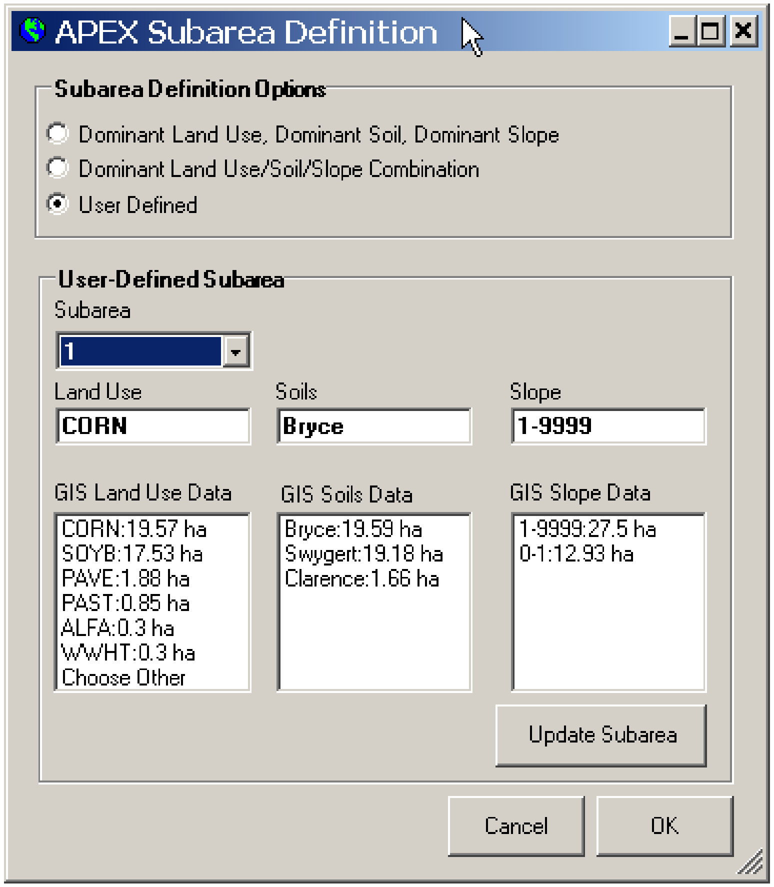
The ArcAPEX Interface

- An ArcGIS interface to the APEX model
- Provides automatic watershed delineation, or option for incorporating user-defined subareas, useful for detailed modeling at farm/small watershed scale.
- Provides tool for land use, soils, and slope analysis for characterization of APEX subareas
- Provides capability to link directly to a SWAT model for multi-scale integrated modeling
- ArcAPEX is currently undergoing beta testing



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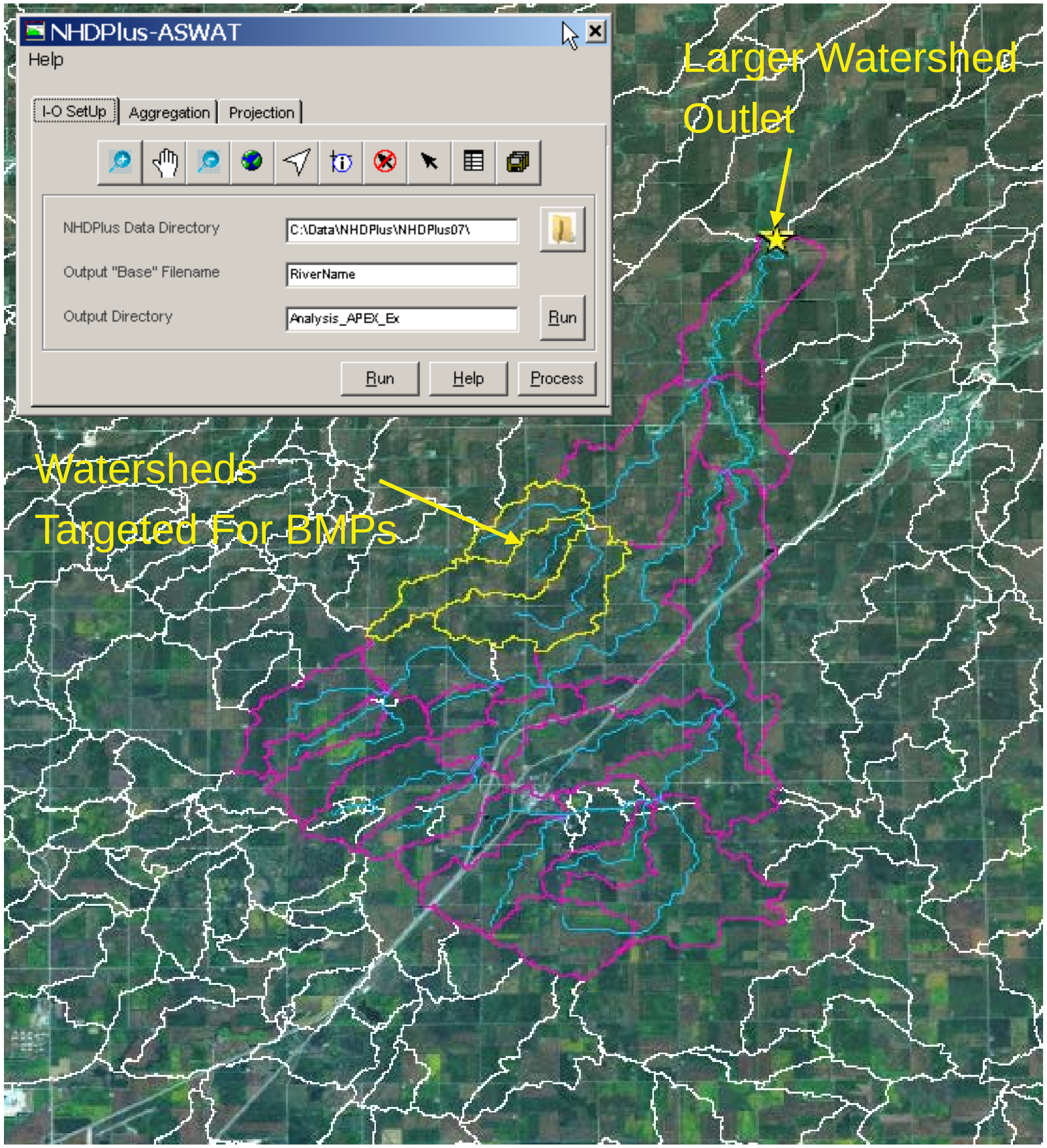
Using ArcAPEX to Evaluate BMPs at the Watershed Scale

- Objective:
  - Evaluate the effectiveness of several BMPs at reducing pesticide concentrations in runoff and sediment in several small watersheds.
  - Integrate results with a larger watershed scale model
- Approach:
  - Extract watersheds of interest from NHDPlus dataset
  - Apply APEX to evaluate a grass waterway using manually delineated subareas
  - Apply APEX to evaluate vegetated buffers using automated subarea delineation and virtual buffer approach
  - Integrate sub-watersheds modeled with APEX into the larger watershed SWAT model.

Extract Watersheds of Interest From NHDPlus

- Larger watershed of interest identified in NHDPlus
- Use NHDPlus->SWAT tool to extract watersheds in SWAT format
- Import watershed boundaries into ArcSWAT and parameterize SWAT model



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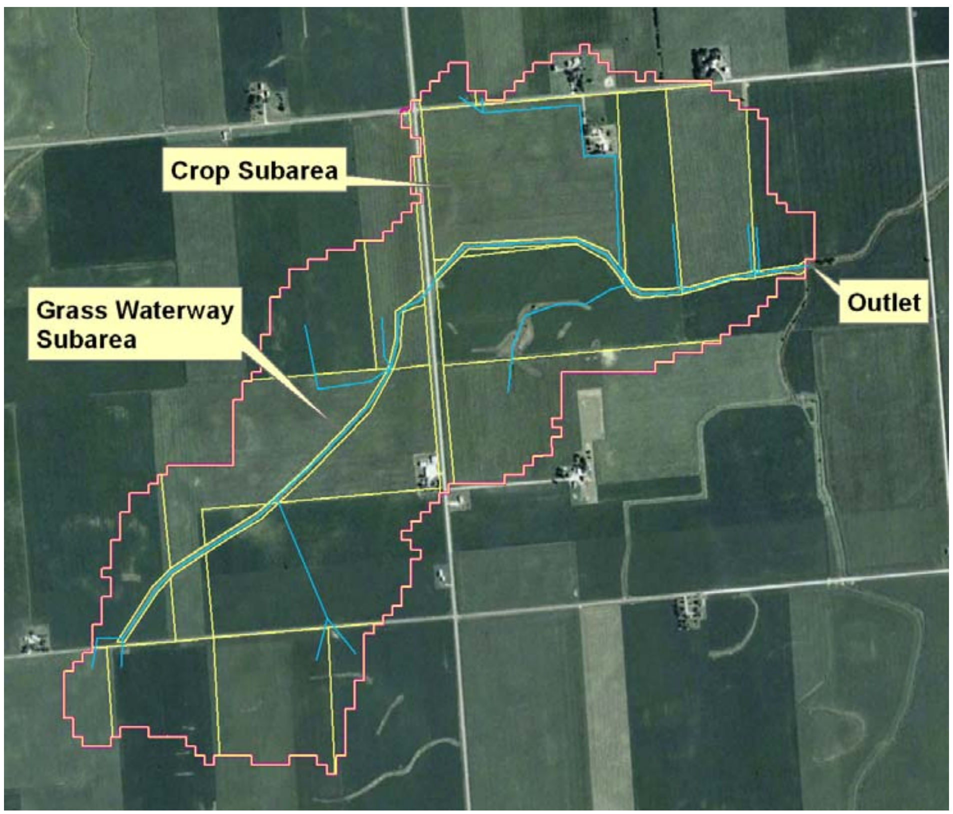
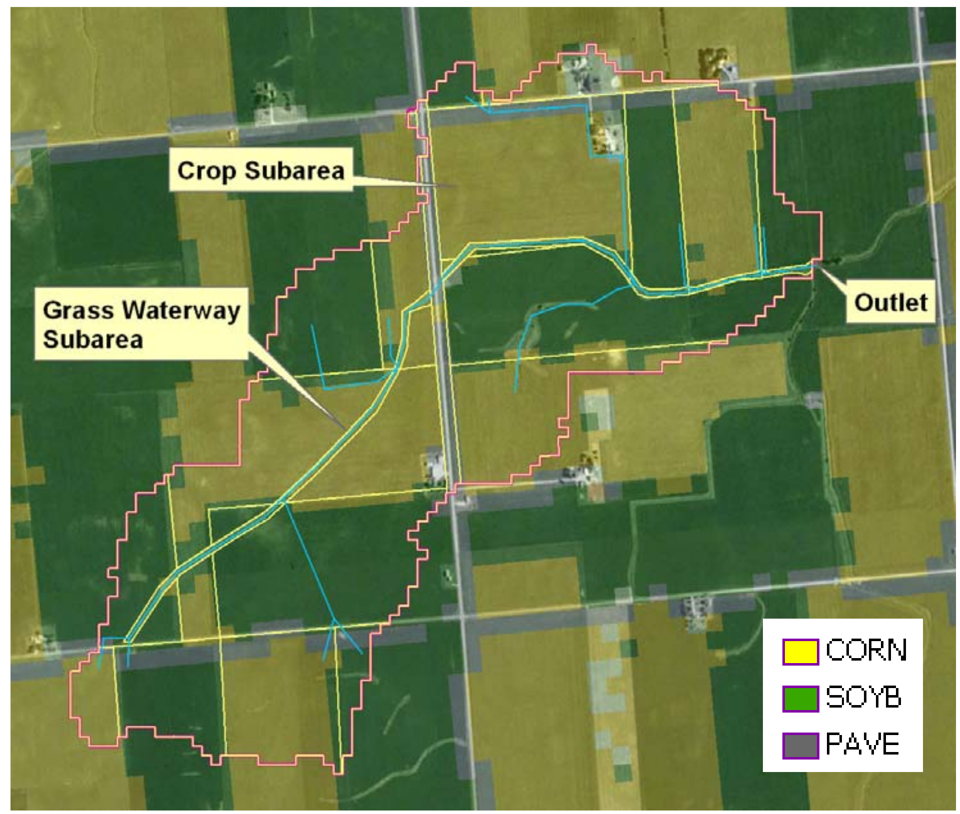
Modeling of Watershed with Grass Waterway in APEX

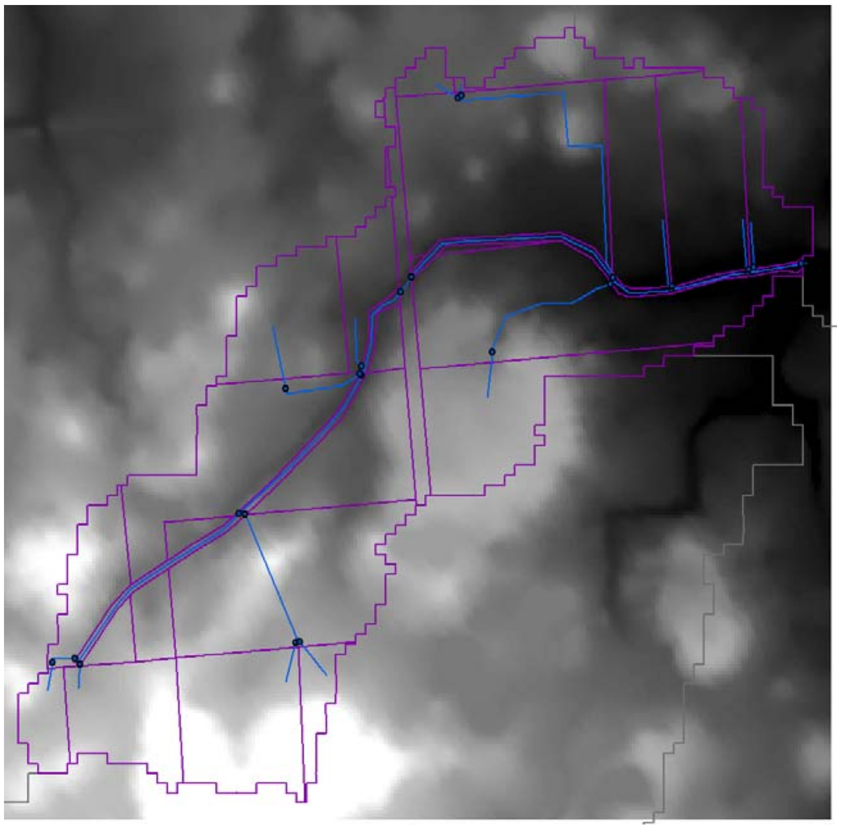
- Approach suitable for smaller watersheds.
- Crop subareas (fields) and grass waterway subareas explicitly defined and delineated from aerial photo.
- Crop class from NASS CDL dataset used to classify each

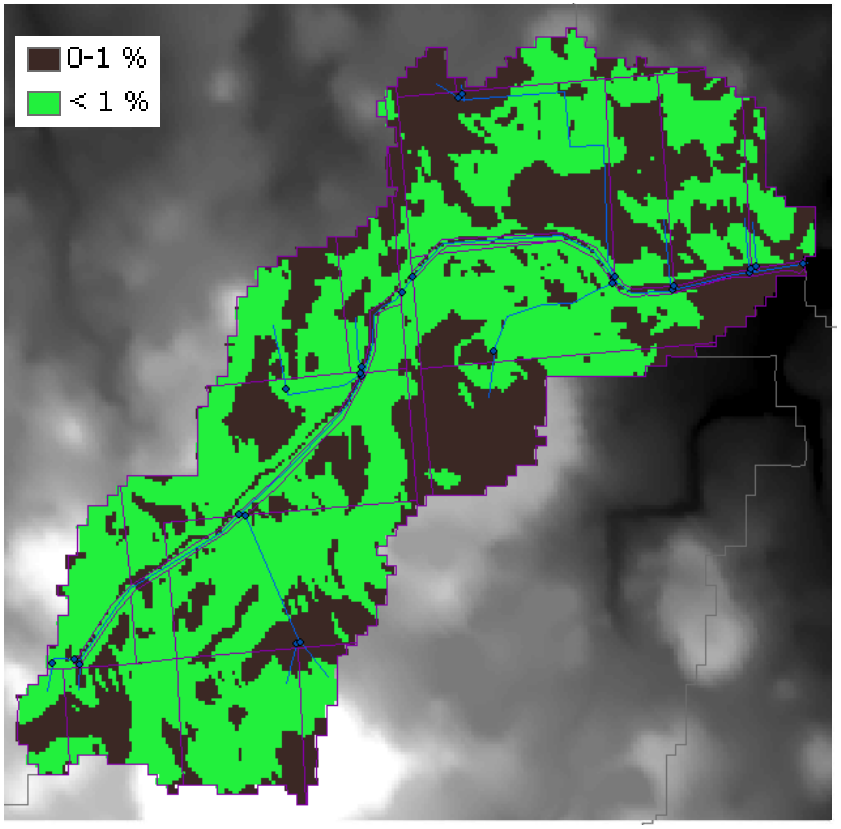




Grass Waterway Model Development in ArcAPEX

- Manually-delineated subareas imported, and topographic characteristics calculated.
- Land use, soils, and slope characterized for each subarea





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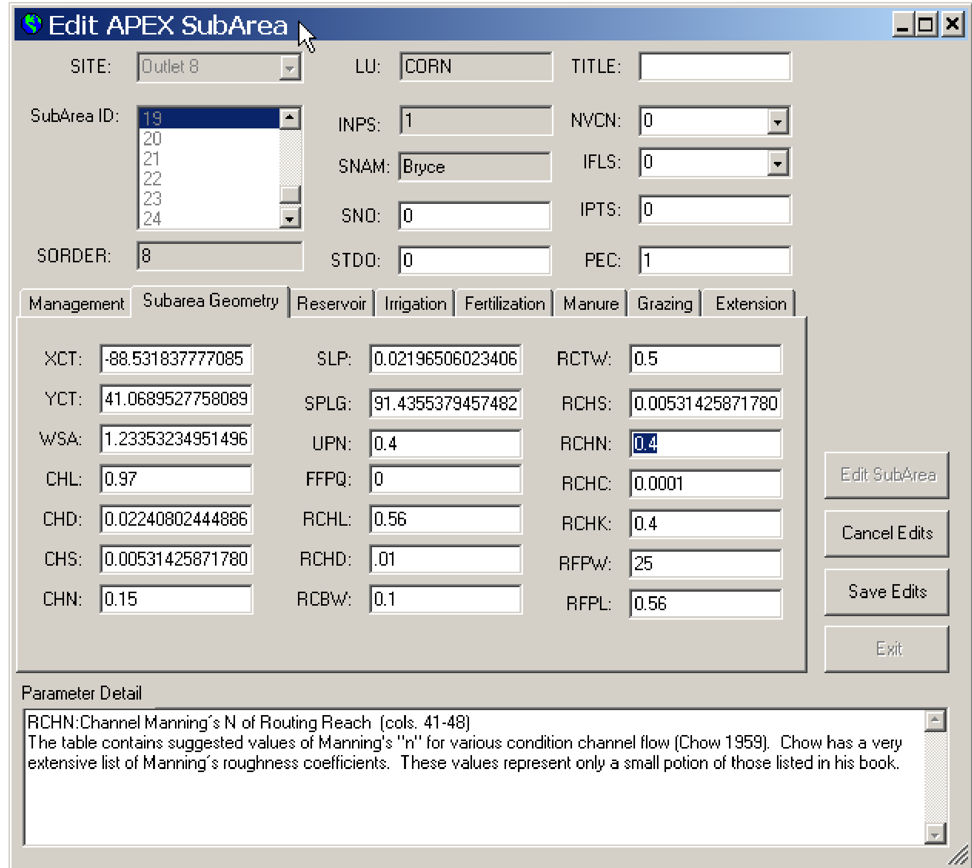
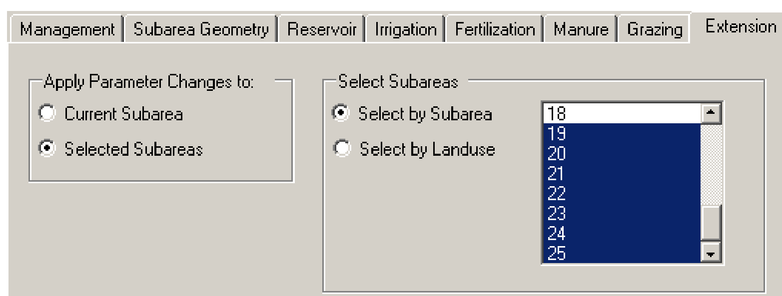
Parameterization of Grass Waterway Subareas

- Pesticide is applied at planting to all corn subareas at 2 kg/ha (KOC = 200, SOL = 530 mg/l, t-half = 90 d)
- Set waterway subareas as a bermuda grass cover
- Set mowing interval at once every 3 months
- Set Manning's n at 0.4 for waterway
- Set channel dimensions to have a very narrow bottom width and shallow depth, forcing floodplain flow
- Apply characteristics to all grass waterway subareas





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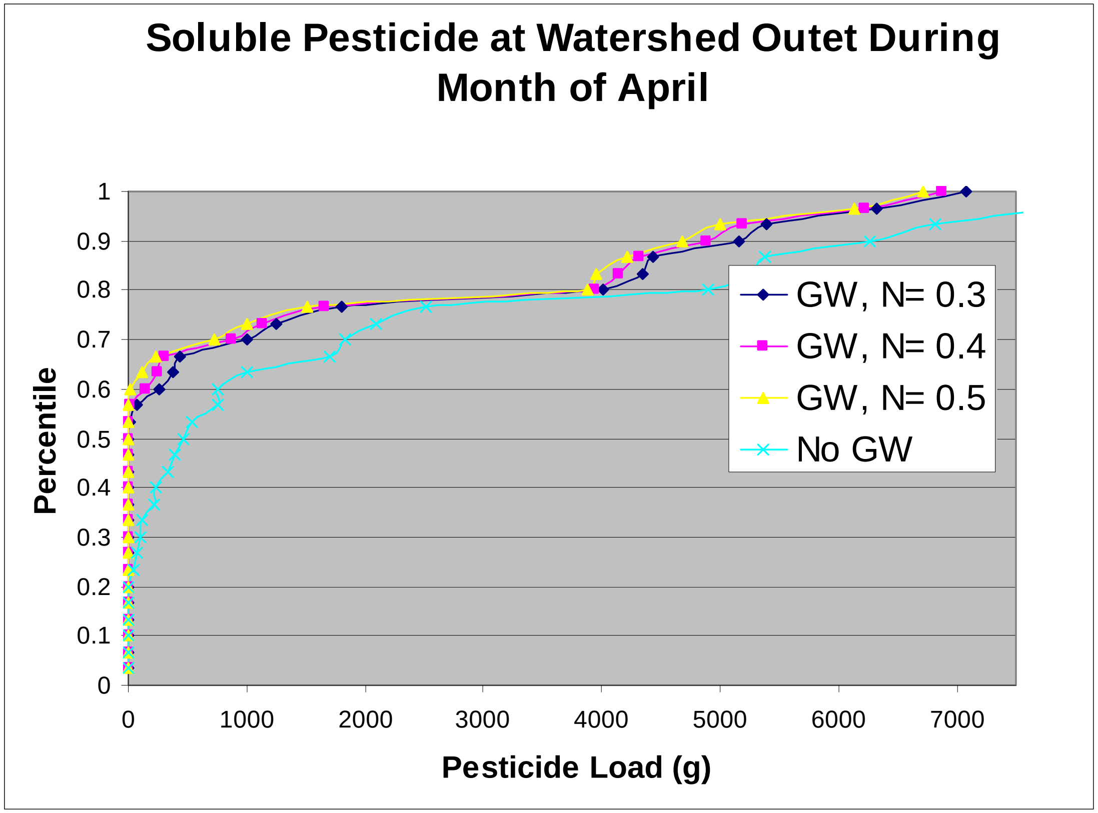
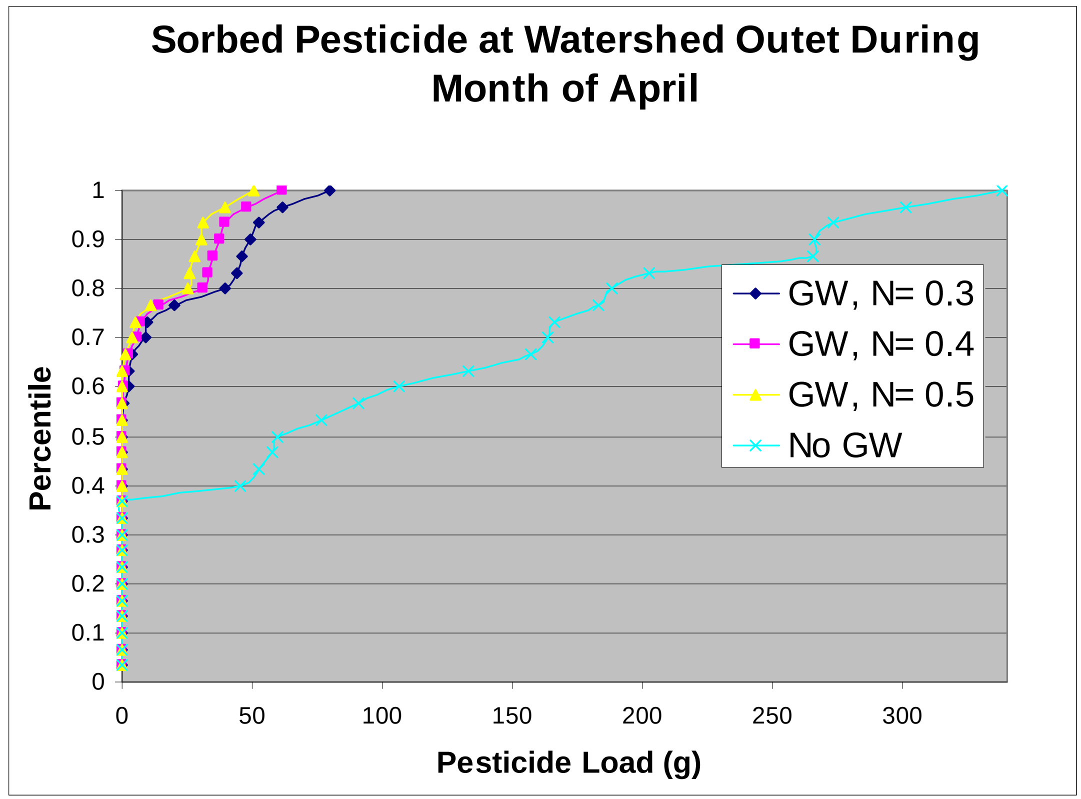
Grass Waterway Model Simulation Results: Soluble Pesticide

- Model run continuously for 30 years
- Weather inputs from weather generator
- Parameterized grass waterway assuming Manning's N from 0.3 to 0.5
- April mass reduction, 90th percentile: 18% - 25%
- Avg. annual mass reduction: 22%- 27%
- Greater percent reduction in dryer years (e.g., for median year, almost 100% removal)



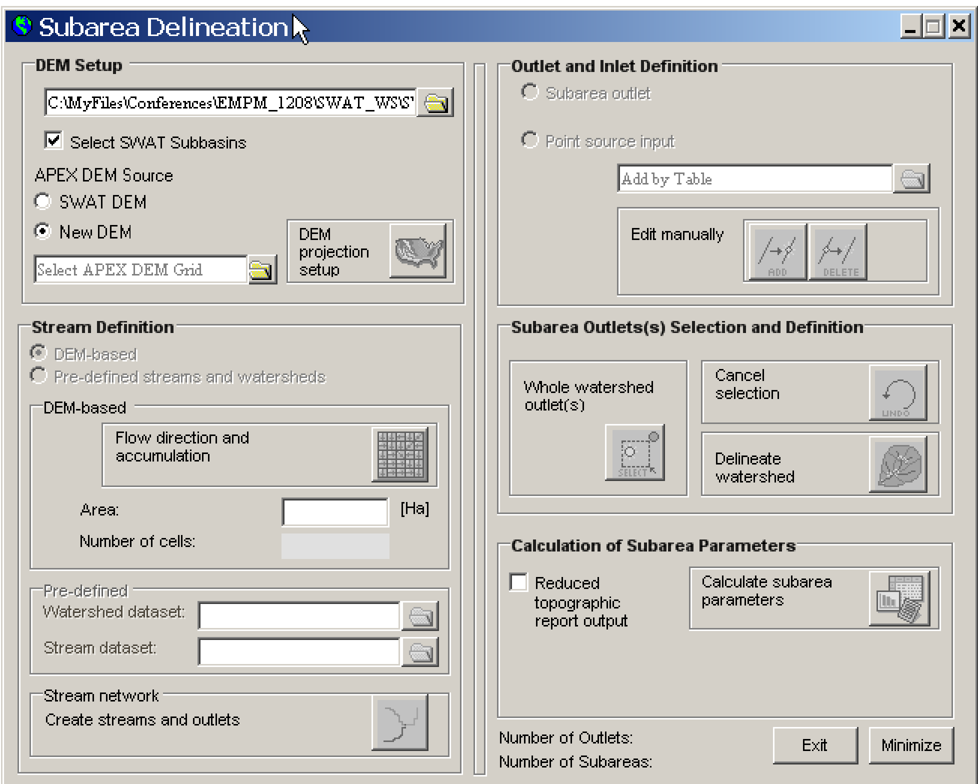
Grass Waterway Model Simulation Results: Sorbed Pesticide

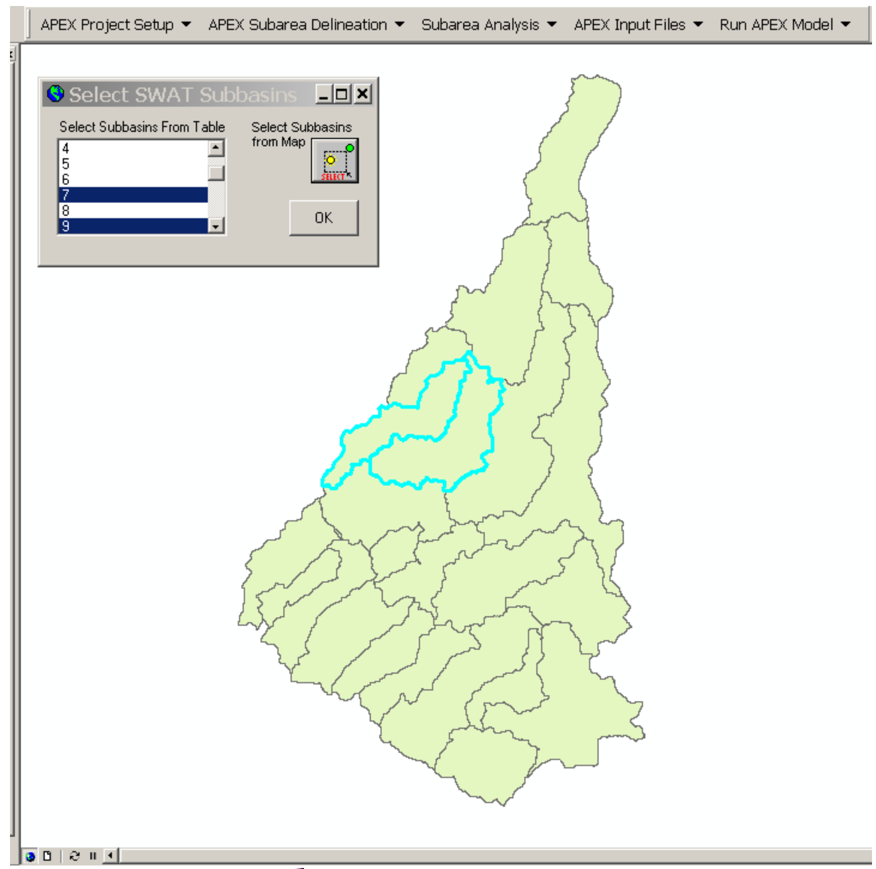
- Model run continuously for 30 years
- Weather inputs from weather generator
- Grass waterway assuming Manning's N from 0.3 to 0.5
- April mass reduction, 90th percentile: 81% - 89%
- Avg. annual mass reduction: 85% - 91%
- As expected, much greater effectiveness than for soluble pesticide



Integration of APEX Model into Existing SWAT Model

- Existing SWAT model specified in interface
- SWAT subbasins to be modeled with APEX are selected interactively
- SWAT DEM may be used for delineation, or a higher resolution DEM for localized APEX model may be chosen





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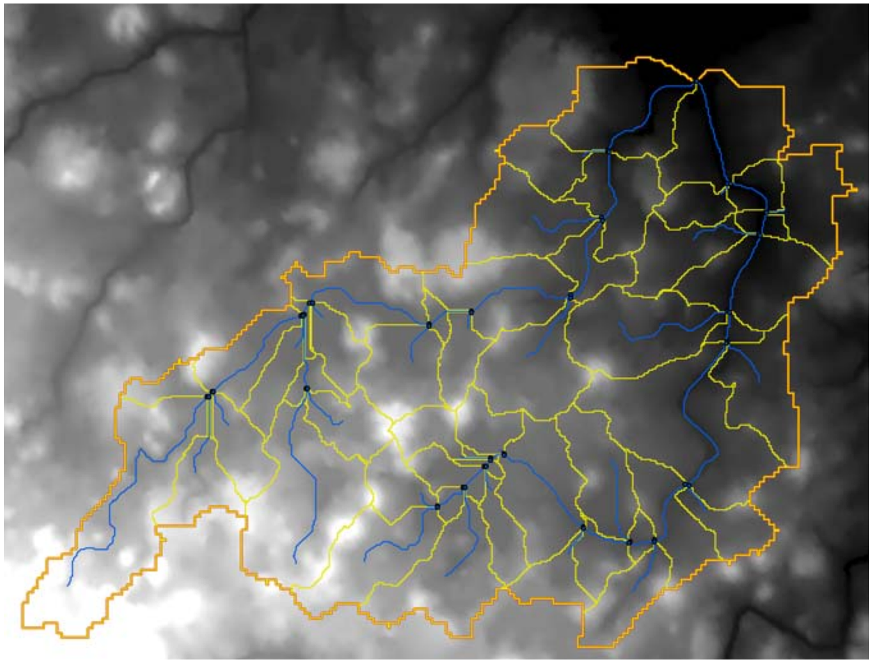
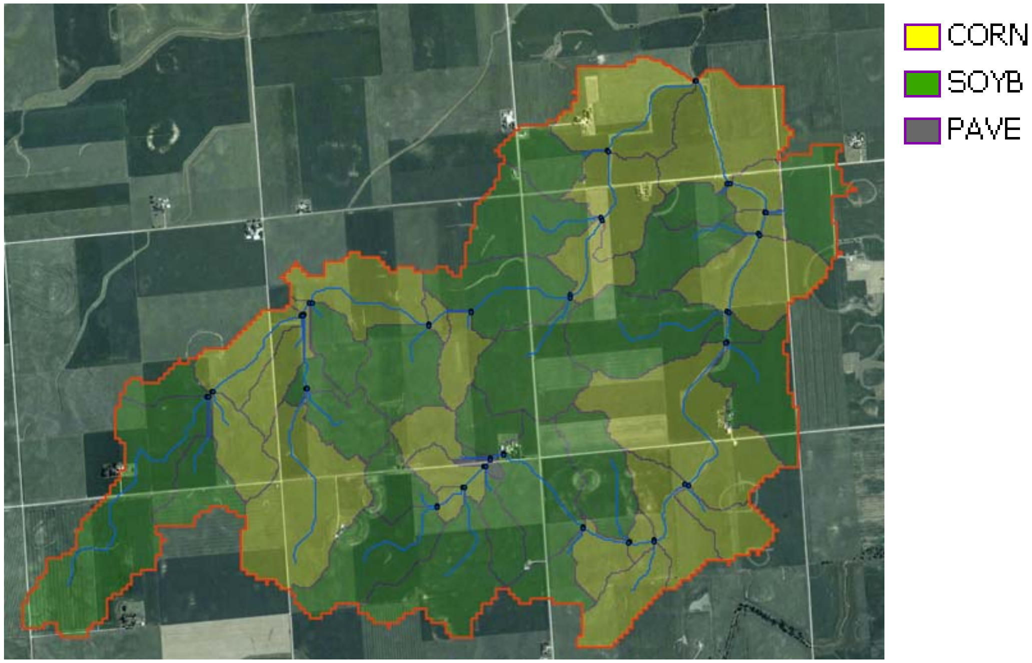
Modeling of Watershed with Vegetated Buffer Strips in APEX

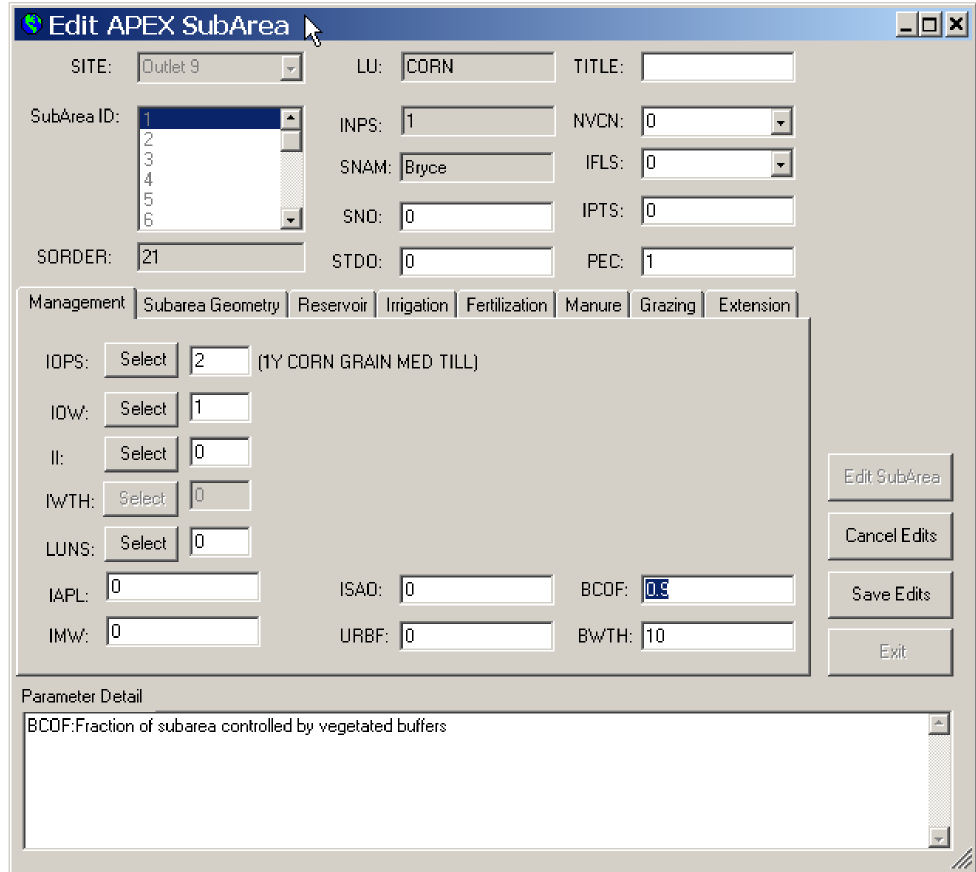
- Approach suitable for somewhat larger watersheds
- Subareas are delineated via DEM-based automatic watershed delineation in ArcAPEX (10-m resolution NED)
- The dominant land use (NASS CDL), soil (SSURGO), and slope selected for each subarea

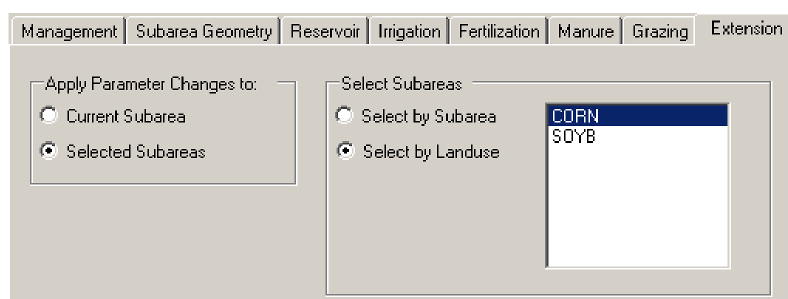




Parameterization of Vegetated Buffer Strip Subareas

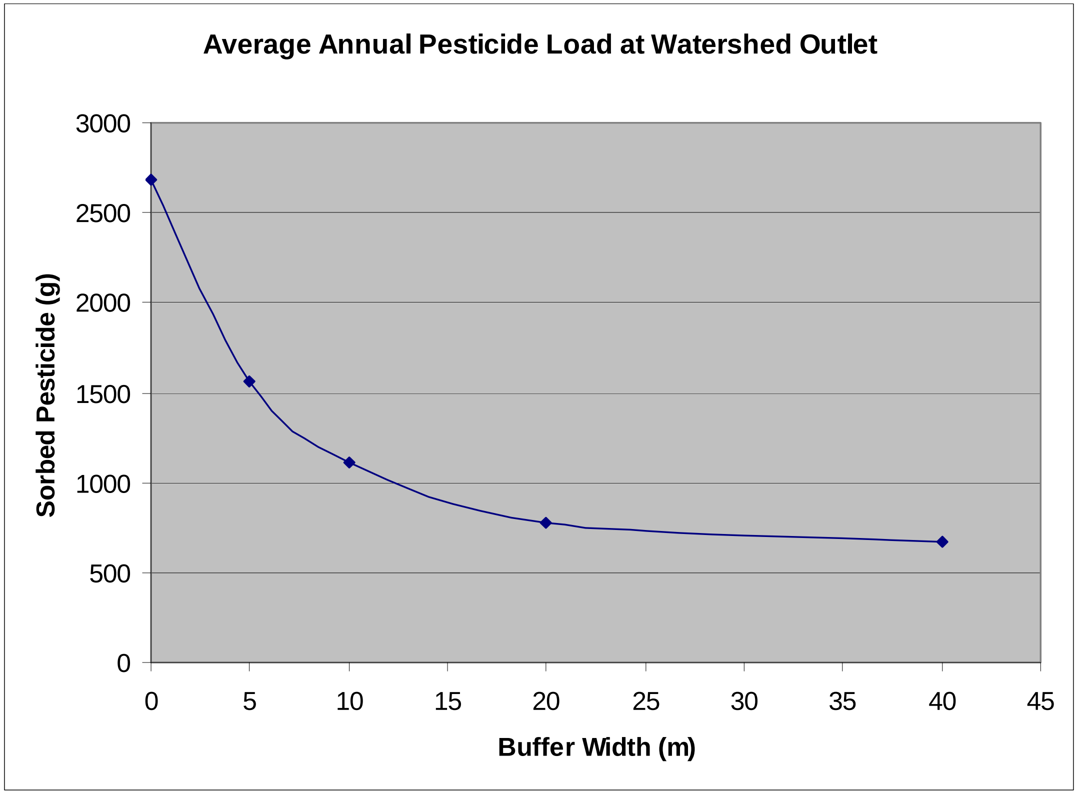
- Subareas where pesticide is applied (corn) are designated as having buffer strips.
- Pesticide is applied at planting to all corn subareas at 2 kg/ha (KOC = 200, SOL = 530 mg/l, t-half = 90 d)
- Virtual buffer subareas added by model
- The fraction of area controlled by buffer is specified (0 to 1)
- The buffer width is specified
- Same buffer parameters are applied to all corn subareas





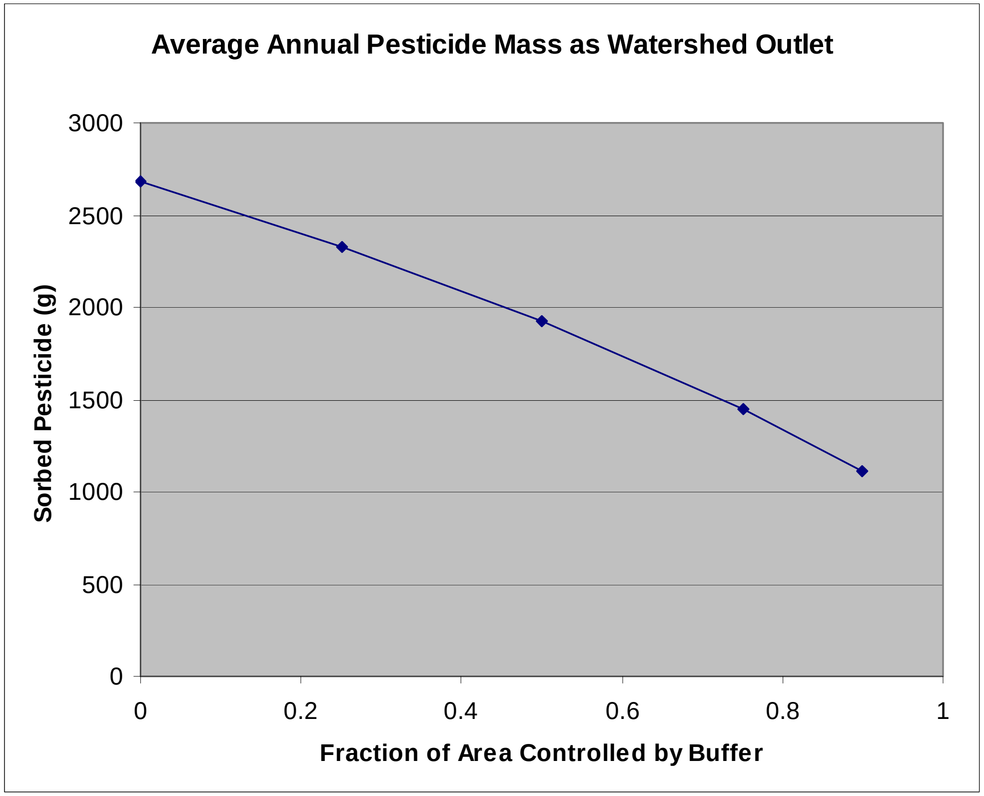
Vegetated Buffer Strip Model Simulation Results: Buffer Widths

- Model run continuously for 30 years
- Weather inputs from weather generator
- Buffer widths varied from no buffer to 40 m
- Avg. annual mass reduction:
  - 5 m: 42%
  - 20 m: 71%
  - 40 m: 75%
- Gains in mass removal most significant between 0 and 20 m widths



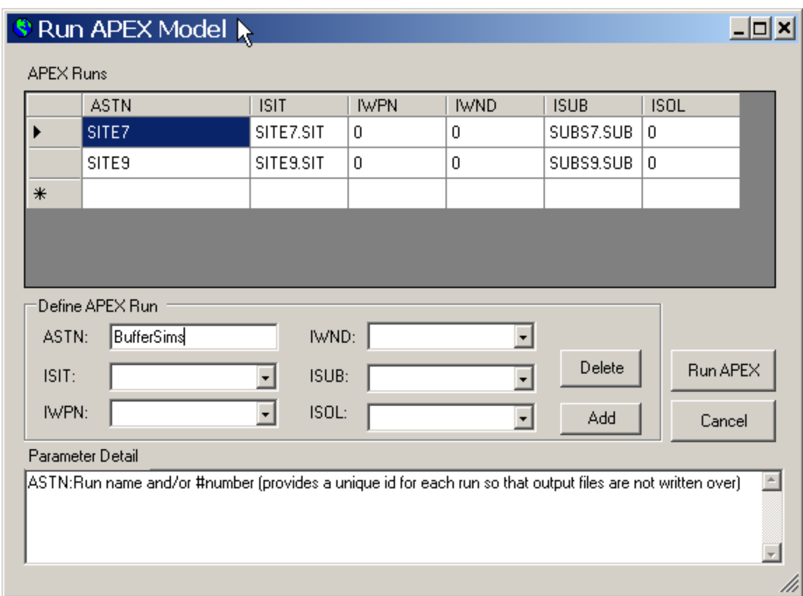
Vegetated Buffer Strip Model Simulation Results: Buffer Fraction

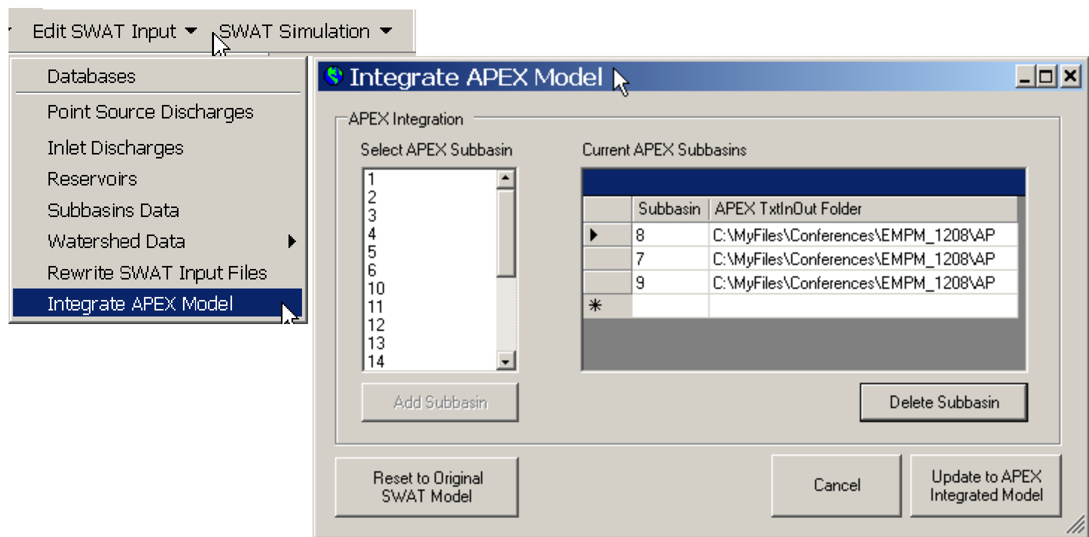
- Model run continuously for 30 years
- Weather inputs from weather generator
- Fraction of subarea controlled by 10 m buffer varied from 0 to 90%
- Avg. annual mass reduction:
  - 50% Controlled: 28%
  - 90% Controlled: 59%
- Approximately linear



Integrating APEX Simulations with SWAT

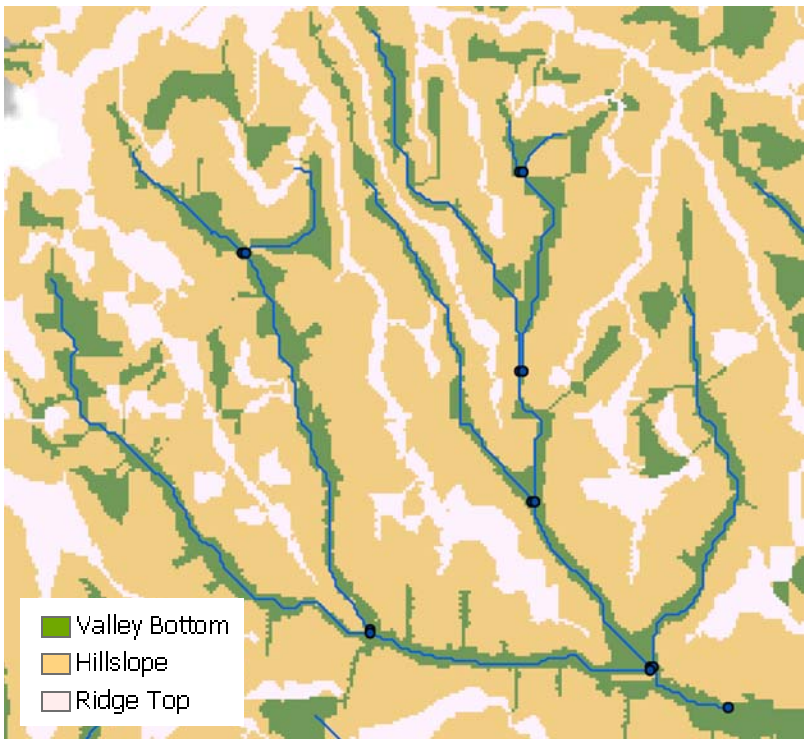
- Suitable approach for larger, multiple use watersheds
- Offers benefits of more detailed modeling of BMPs offered by APEX with ability to scale up to larger watersheds with SWAT
  - Run APEX model
  - Open SWAT model, choose which subbasins will be APEX simulations

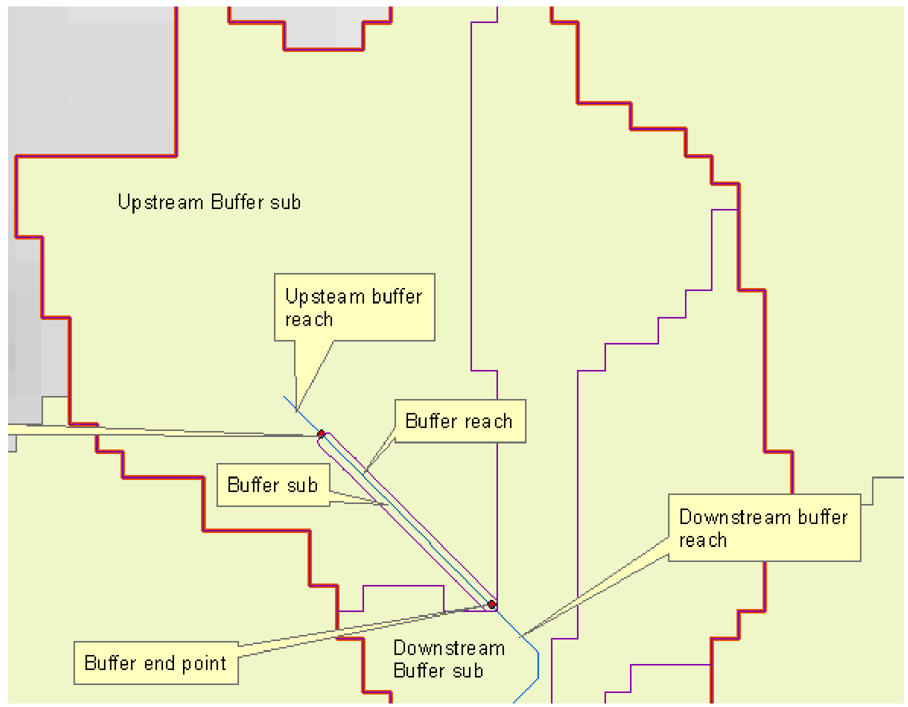




Next Steps: ArcAPEX Enhancements for Riparian Buffers

- Development of an automated approach to defining spatially explicit riparian buffers/vegetated waterways
  - A slope position based algorithm to define uplands, hillslopes, and valley bottoms (riparian areas)
  - Spatially explicit buffers generated around user-specified streams





Next Steps: APEX Model

- Continued development of virtual buffer approach
  - Fine-tune parameterization of buffer characteristics
  - Additional user-defined parameters
- Additional testing and validation of model predictions for buffer and grass waterway effectiveness with pesticides (original model validation conducted with nutrients and sediment)