Integrating Water Quality and Vegetation with River and Watershed Models

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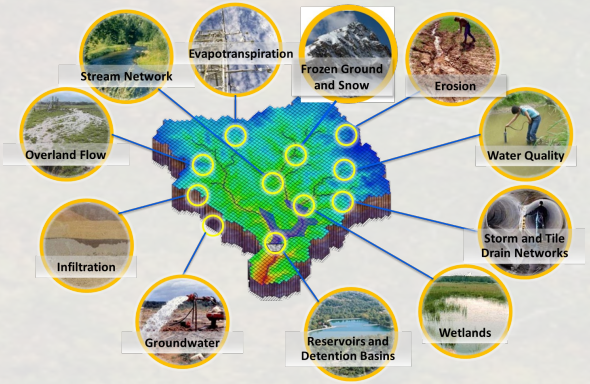
Environmental Laboratory
U.S. Army Engineer Research and Development Center (ERDC)

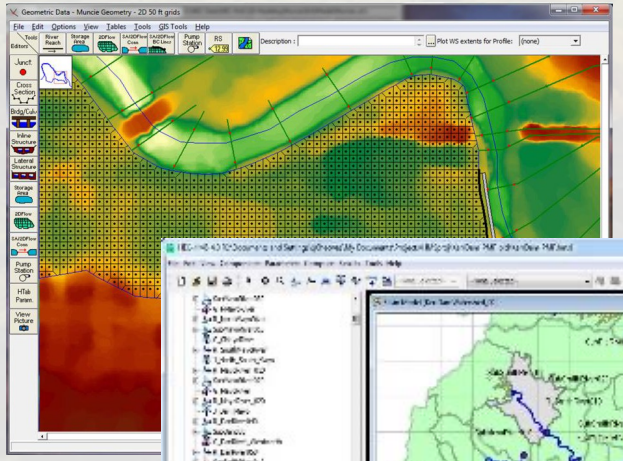
UVA-EPA-USACE Meeting

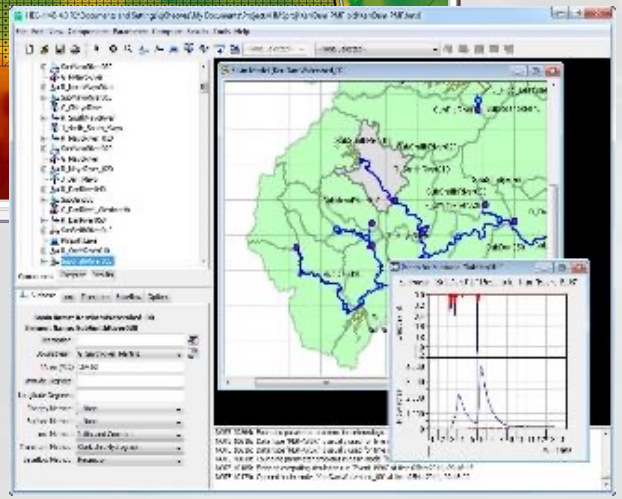
June 22 – 24, 2021

Water Quality Modeling Tools

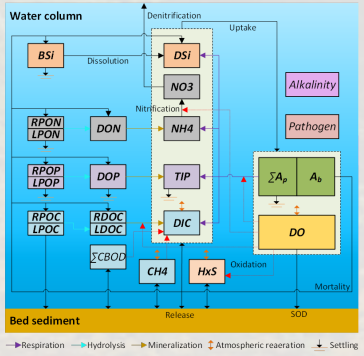
Hydraulics and Hydrology

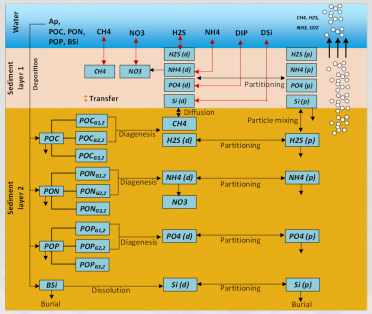


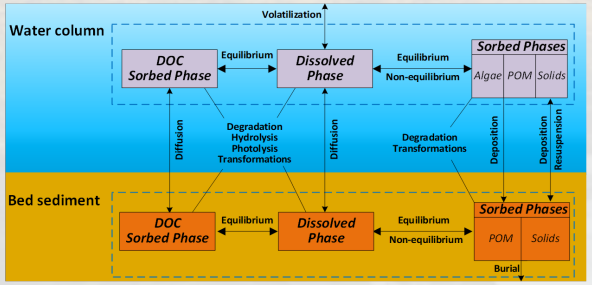


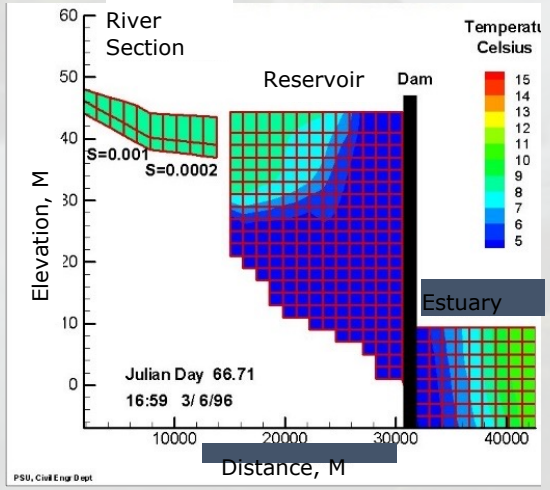


Water Quality

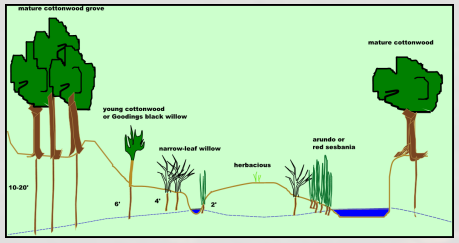


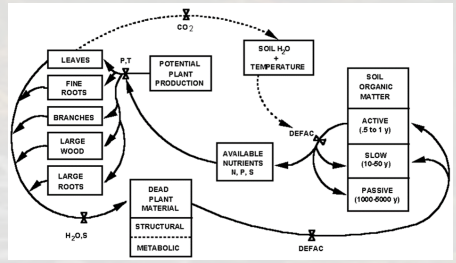


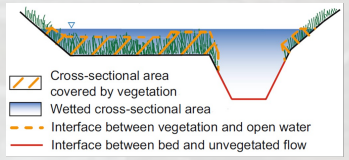




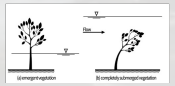
Vegetation







As Vegetation grows and dies, Hydraulic Roughness is allowed to change.



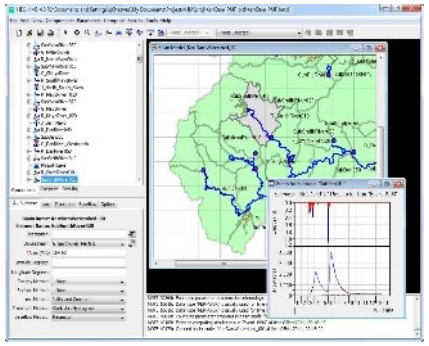
Design with Natural Features

Dallas, TX – Trinity River Project Includes:

- River Channel modification / stream geomorphology
- Wetlands creation
- Park and trail planning
- Flood management
- Sediment management
- Corps permitting and levee management

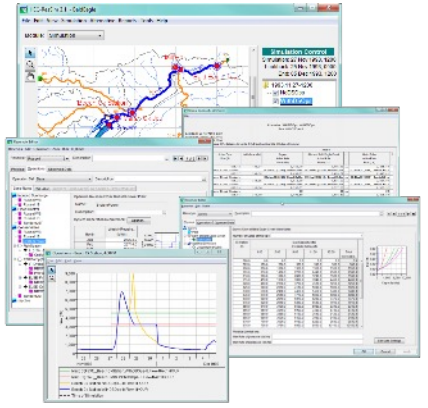
Integrated Watershed Water Quality Modeling

HEC-HMS
Runoff

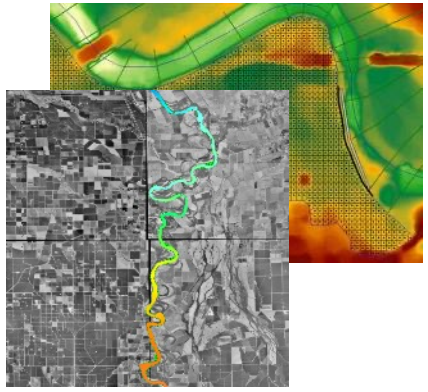


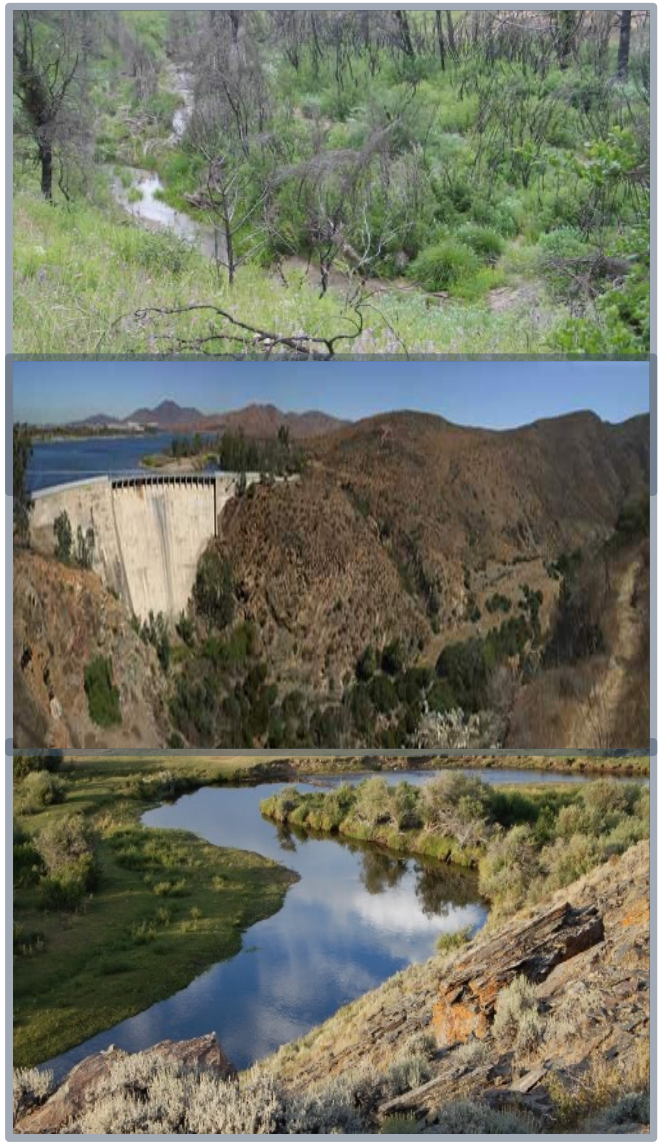
HEC-ResSim
Reservoir release decisions

CE-QUAL-W2
2D Reservoir WQ

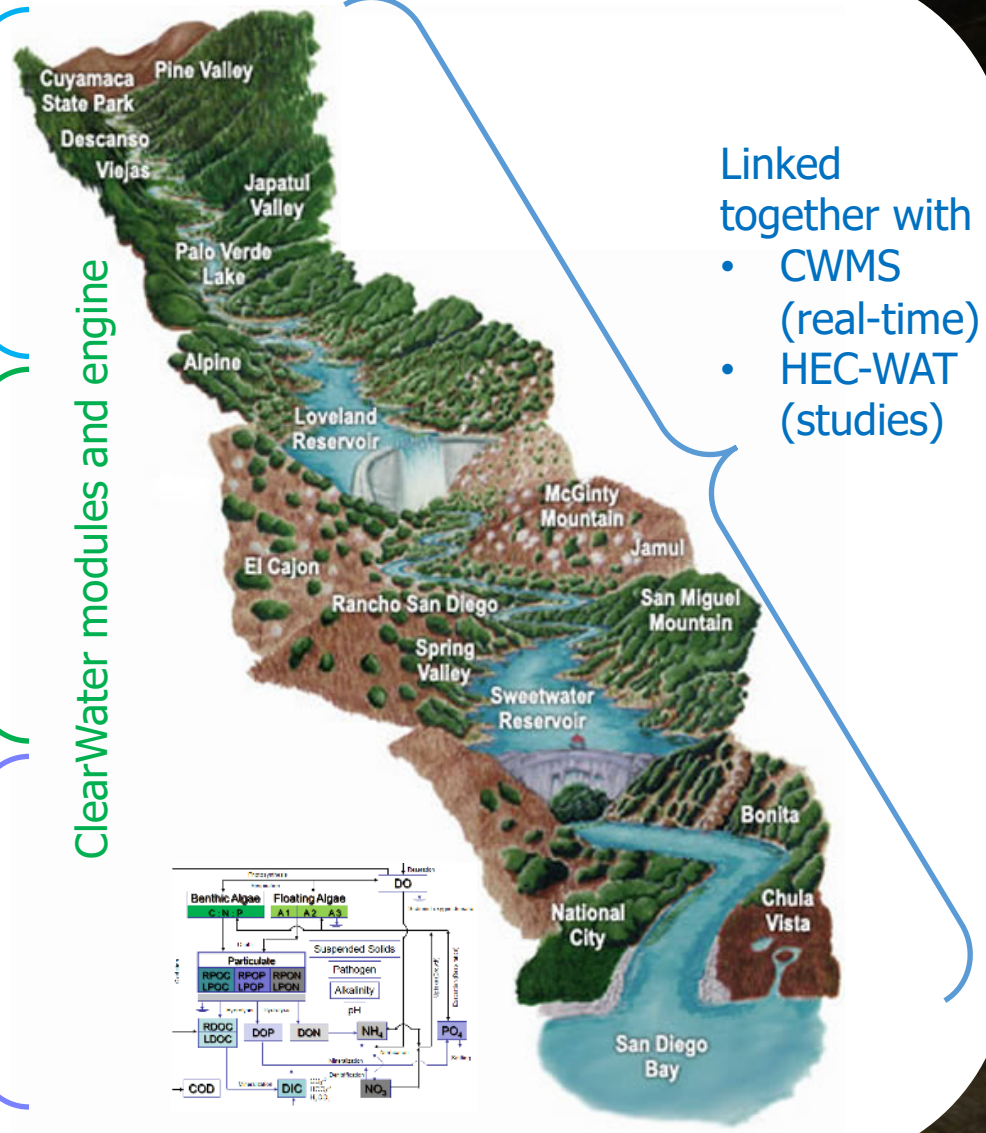


HEC-RAS
River hydraulics





ClearWater modules and engine



Linked together with

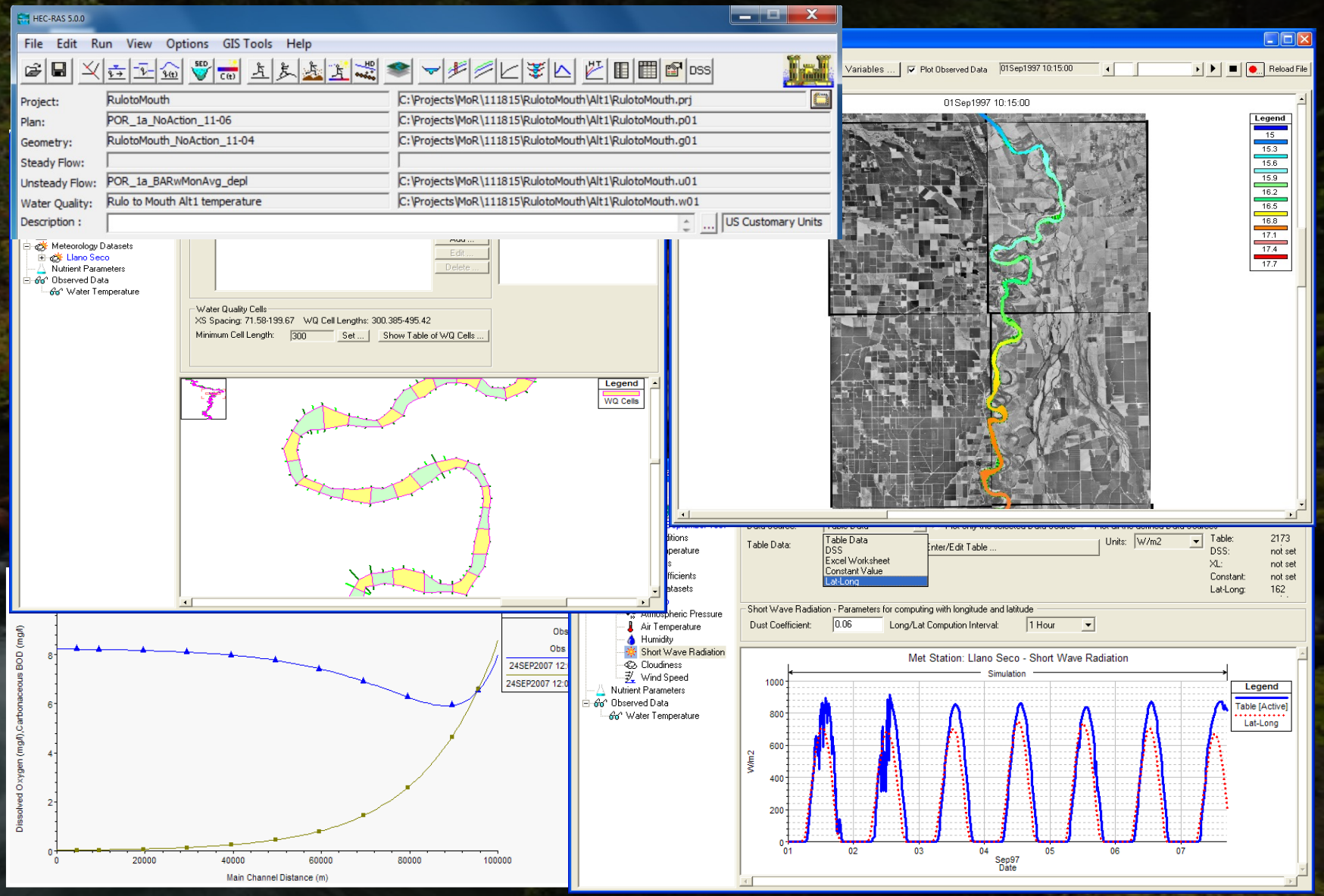
- CWMS (real-time)
- HEC-WAT (studies)

Water Quality and Ecological Modeling Capabilities

- ClearWater (Computational Library for Environmental Analysis and Restoration of Watersheds) is a computational library that is being embedded in existing water resources simulation models.
  - 1. Modules that simulate water temperature, chemical reactions and transformations, and riparian vegetation. These modules are:
    - NSM: Nutrient Simulation Module
    - TSM: Temperature Simulation Module
    - MSM: Mercury Simulation Module
    - CSM: Contaminant Simulation Module
    - SSM: Solids Simulation Module
    - RVSM: Riparian Vegetation Simulation Module
      - VSM: Vegetation Simulation Module (1D/2D riparian and aquatic vegetation)
  - 2. A water quality engine that computes the transport processes and integrates the Clearwater modules with the water resources simulation program (e.g., HEC-ResSim)
  - 3. Graphical User Interface (GUI) components for WQ modeling:
    - Controls and tables to input/import set up a WQ model
      - Boundary & initial conditions, variables, parameters, etc.
    - Plots
    - Reports

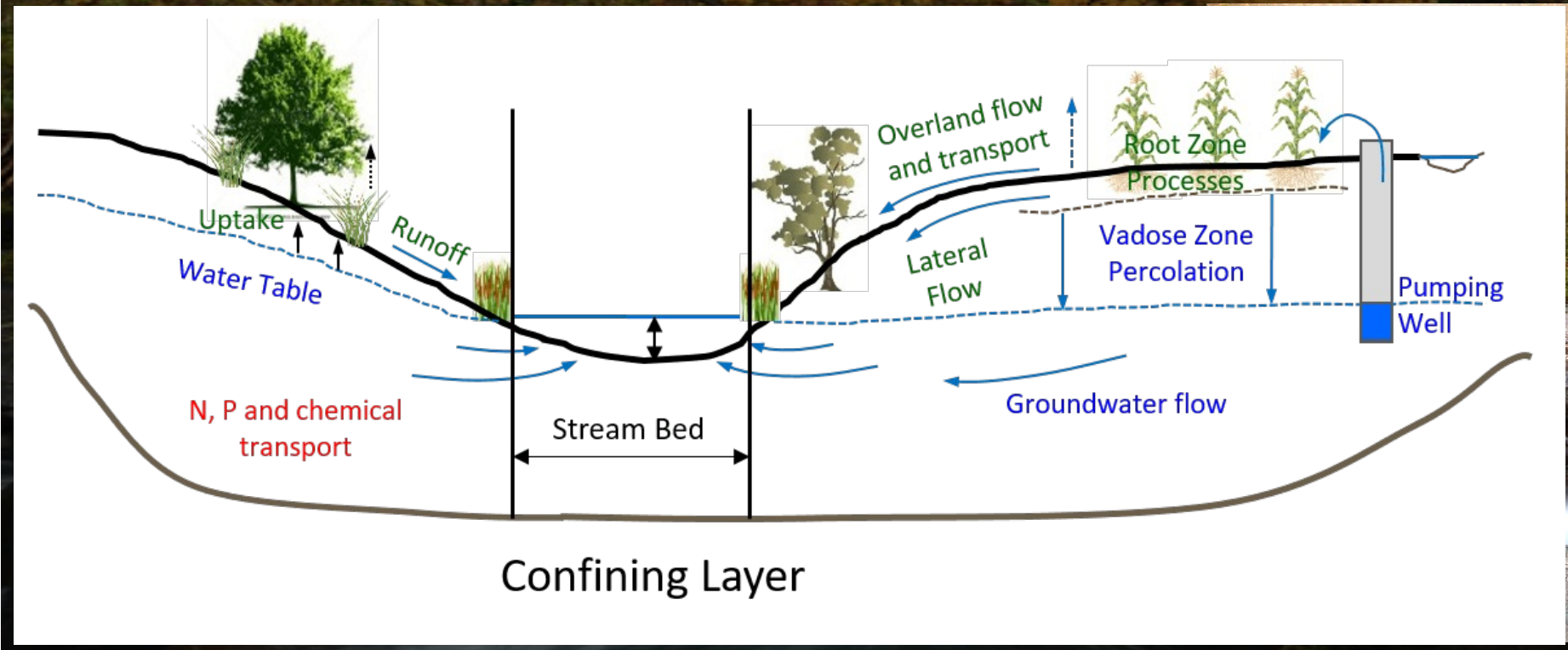
HEC-RAS
River Water Quality (1D)

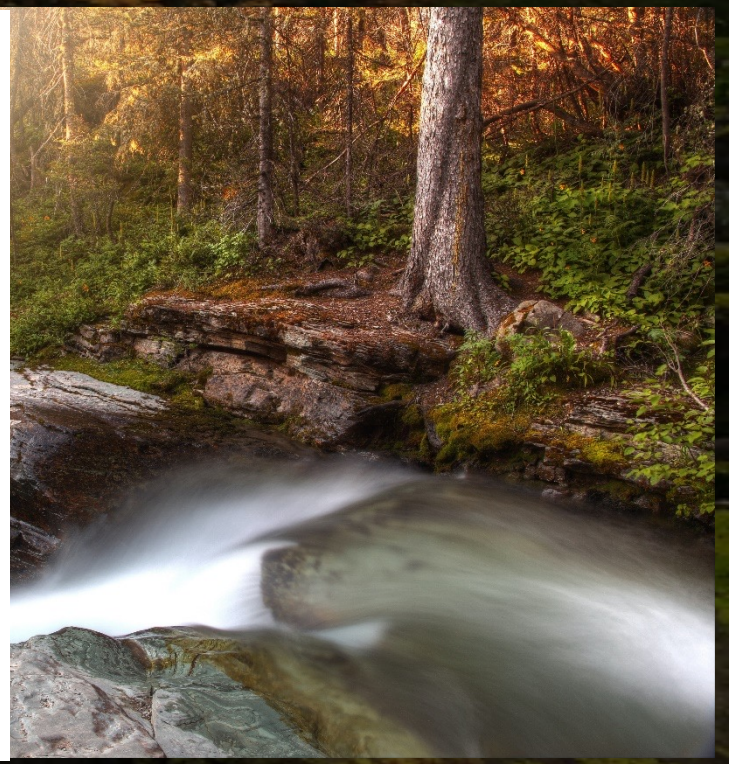
- HEC-RAS (River Analysis System) simulates 1D and 2D river hydraulics
  - Computes river velocities, stages, profiles, and inundated areas (with RAS Mapper) given stream flow and geometry
- Industry standard hydraulic tool used worldwide
- 100,000 worldwide downloads/year
- One-dimensional (1D) water quality capabilities allow environmental impacts assessments in rivers and streams



Riparian Vegetation Simulation Module (RVSM)

- The Riparian Vegetation Simulation Module (RVSM) simulates the lifecycle of vegetation, including seed dispersal, seedling establishment, and plant growth and mortality in response to dynamic physical conditions.
  - RVSM includes eleven vegetation roughness computation methods.
- Hydrologic Processes:

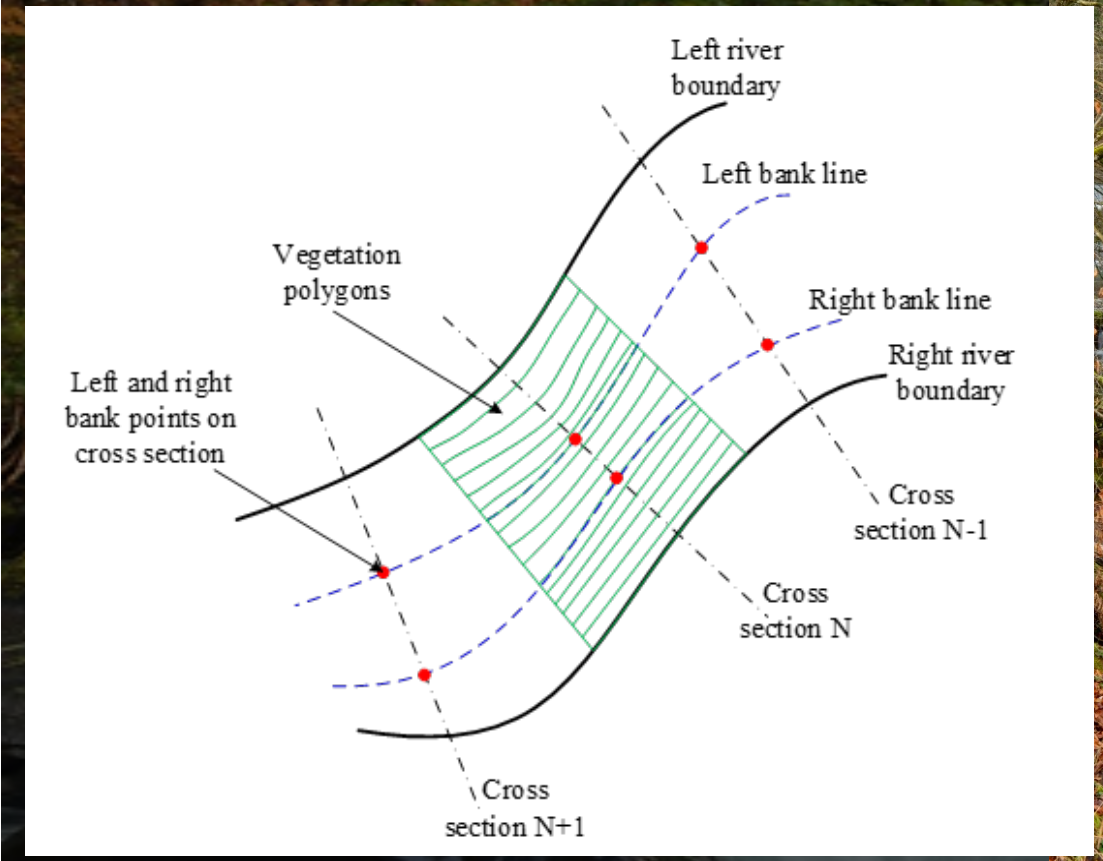


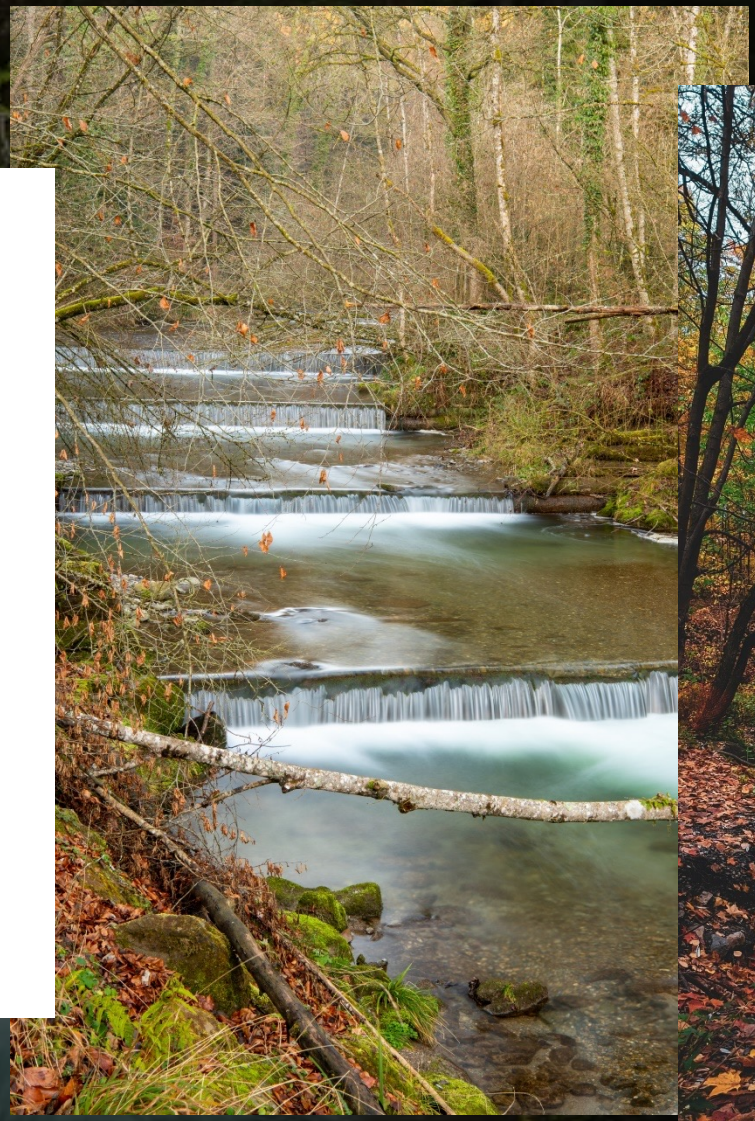


HEC-RAS Riparian Vegetation Simulation

- RVSM was integrated into HEC-RAS to simulate the interactions between flow and riparian vegetation on floodplains.
- RVSM can help answer the following questions:
  - What impact does riparian vegetation have on local flood conditions?
  - What set of riverine operations can be used to encourage recruitment and survival of native vegetation (and control the spread of invasive species)?
  - What impact will management actions have on habitat for endangered and threatened species?
- For each time step:
  - HEC-RAS computes water surface elevation, discharge, average velocity, energy slope of each cross section.
  - RVSM simulates the impacts of these variables on the riparian vegetation lifecycle and computes the impacts of riparian vegetation on channel roughness (Manning's n values).
  - The new roughness values replace the previous values in the HEC-RAS model and are used to compute new hydraulic variables for the next time step.

HEC-RAS Riparian Vegetation Simulation





HEC-RAS RVSM – Jupyter Notebook

jupyter RVSM_Notebook Last Checkpoint: 11 minutes ago (autosaved) Logout

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

Run Markdown

ERDC

Riparian Vegetation Simulation Module (RVSM)

October 1, 2020

Step 1. Set up HEC-RAS river hydraulics model

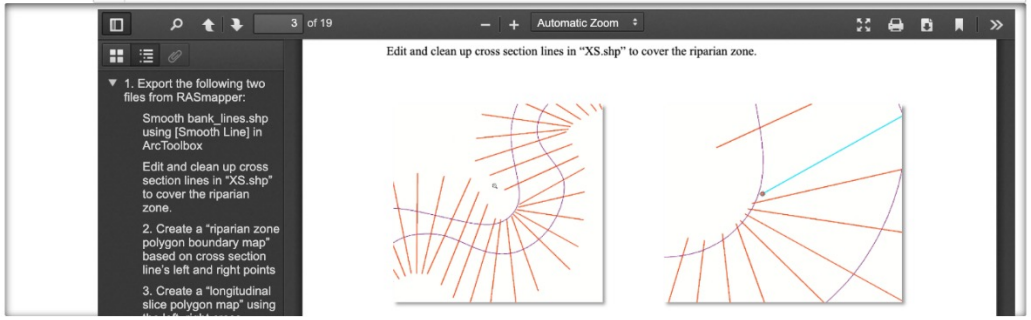
- Download HEC-RAS, Version 6.0
- HEC-RAS User's Manual

In [1]:
```
# Import functions
%run RVSM_CODE.ipynb
```

Step 2. Delineate vegetation polygons

- Export river cross-sections from the HEC-RAS model
- Import cross-sections into ArcGIS
- Draw vegetation polygons to delineate the boundaries of each vegetation type
- Export the polygons to ASCII tables
- Detailed instructions are found in the following document:

In [2]:
```
display(vegetation_polygons)
```



If the PDF above is blank or displays only one page:

- Add the PDF Chromium extension, if you are using Chrome or Opera.
- Open the PDF in an external viewer.
- Uncomment the function below to open the PDF.

In [3]:
```
#show_vegetation_polygon_delineation_pdf()
```

Step 3. Set paths to HEC-RAS vegetation polygon folders

In [4]:
```
set_paths();
```

HEC-RAS Executable: C:/Program Files (x86)/HEC/HEC-RAS/6.0/Ras.exe

HEC-RAS Project Folder: C:/Users/usr/Documents/HEC Data/HEC-RAS/projname

Vegetation Polygon Folder: C:/Users/usr/Documents/RAS_RVSM/Veg_Poly

Step 4. Run or debug HEC-RAS-RVSM

In [5]:
```
run_hec_ras();
```

Run HEC-RAS-RVSM

Debug HEC-RAS-RVSM

More information on Jupyter Notebooks and JupyterLab can be found at:

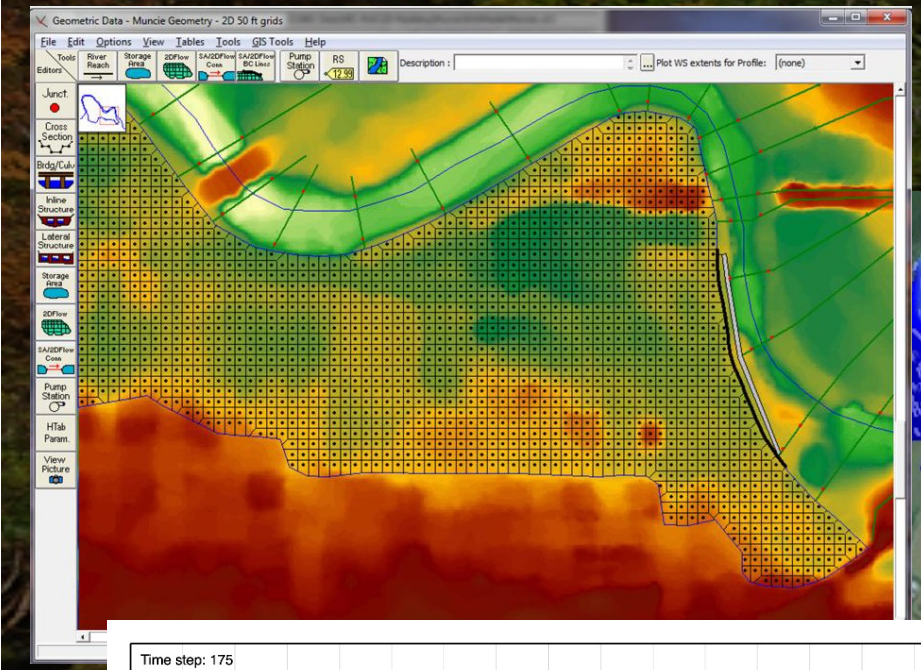
- Jupyter Notebook
- JupyterLab

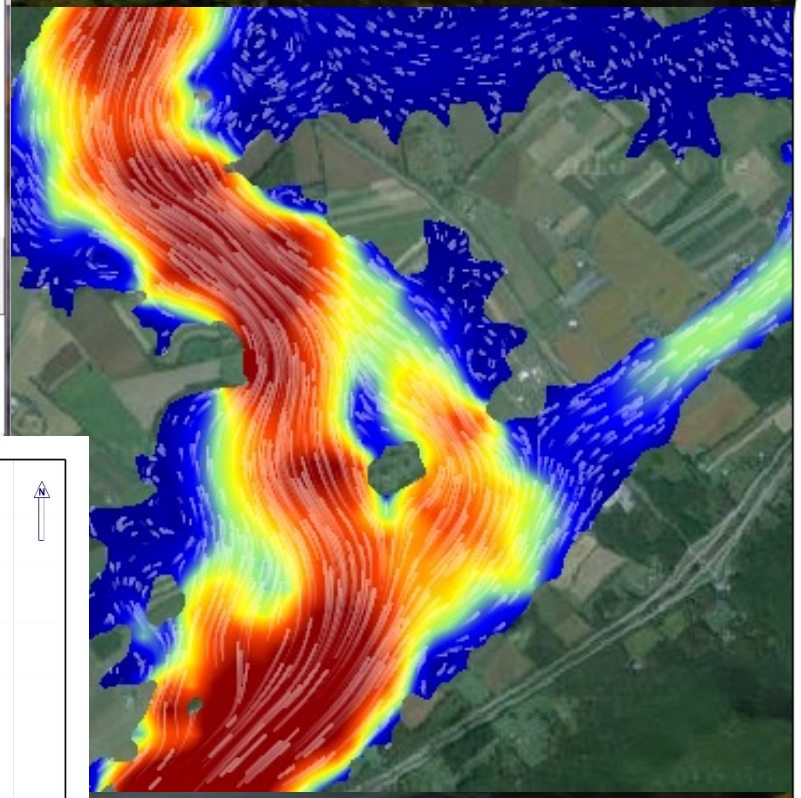
See the following for information on the Python programming language and its wide array of scientific and visualization libraries:

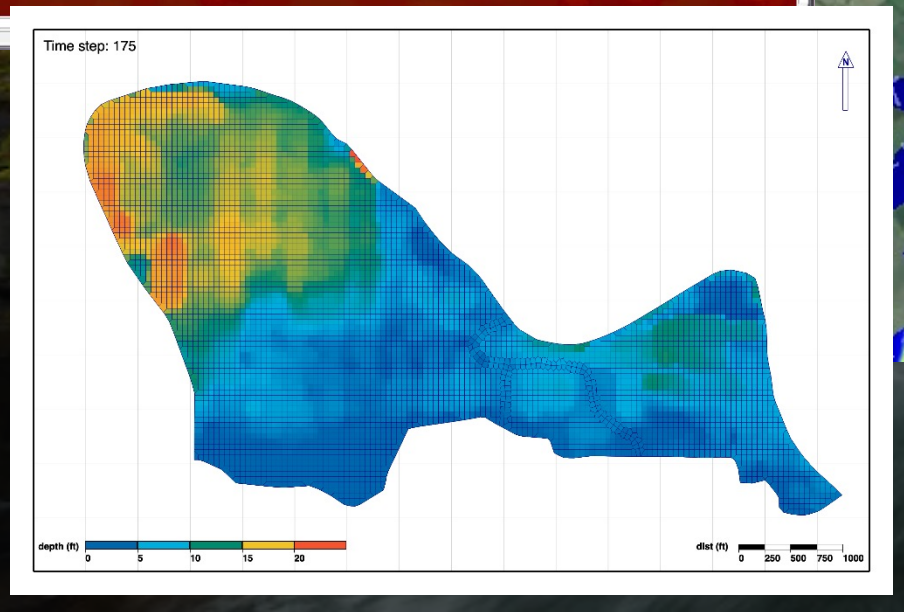
- Python
- SciPy
- Matplotlib
- Pandas
- NumPy

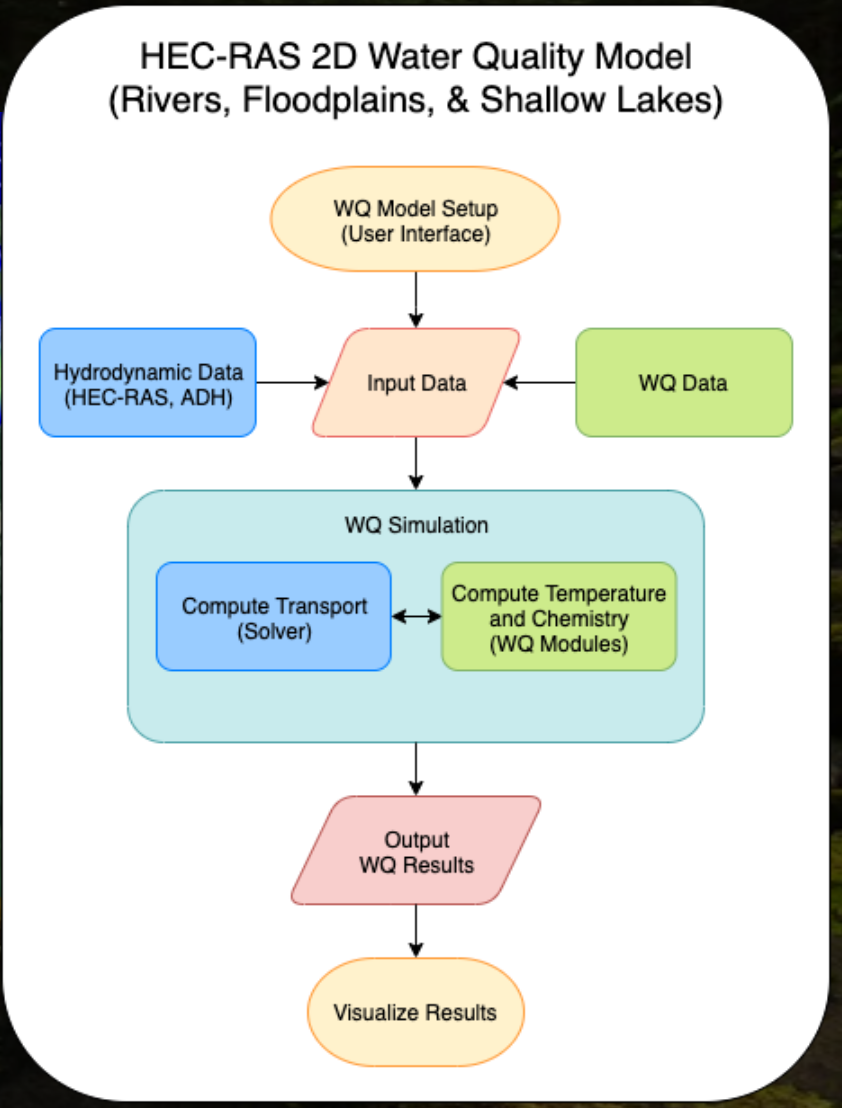
HEC-RAS - 2D Water Quality

Two-Dimensional (2D) Depth-Averaged Water Quality



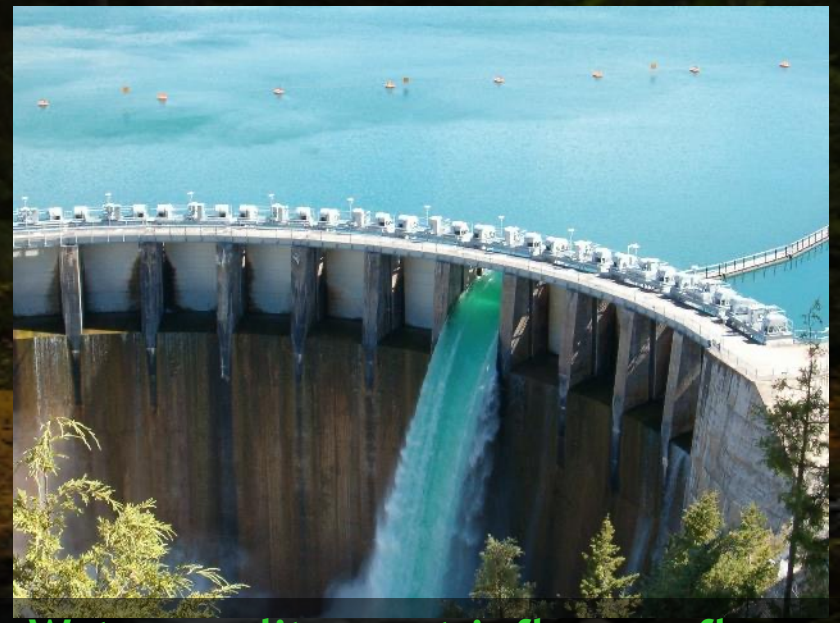






HEC-ResSim Water Quality

Flows influence water quality

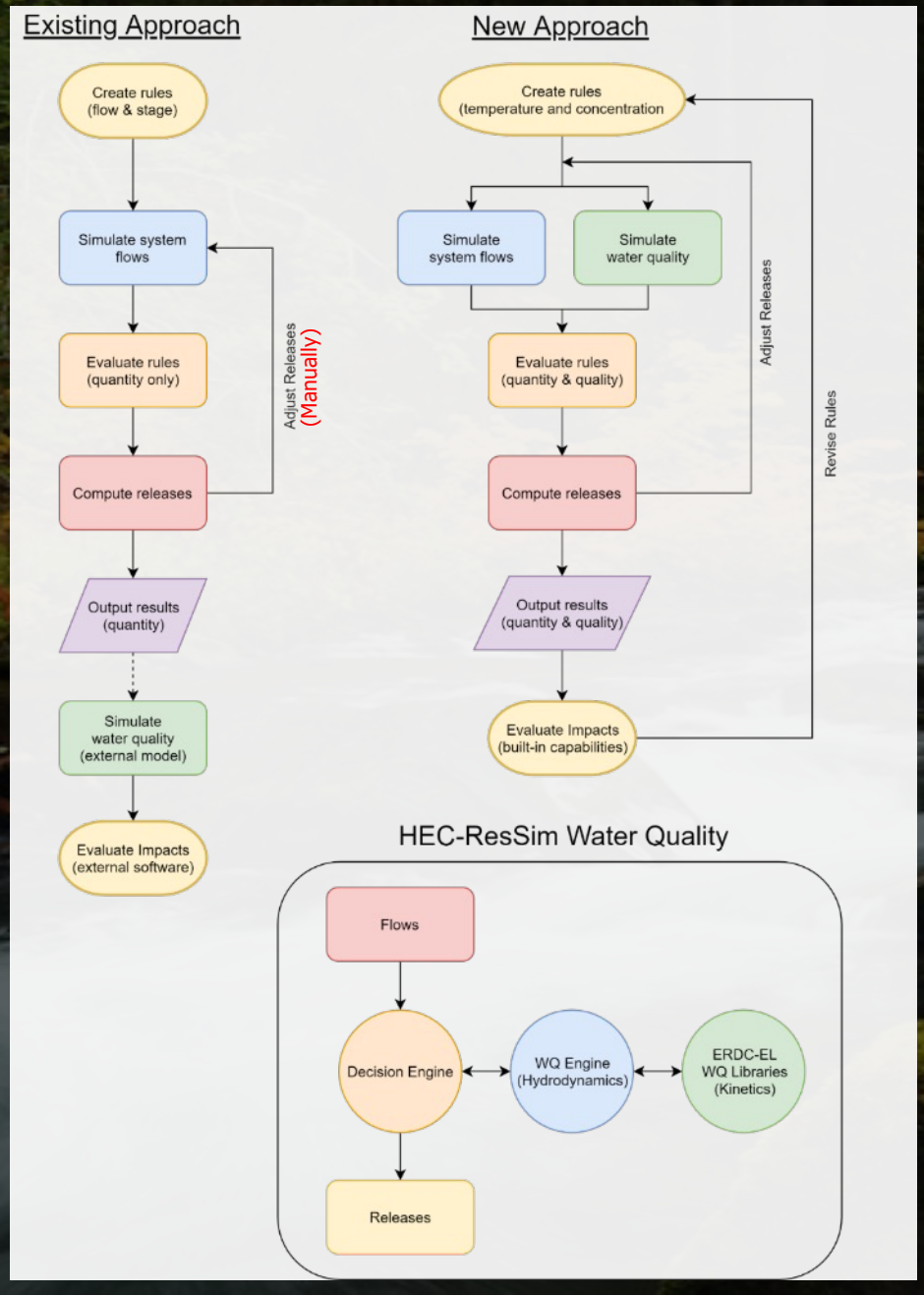


Water quality must influence flows

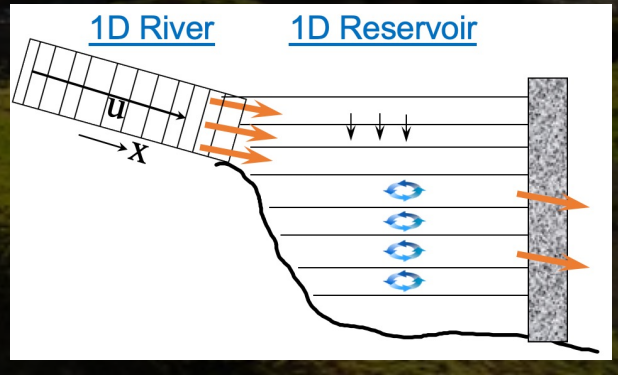
- Problem: Currently, water quality modeling is performed separately from reservoir operation decision-making, with results being laboriously transferred between models, which have to be repeatedly adjusted and recomputed to achieve environmental project objectives. Environmental considerations are not directly accounted for in reservoir operations decision-making, since existing reservoir water quality models cannot continuously inform reservoir operations models about how much water should be released meet these requirements.
- Purpose: Integrate water quality modeling capabilities into HEC-ResSim so that water quality and related environmental objectives can directly influence reservoir release decision-making as well as providing capabilities for watershed-scale ecosystem assessment and management.

HEC-ResSim Water Quality

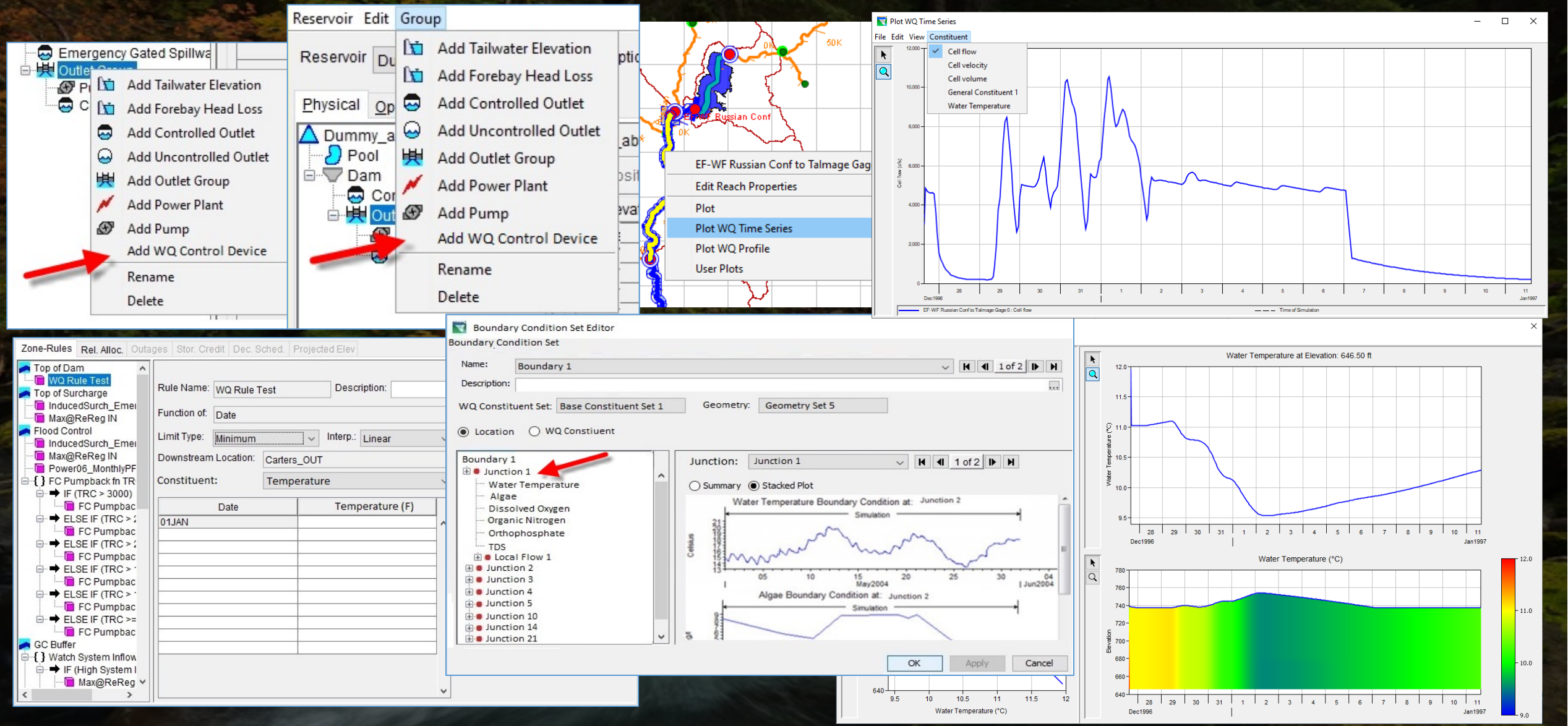
- Existing Approach
  - WQ is simulated with an external model (e.g., HEC-5Q) after the HEC-ResSim flow simulation is complete.
  - Rules are specified in terms of stage or flow.
  - Environmental objectives are often lumped with other objectives, like navigation, flood control, or hydropower.
  - If the desired environmental benefits of an alternative are not achieved, new guesses need to be made, and the simulation recomputed. This stage is often skipped altogether.



- New Approach
  - WQ runs in parallel with the system hydrology and release decisions
  - Reservoir operation rules can be specified directly (i.e., temperature, concentration, or load) to meet environmental objectives
  - Project teams will have the opportunity to define rules for environmental objectives independent of other objectives,



HEC-ResSim v4.0



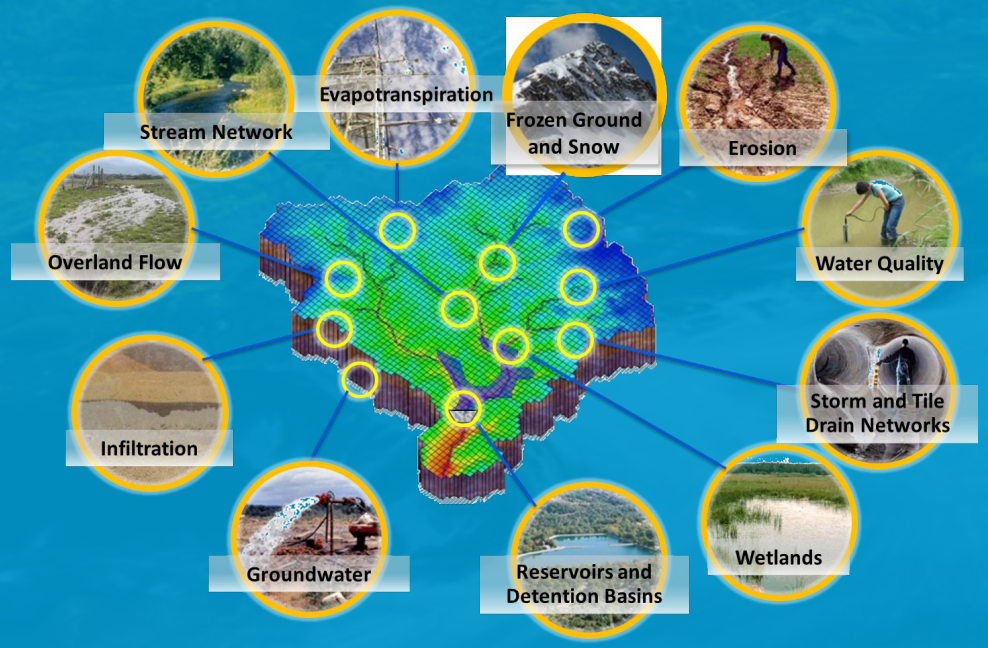
Watershed Runoff Water Quality Modeling

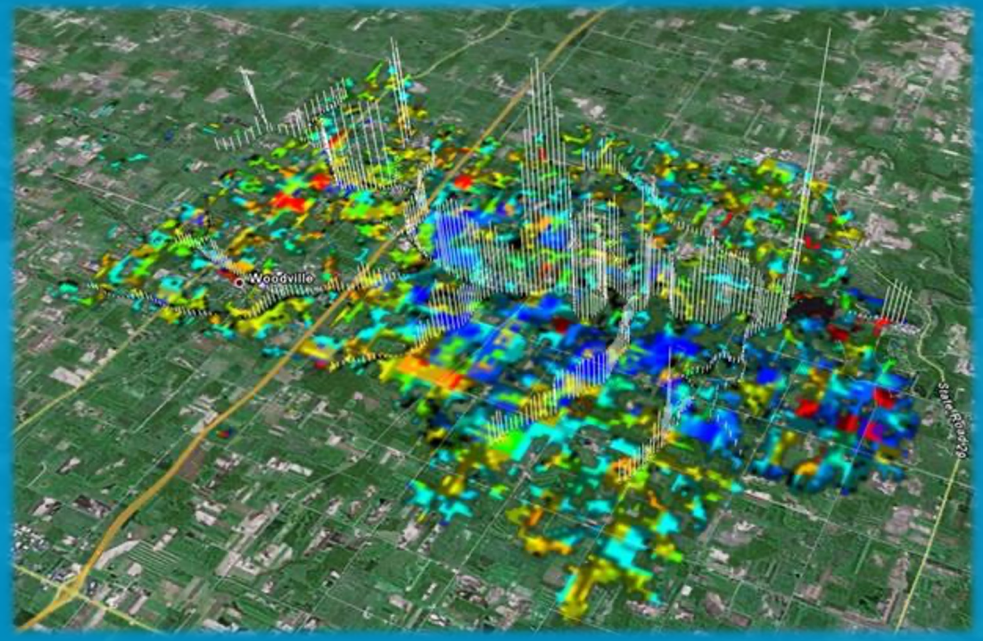
HEC-HMS Water Quality

- Develop water quality modeling and analysis capabilities for HEC-HMS
- ERDC-EL is collaborating with HEC to implement simulation of the water temperature and user-defined general constituents for:
  - Watershed runoff (overland flow)
  - Streams (hydrologic routing)
  - Reservoirs / detention ponds

GSSHA Water Quality and Vegetation

- The ERDC Environmental Laboratory (EL) and Coastal and Hydraulic Laboratory (CHL) are collaborating to link water quality and vegetation (aquatic and terrestrial) modeling capabilities with the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) program.
- The new capabilities will enable simulation of the surface and sub-surface flow of heat and nutrients in ecosystems at watershed scales.






Thank You
Questions?