What's New in HEC-RAS 5.1?

Gary W. Brunner, P.E., M. ASCE, D.WRE, Senior Hydraulic Engineer, Hydrologic Engineering Center, Institute for Water Resources, U.S. Army Corps of Engineers, 609 2nd St., Davis, CA 95616; gary.w.brunner@usace.army.mil

Abstract

HEC-RAS 5.1 will have several significant new features that will dramatically improve the applicability and range of modeling problems that the software can be used to solve. There will be a wide range of new capabilities, such as: spatial precipitation (gridded and point gage options); spatial infiltration; wind forces for 1D and 2D modeling; a new shallow water solution scheme and turbulence modeling; 1D finite volume solution algorithm; pump stations for 2D areas; bridge modeling inside of 2D areas; structure layout in HEC-RAS Mapper; a new 3D viewer for terrain and model results; and calibration tools inside of HEC-RAS Mapper for 1D and 2D regions.

This paper will discuss the details of the new features contained in HEC-RAS 5.1, as well as show real world example applications of their use.

Introduction

HEC-RAS 5.1 will have several significant new features that will dramatically improve the applicability and range of modeling problems that the software can be used to solve. There will be a wide range of new capabilities, such as: spatial precipitation (gridded and point gage options); spatial infiltration; wind forces for 1D and 2D modeling; a new shallow water solution scheme and turbulence modeling; 1D finite volume solution algorithm; pump stations for 2D areas; bridge modeling inside of 2D areas; structure layout in HEC-RAS Mapper; a new 3D viewer for terrain and model results; and calibration tools inside of HEC-RAS Mapper for 1D and 2D regions. This version of HEC-RAS will replace the current version, 5.0.7. At this time there is no scheduled release date for version 5.1.

Spatial Precipitation

The HEC-RAS team has added the ability to apply spatial precipitation as a boundary condition to 2D flow areas and storage areas. The precipitation can be in either a gridded form or based on multiple point gages. Gridded precipitation data can be imported from multiple file formats/sources. Currently, supported gridded precipitation formats include: HEC-DSS; GRIB, and NetCDF. The GRIB and NetCDF formats supported are those precipitation datasets downloadable from the National Weather Service (NWS). GRIB and NetCDF precipitation files from other sources might not be supported as the file format could be different than files from the NWS The HEC-DSS file format has supported gridded datasets for 20 years and HEC has a number of utility programs for converting files in other formats to records inside of a HEC-DSS file. The software HEC-MetVue can be used to download data, visualize the data, and store it into multiple data formats, including the HEC-DSS file format.

Shown in Figure 1 is a visualization of spatial precipitation being used in HEC-RAS overtop of a 2D Flow Area model. The data shown in Figure 1 is the precipitation that fell in a 1 hour time period.

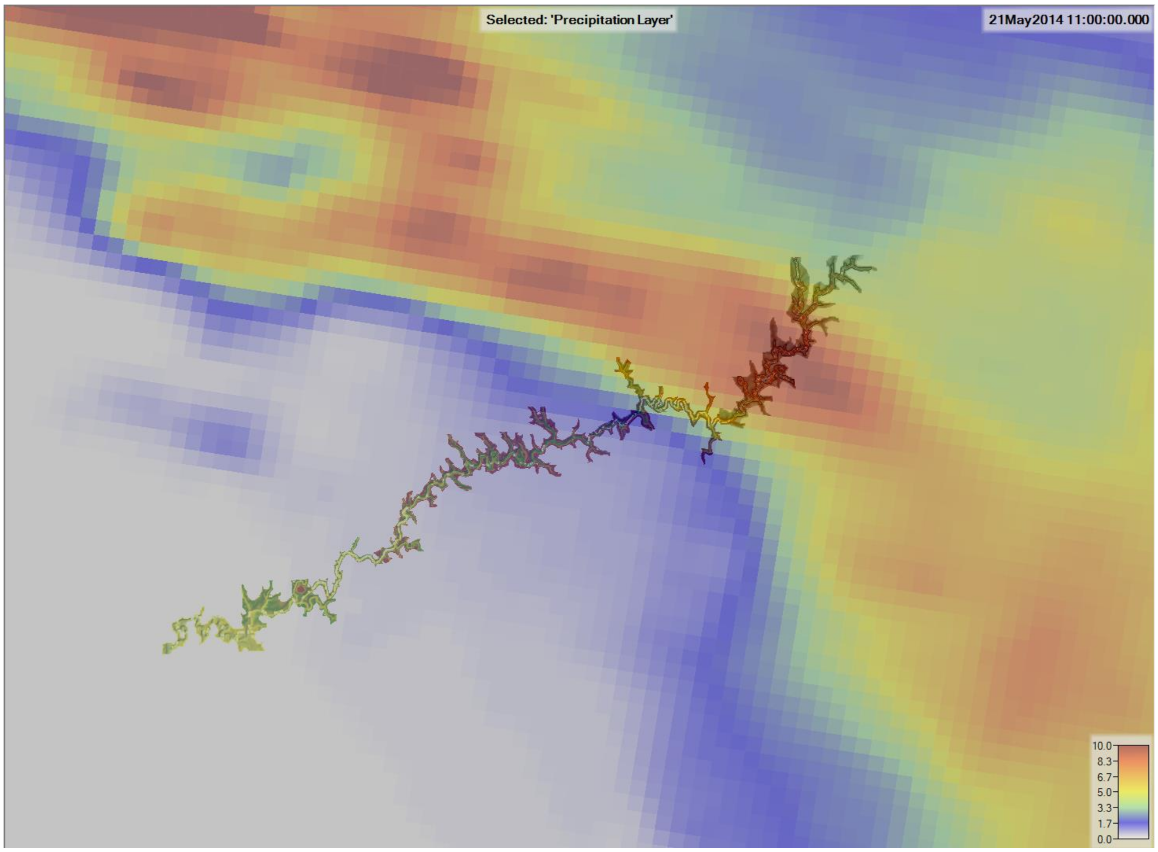

Figure 1. Gridded Spatial Precipitation Boundary Condition for HEC-RAS Modeling.

Spatial Infiltration

The HEC-RAS team has added the option for spatial infiltration to be used along with spatial precipitation. Currently three infiltration methods will be available to users, these are: Deficit/Initial and Constant; Modified SCS Curve Number; and a continuous implementation of the Green and Ampt method. All three infiltration methods work directly from the precipitation hyetograph and do not account for ponding and continuous infiltration on the land surface (that will be in future versions of the software). Additionally, the SCS Curve Number method has several modifications/options. These options include: user specified initial loss (instead of 0.2S); separate Curve Number for pervious only areas, while impervious areas are given a separate curve number (100 by default); the ability to set a minimum infiltration rate, such as the saturated hydraulic conductivity rate (the Curve Number method results in zero infiltration when applied to a precipitation time-series that includes a total precipitation depth that reaches the curve number's Storage (S) volume); and the option to recover the initial loss once a dry duration has been reached.

Wind forces for 1D and 2D modeling

The option to add in wind forces for both 1D and 2D modeling has also been incorporated into the software for version 5.1. This work has been funded by the Tennessee Valley Authority (TVA). This is only an option for the Full Momentum Equation solution scheme for 1D river reaches and 2D flow areas (i.e. if you are using Diffusion Wave equation solver, no wind forces can be included). Wind data can be included as a boundary condition in both gridded and point gage forms. Gridded data can be in any of the same three formats allowed for precipitation (HEC-DSS, GRIB, and NetCDF). In addition to adding wind surface stresses into the momentum equation as an additional force, user options are available for: computation of the wind drag coefficient; wind height corrections; wind velocity factors; data conversions; and wind hiding factors. An example wind field applied to an HEC-RAS 1D model is shown in Figure 2 below.

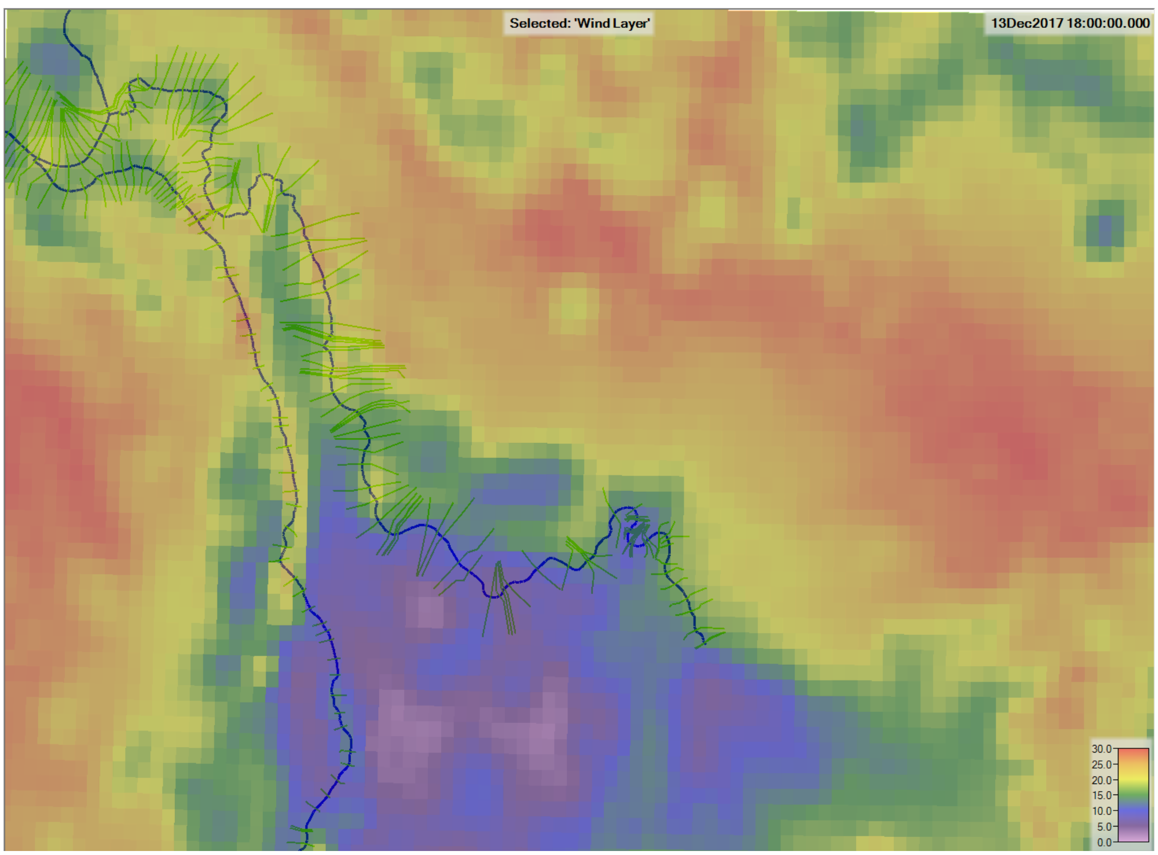

Figure 2. Example Gridded Wind Field Applied to a 1D HEC-RAS Model.

1D Finite Volume Solution Algorithm

A brand new solution algorithm has been developed for 1D modeling. A Finite-Volume solution approach, similar to what was added for 2D modeling is available for 1D modeling in HEC-RAS version 5.1.

The current 1D Finite Difference solution scheme has the following deficiencies:

1. Cannot handle starting or going dry in a XS
2. Low flow model stability issues with irregular XS data.
3. Extremely rapid rising hydrographs can be difficult to get stable
4. Mixed flow regime (i.e. flow transitions) approach is approximate
5. Stream junctions do not transfer momentum

The new 1D Finite Volume approach has the following positive attributes:

1. Can start with channels completely dry, or they can go dry during a simulation (wetting/drying).
2. Very stable for low flow modeling
3. Can handle extremely rapid rising hydrographs without going unstable.
4. Handles subcritical to supercritical flow, and hydraulic jumps better.
5. Junction analysis is performed as a single 2D cell when connecting 1D reaches (continuity and momentum is conserved through the junction).

Additionally, the new 1D Finite Volume approached is solved in the same matrix as the 2D equations. Solving in the same matrix allows for faster 1D/2D model solutions and more accurate flow transfers between 1D and 2D elements. The equations are solved together and all hydraulic connections are updated together on an iteration by iteration approach, rather than separately, as in previous versions of HEC-RAS.

New Shallow Water Solution Scheme and Turbulence Modeling

One of the goals of the HEC-RAS 5.1 software release was to add a third solution scheme for 2D modeling. Previous versions of HEC-RAS had two options for 2D modeling, Diffusion Wave and a Full Momentum (Shallow Water, SW) solution approaches. The current Full Momentum equation solver uses a semi-Lagrangian approach to discretize the acceleration terms in the momentum equation. While this approach has the advantage of being stable for large time steps, in some instances it can create numerical diffusion of momentum. The numerical diffusion can lead to potentially inaccurate results, especially in lab-scale simulations, as well as detailed structure design and analysis, where strict conservation of momentum is important. For this reason, an alternative SW solver option has been developed. The alternative approach utilizes the Eulerian momentum-conservative discretization of the acceleration terms suggested by Kramer and Stelling (2008). However, the tradeoff for more accurate momentum conservation is that the method requires the 2D grid to be strictly orthogonal, and the time step necessary for stability is limited by the Courant condition.

The new Shallow Water solution scheme has been thoroughly tested for several very difficult hydrodynamic problems. One such problem is the sudden dambreak over a completely dry surface. This test is where a wall of water is instantaneously released to a dry downstream reach. A lab study of this problem was performed by the Waterways Experimentation Station (WES, 1960) of the U.S. Army Corps of Engineers. A 400 ft. flume, place on a slope was used to perform this experiment. The details of this experiment can be found in the HEC-RAS Verification and Validation document on the HEC-RAS web page. Shown in Figure 3 are the observed lab data water surface elevations and computed results from the current (version 5.0.7) HEC-RAS Full Momentum solver. As you can see, the current full momentum solver provides an adequate solution to this problem, but it is not able to track the leading edge of the floodwave accurately. This is due to the fact that the method is computing too much numerical diffusion on the wetting front of this extremely dynamic wave problem. Because of the numerical diffusion, the computed wave front is too deep and too slow compared to the observed lab data.

Shown in Figure 4 is the results from the same test with the new Shallow Water Equation solver solution. As you can see, the new solver does extremely well at tracking the wetting front, as well as the negative wave that propagates upstream. The new solver does an excellent job at conserving the momentum and speed of the floodwave as it propagates downstream.

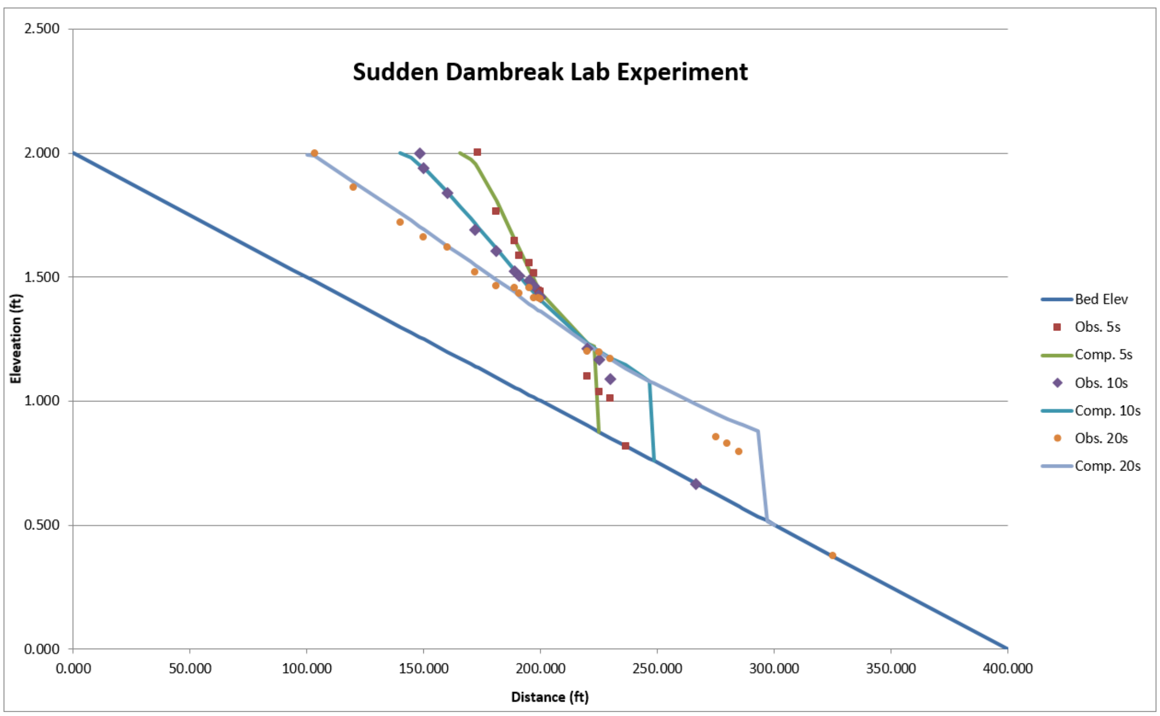

Figure 3. Original Shallow Water Solver vs Lab Results.

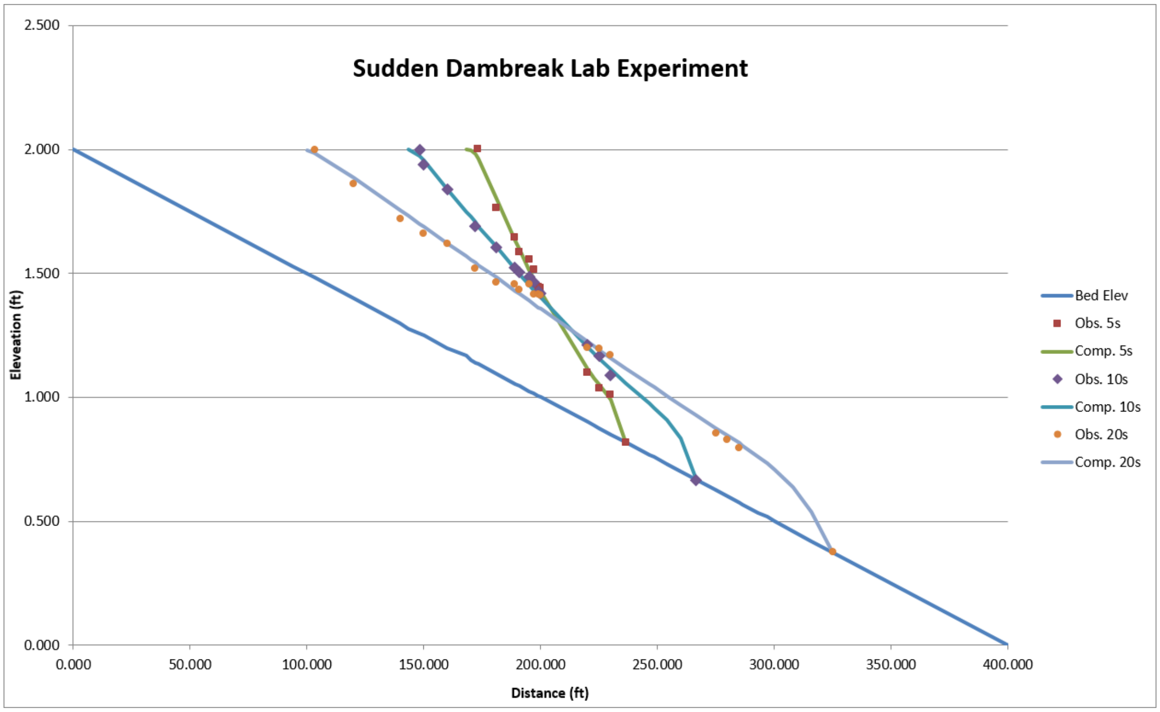

Figure 4. New Shallow Water Equation Solver vs Lab Results.

Pump stations for 2D areas

Previous to HEC-RAS version 5.1, pump stations could not be connected to 2D cells. HEC-RAS version 5.1 allows the user to connect pumps from 1D elements (cross section or storage area) to 2D cells, or 2D cells to another 2D cell. All previous types of pump connections are also still valid (1D to 1D). Each pump can connect to only a single 2D cell; however, users can have multiple pumps at a pump station, and each pump can be explicitly connected to 1D elements and 2D cells. Pump flow is added and extracted with a source/sink type of approach, meaning it is only a flow transfer with no accounting for velocity/momentum.

Bridge modeling inside of 2D areas

Previous to HEC-RAS version 5.1, no direct bridge modeling option (similar to what is in the 1D approach) was available inside of a 2D flow area. Users could model bridge flow in great detail, as long as water depths remained in a low flow condition, and never became either pressurized or pressure flow plus overtopping at the bridge deck. HEC-RAS version 5.1 includes an optional 1D type of bridge modeling approach. Users will be able to put in bridge data (Deck, abutments, piers, etc…) and choose from the full array of 1D solution approaches (Energy, Momentum, Yarnell, WSPRO, Pressure flow, and pressure plus weir flow). A family of rating curves will be developed for the structure, then that family of rating curves is used to solve for the flow and headwater water surface elevations at the structure, for the full range of possible flow regimes.

Additionally, users will have the option to only use the 1D family of bridge curves for the flow going through the bridge opening, while computing any overflow with the full 2D equations. The HEC-RAS team has also developed an approach to account for momentum transfer through the bridge by taking into account, both the velocity and the flow through the bridge opening.

Structure layout in HEC-RAS Mapper

Many new features have been added to HEC-RAS Mapper in order to make a complete set of tools for laying out an HEC-RAS model. The new tools are: ability to layout hydraulic structures spatially (bridges/culverts, inline structures, lateral structures, and SA/2D hydraulic connections); the ability to extract Manning's n values from spatial roughness layers; and the ability to define cross section properties such as ineffective flow areas and blocked obstructions. An example of a model with bridges and lateral structures that were defined in HEC-RAS Mapper is shown in Figure 5 below.

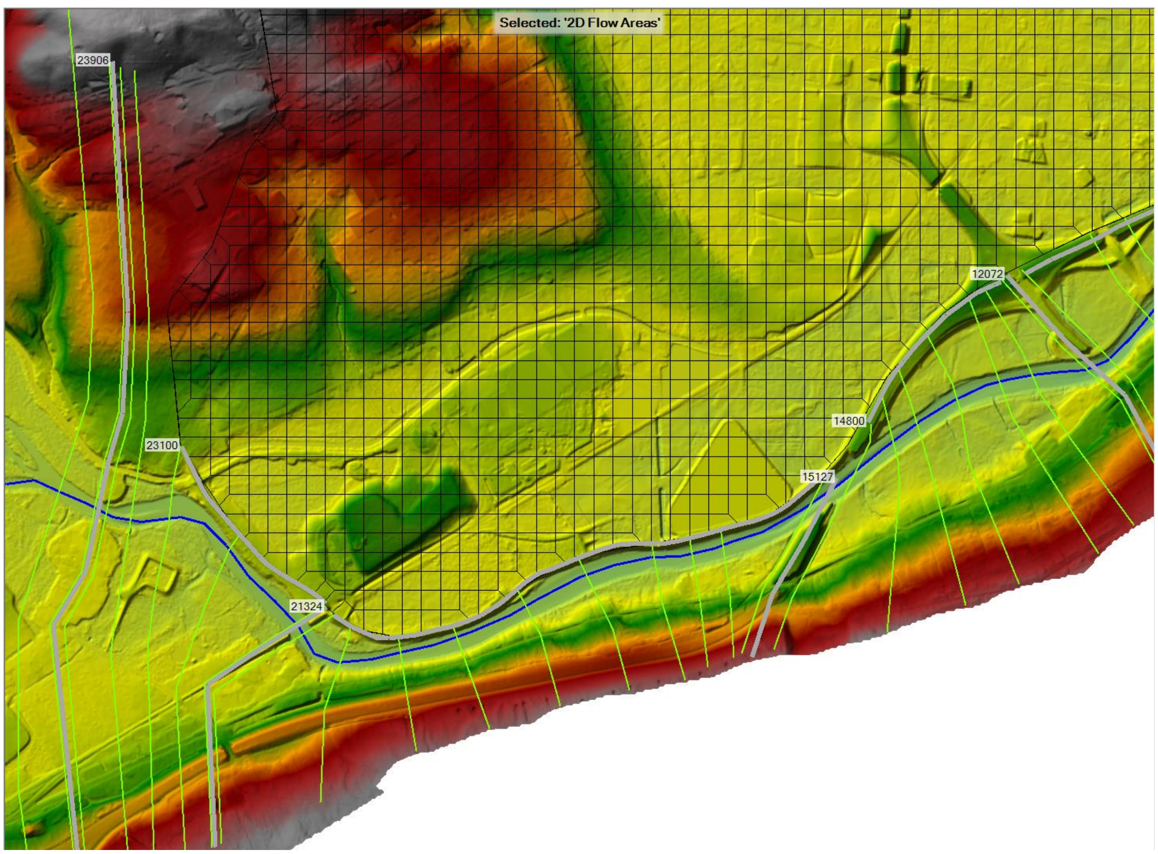

Figure 5. Example Model with Hydraulic Structures laid out in HEC-RAS Mapper.

New 3D viewer for terrain and model results

The HEC-RAS team has developed a new 3D viewer that allows users to visualize the terrain data and model results. The model results can be animated in time and the user can move through the model in a manner similar to a plane flying over an area. Additionally, users will be able to drape various layers over the top of the terrain, such as aerial photography, buildings, and roads. Shown in Figure 6 is a 3D view of Bald Eagle Creek and Sayers Dam, along with the HEC-RAS model results for water depth.

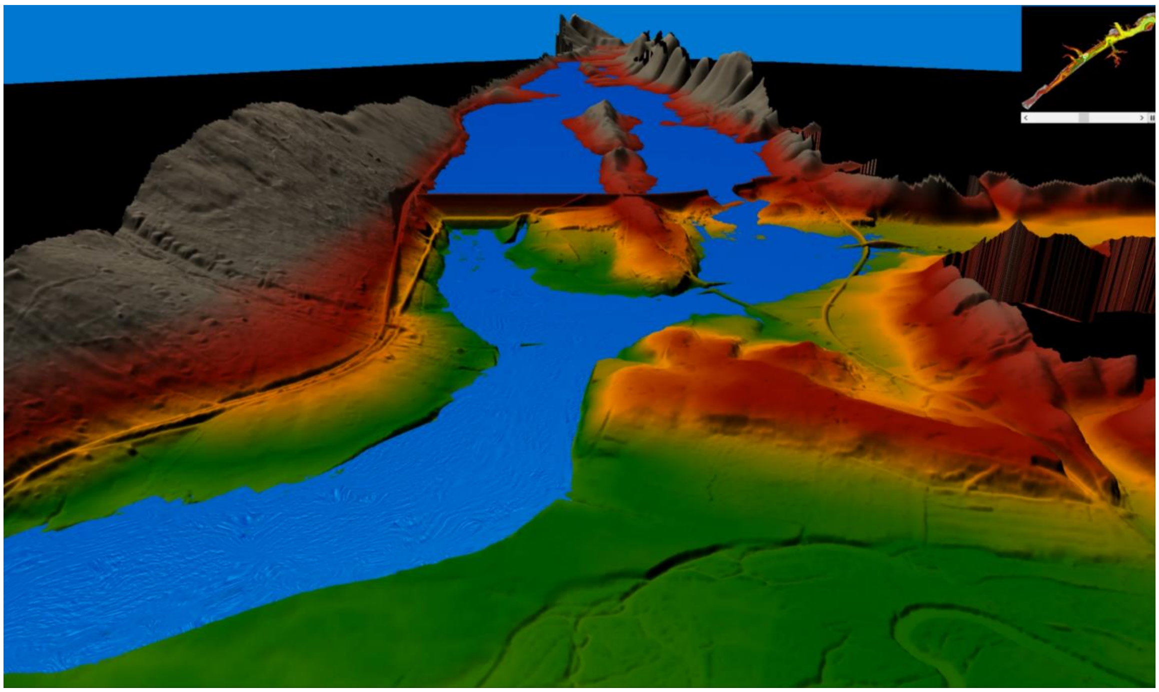

Figure 6. 3D view of Terrain data and HEC-RAS model results.

Calibration tools inside of HEC-RAS Mapper for 1D and 2D regions

The HEC-RAS team has added the ability to display observed data along with computed results from within HEC-RAS Mapper. This will facilitate the model calibration process for 1D and 2D modeling approaches. Users can now plot observed time series data (stage and flow) against HEC-RAS model computed stages and flows at cross sections and user specified profile lines within HEC-RAS Mapper. Users can also plot high water marks against computed results at user defined profile lines. Additionally, observed rating curve data can be entered and compared to computed results at cross sections and user defined profile lines. Figure 7 below shows HEC-RAS Mapper plots for computed stage and observed stage data at two locations in a model.

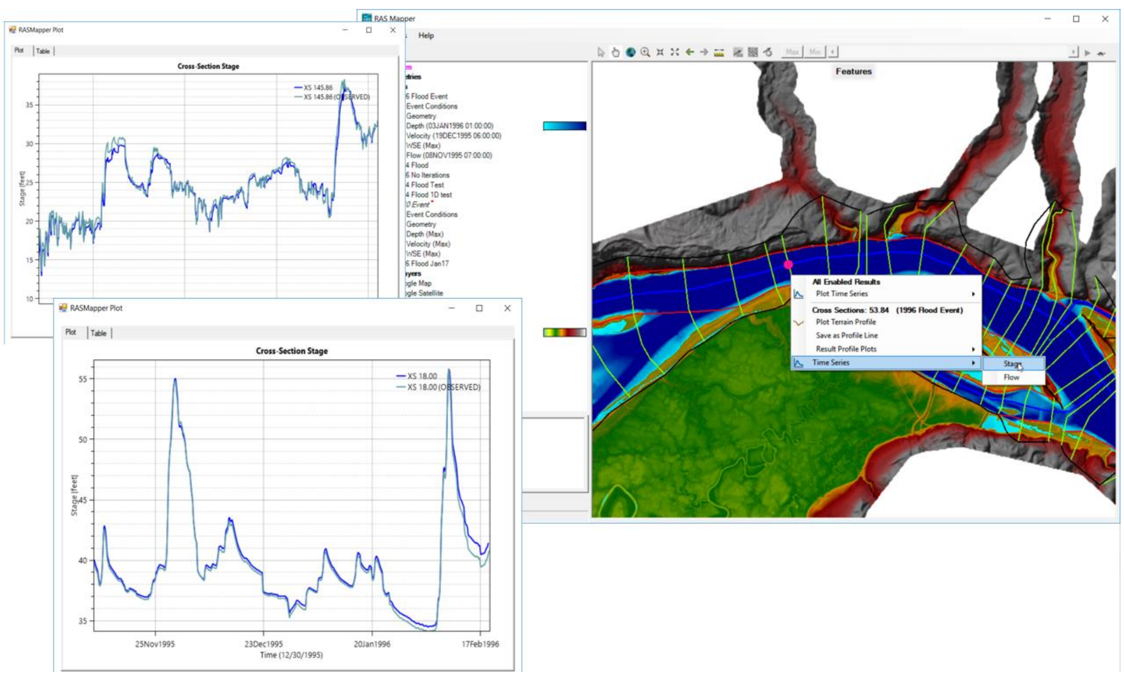

Figure 7. Example of plotting computes and observed data from HEC-RAS Mapper.

References

Kramer, S.C, Stelling, G.S. 2008. A conservative unstructured scheme for rapidly varied flows. International Journal for Numerical Methods in Fluids 58:183-212. DOI: 10.1002/fld.1722.

WES, 1960. Floods Resulting from Suddenly Breached Dams, Conditions of Minimum Resistance. Paper No. 2-374, Report 1. U.S. Army Corps of Engineers, Waterways Experimentation Station, Vicksburg, Mississippi. February 1960.