Tools for Wetlands Permit Evaluation: Modeling Groundwater and Surface Water Interaction

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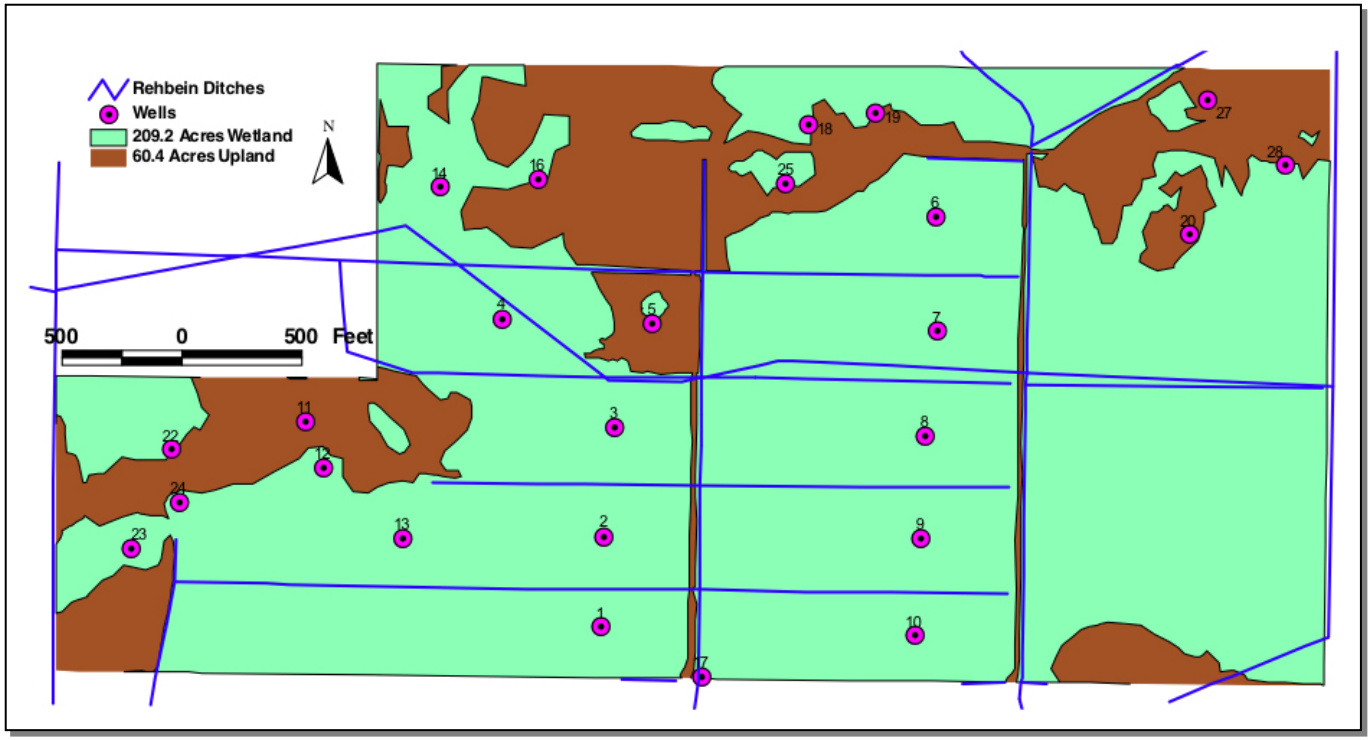
Example Wetland Permit Problem

- Applicant claimed proper drainage ditch maintenance would reduce acreage classified as wetland in proposed development area



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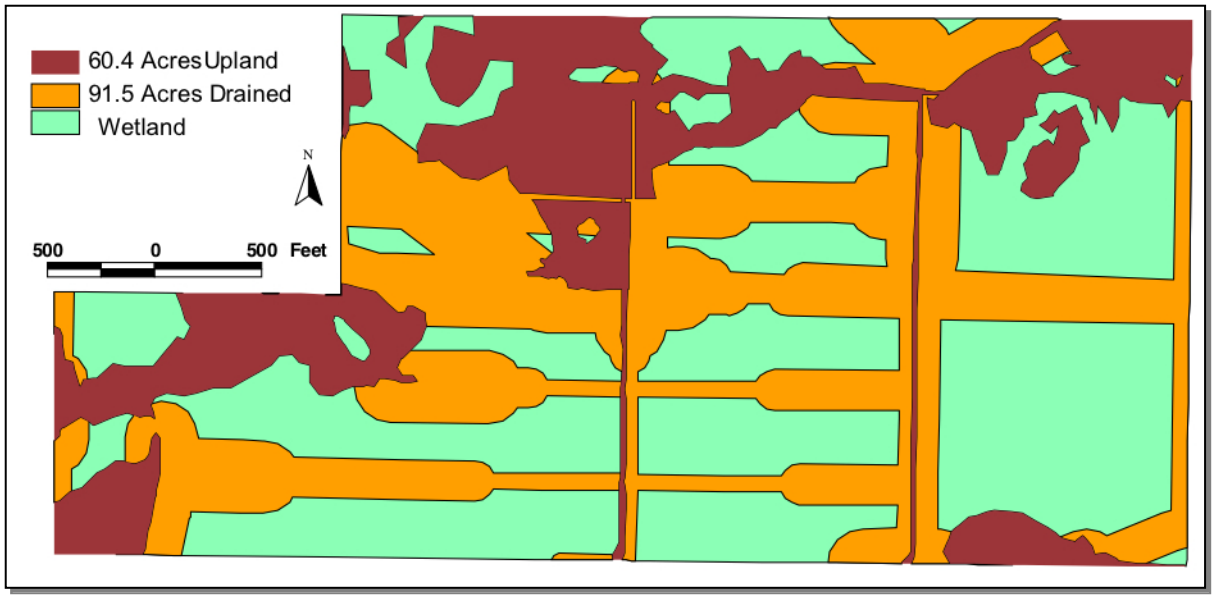
Example Wetland Permit Problem

- Applicant used various analytic 1-D approaches along with a 3-D saturated flow-only groundwater model (MODFLOW) to estimate drainage
- No surface water-groundwater interaction effects simulated



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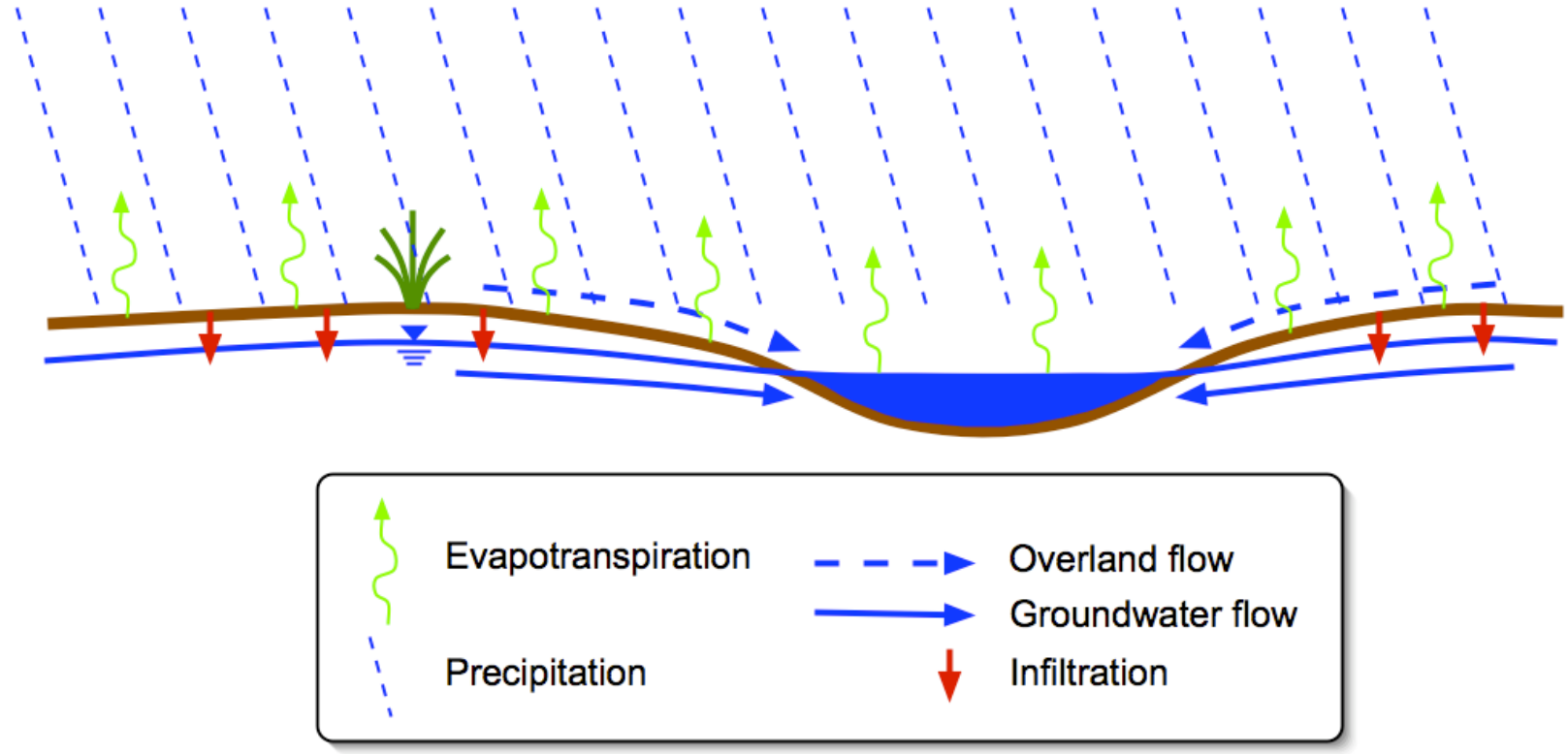
Typical Wetland System with Surface Water Flow Channels



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EM 1110-2-1421 ~ Groundwater Hydrology

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Manual
No. 1110-2-1421

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Engineering and Design
GROUNDWATER HYDROLOGY

1. Purpose. The purpose of this manual is to provide guidance to Corps of Engineers personnel who are responsible for groundwater-related projects.

2. Applicability. This manual applies to all USACE Commands having responsibility for design of civil works projects.

3. Distribution Statement. Approved for public release, distribution is unlimited.

FOR THE COMMANDER:

ALBERT J. GENETTI, JR.
Major General, USA
Chief of Staff

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of Engineers

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EM 1110-2-1421 ~ Groundwater Hydrology

- Section 6-11, Numerical Modeling of Surface Water and Groundwater Systems:

  "Although mathematically exact, analytic models generally can be applied only to simple one-dimensional problems because of rigid boundary conditions and simplifying assumptions. However, for many studies, analysis of one-dimensional flow is not adequate. Complex systems do not lend themselves to analytical solutions, particularly if the types of stresses acting on the system change with time. Numerical models allow for the approximation of more complex equations and can be applied to more complicated problems without many of the simplifying assumptions required for analytical solutions…" *(emphasis added)*

EM 1110-2-1421 ~ Groundwater Hydrology

- Section 6-11, Numerical Modeling of Surface Water and Groundwater Systems (cont.)

  "…Ideally, a computer model of the surface-water/groundwater regime should be able to simulate three-dimensional variably-saturated flow including: fluctuations in the stage of the surface-water body, infiltration, flow in the unsaturated zone, and flow in the saturated zone. Additionally, simulation of watershed runoff, surface-water flow routing, and evapotranspiration will allow for completeness. However, this is often a complex task, and no matter how powerful the computer or sophisticated the model, simplifying assumptions are necessary." *(emphasis added)*

System-Wide Water Resources Program (SWWRP)

- 7-year USACE R&D initiative designed to assemble and integrate the diverse components of water resources management
- The ultimate goal is to provide to the Corps, its partners, and stakeholders the overall technological framework and analytical tools to restore and manage water resources and balance human development activities with natural system requirements

System-Wide Water Resources Program
SWWRP Water Resources Depot

https://swwrp.usace.army.mil

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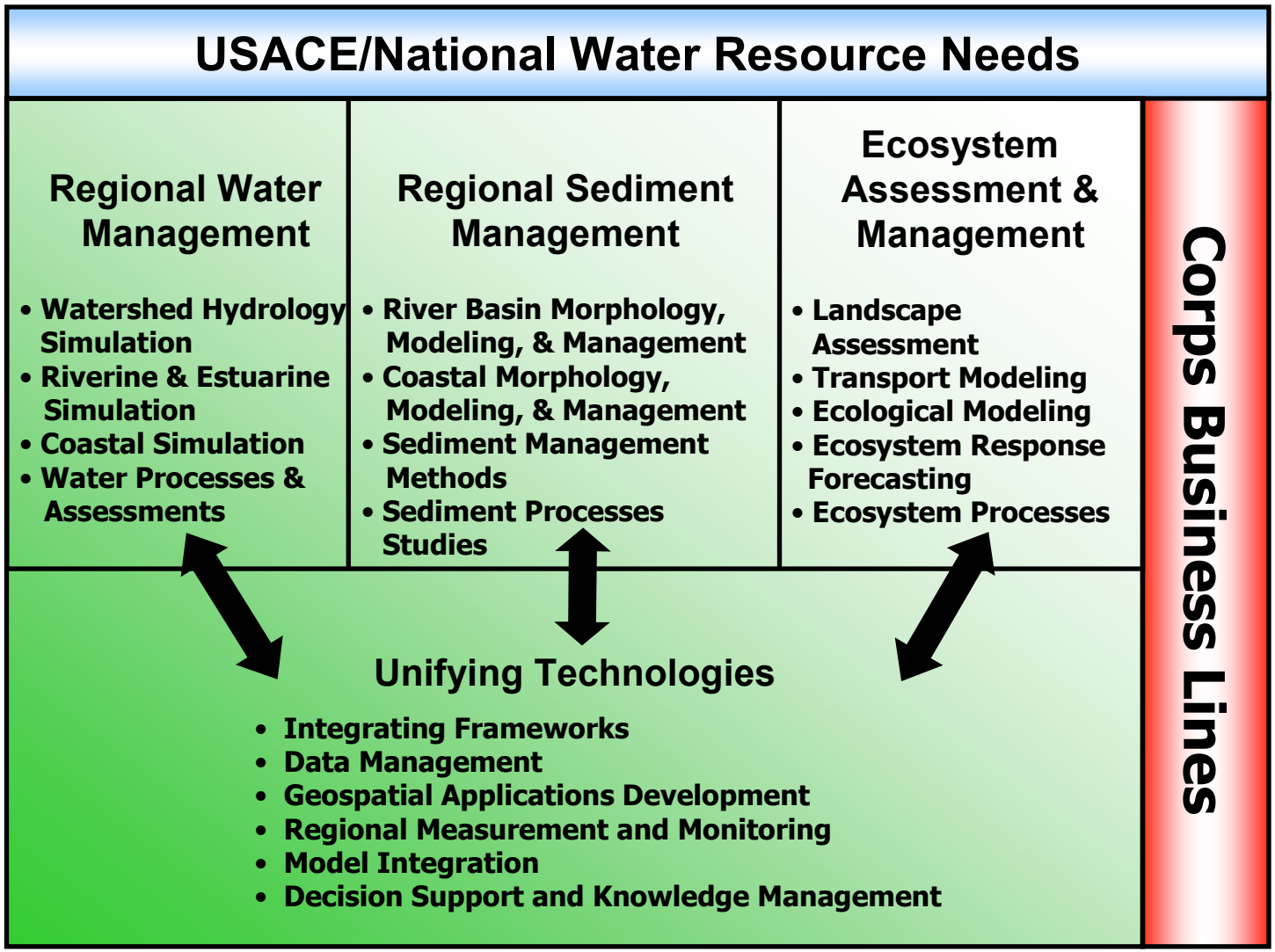
SWWRP Program Structure



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SWWRP Watershed Hydrology Simulation

- 5 research areas
  - HMS development
  - GSSHA development
  - Uncertainty/parameter estimation/stochastic simulation tools for system-scale models
  - Regional flood prediction
  - Coupled, multi-dimensional groundwater-surface water interaction simulation

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USACE Toolbox of GW-SW Interaction Codes

- Coupled, multi-dimensional, SWWRP-supported GW-SW interaction codes
  - GSSHA
  - WASH123D
  - ADH
- All codes fully integrated and supported in XMS (GMS, SMS, WMS)

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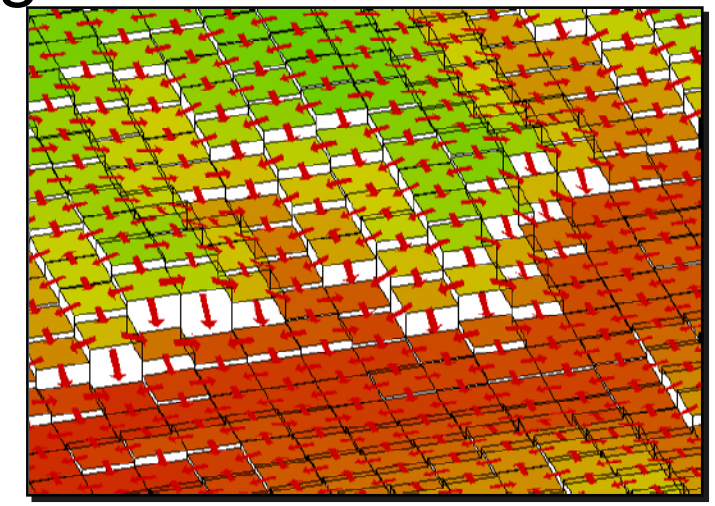
GSSHA

- Distributed, physically-based Gridded Surface Subsurface Hydrological Analysis (GSSHA) model
- Simulates 2D overland flow, 1D channel routing, 2D saturated groundwater flow, canopy retention, microtopography, 1D infiltration and ET using finite-difference and finite-volume methods



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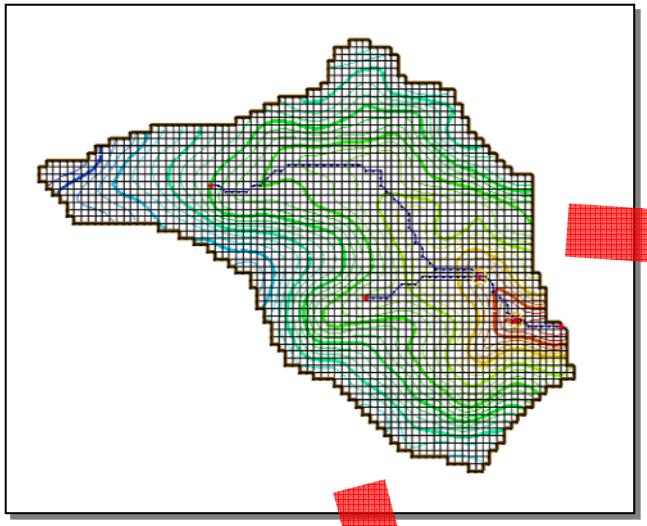
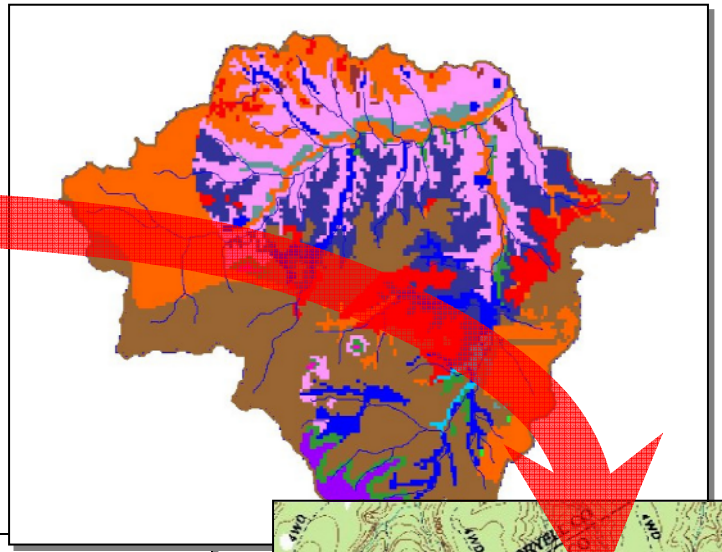
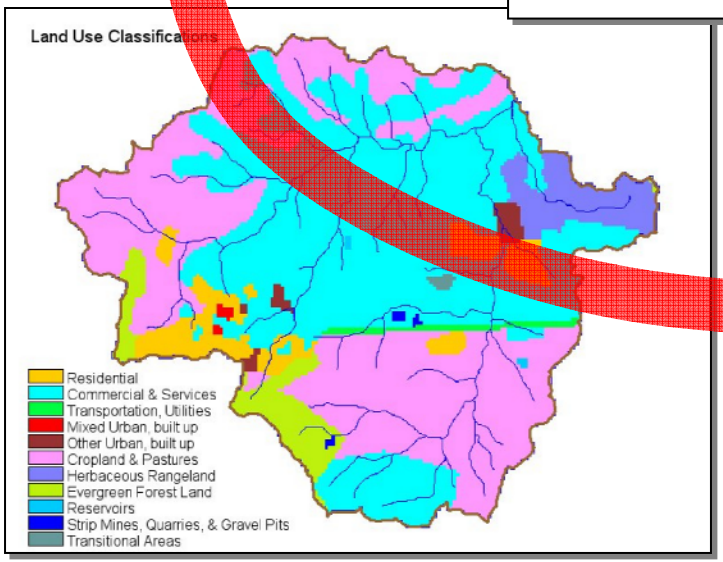
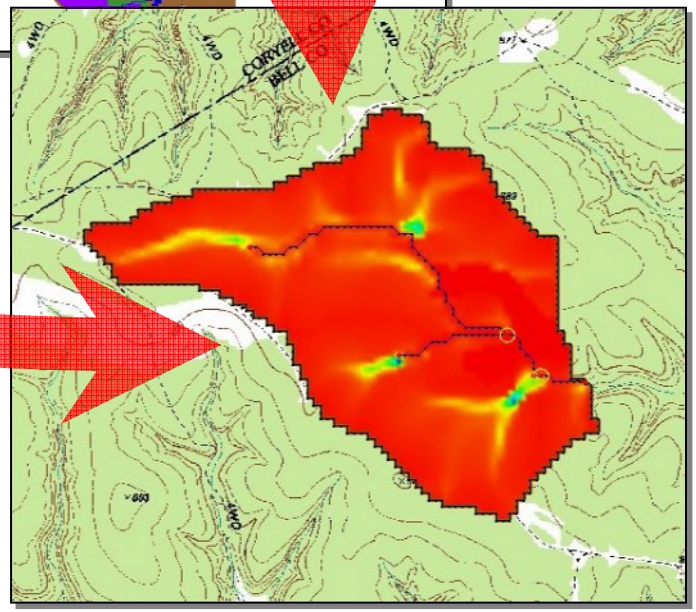
GSSHA









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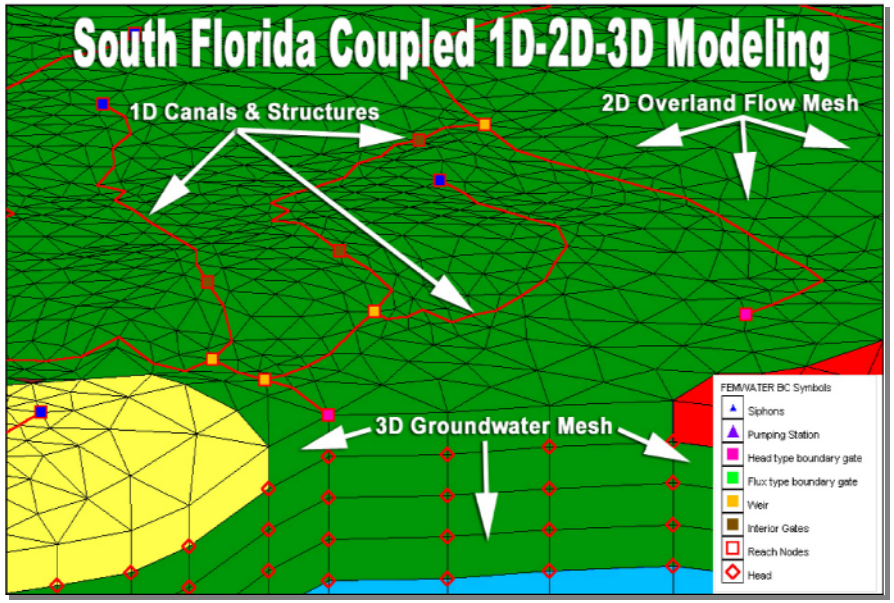
WASH123D

- Water flow and contaminant and sediment transport in WAterSHed systems
- First-principle, physics-based finite element watershed model simulating 1D canal, 2D overland and 3D subsurface flow and transport



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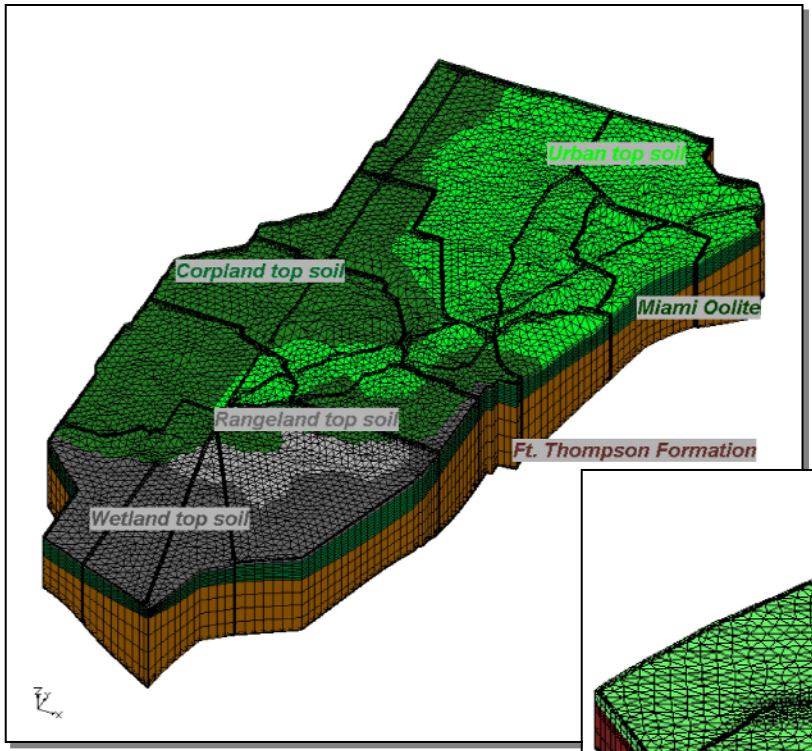
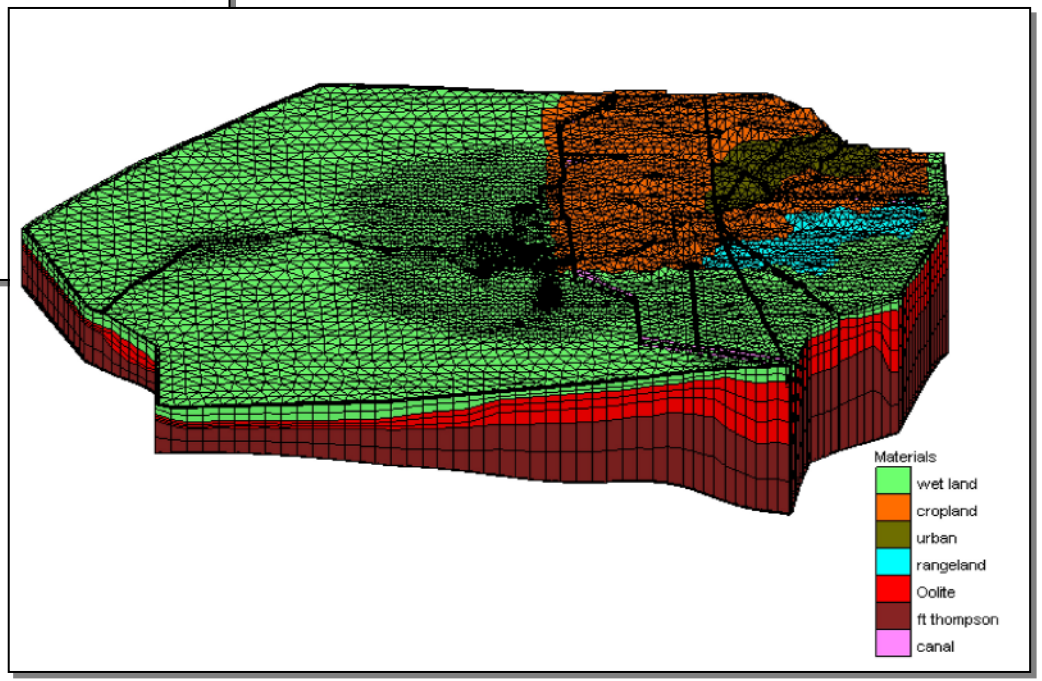
WASH123D



C-111 Spreader Canal Mesh



Biscayne Bay Coastal Wetland Mesh

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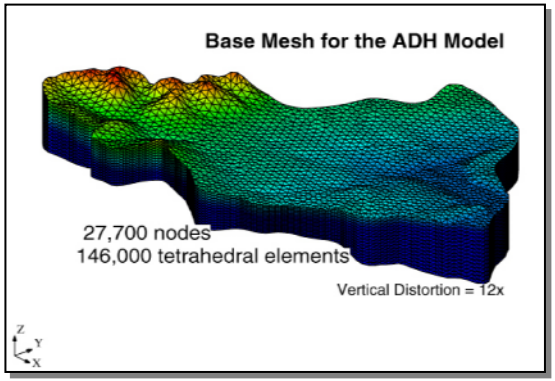
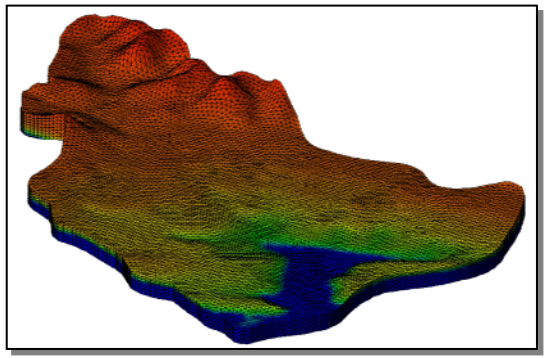
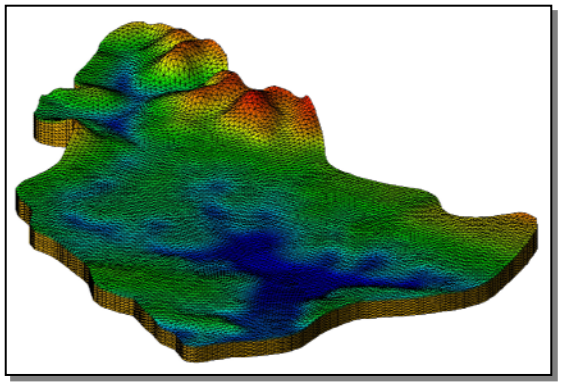
ADH

- ADaptive Hydrology/Hydraulics model that simulates flow and transport in coupled surface water - groundwater systems
- Modular, parallel, adaptive finite element simulation of 2D and 3D dynamic wave surface water and 3D Richards' equation groundwater flow and transport







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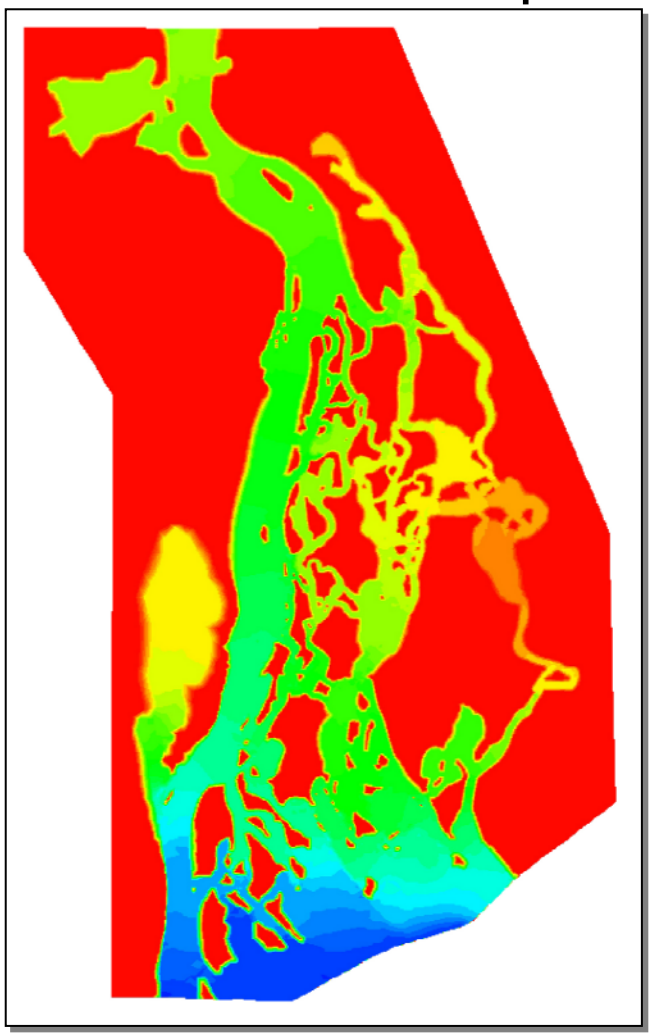
ADH GW-SW Interaction Capabilities

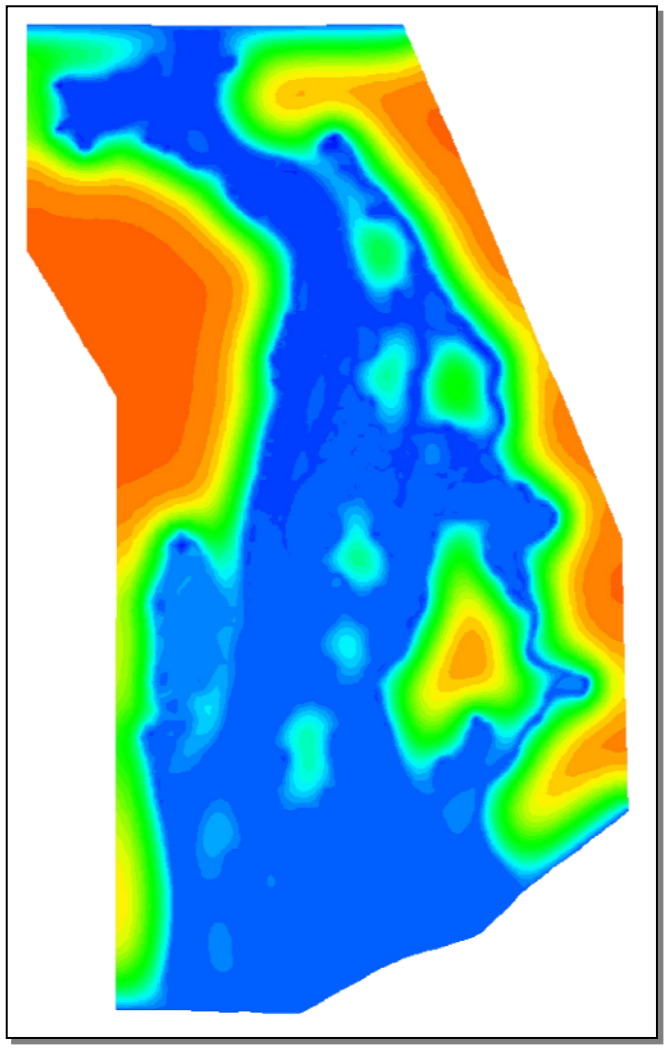
- Coupled 3D groundwater and 2D surface water (diffusive wave and full shallow water) equations
- Flux-based communication avoids switching flux/head boundary
- Dual-valued (SW/GW) nodes on ground surface
- Communication interval is time step
- Separate solves maintain reasonable sizes for the linear systems
- Potential for different time advancement for the hydrologic components

Pool 8 GW-SW ADH Model

Surface Water Depths



Groundwater Heads



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GSSHA Wetland Example

Coon Creek Watershed

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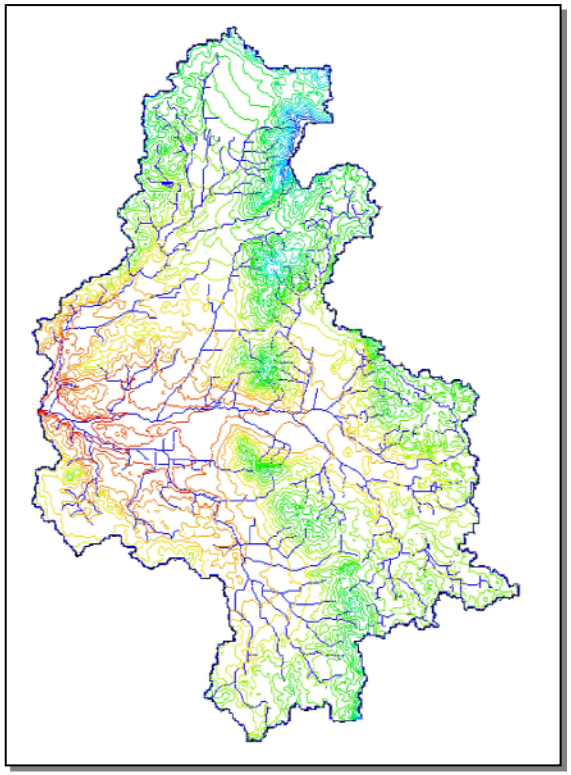
Coon Creek Watershed

- Locate 1600 acre wetland in watershed southwest of Chicago
- Remove tile drains
- Assess impacts of future use



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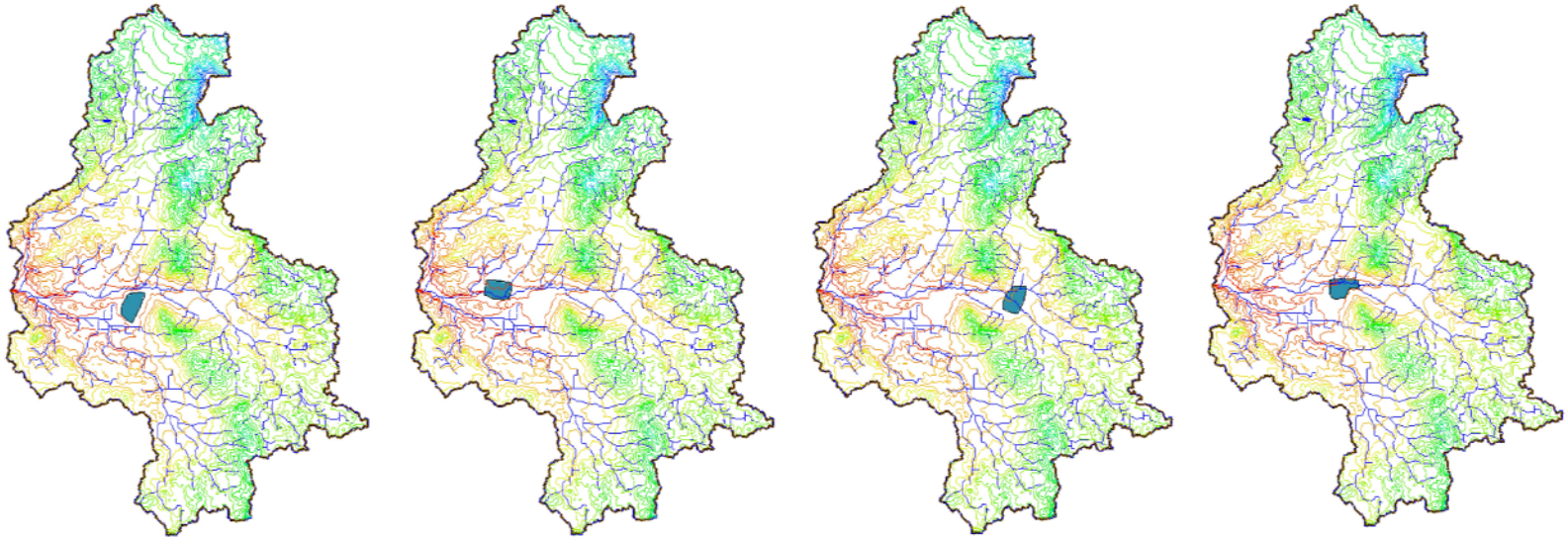
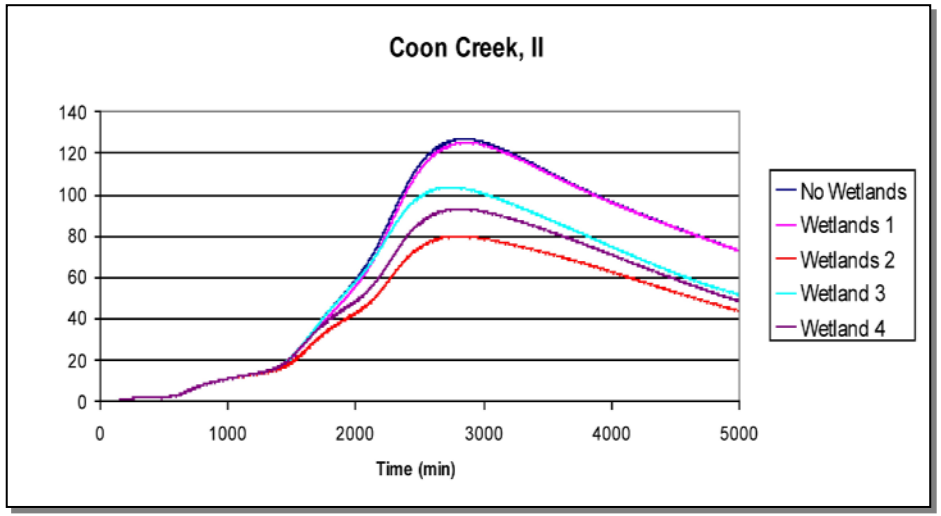
Wetland Placement





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Current Status of GW-SW Interaction Toolbox Codes

- GSSHA
  - Fully supported in WMS version 7.x
  - http://chl.erdc.usace.army.mil/software/wms
- WASH123D
  - Fully supported in GMS version 6.0beta
  - http://chl.erdc.usace.army.mil/software/gms
- ADH
  - Supported in GMS version 5 but full support still under development

SWWRP Deliverables

- Improve infiltration modeling speed by finding physically-based alternatives to Richards' equation
- Addition of 3D unsaturated flow to GSSHA
- Completion of ADH interface development
- Guidance on selection of appropriate physical processes in GW-SW interaction models
- Incorporation of ecological and sediment modeling tools developed in other SWWRP efforts
- Merging of ADH and WASH123D capabilities into single model

Conclusions

- Coupled, multi-dimensional GW-SW interaction codes are needed in complex wetland studies (EM 1110-2-1421)
- Currently, several tools exist for performing such studies
- SWWRP is continuing the development of these tools

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Questions? Comments?

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