HEC-RAS FIM Factsheet (Public Domain)

The Hydrologic Engineering Center'sRiver Analysis System (HEC-RAS) performs hydraulic modeling of rivers,streams, and other open channel systems. It allows hydrologists to simulate water surface profiles, floodplain mapping, unsteady flow routing, bridge and culvert dynamics, sediment transport, and flood inundation mapping (FIM). This factsheet will provide the following information:

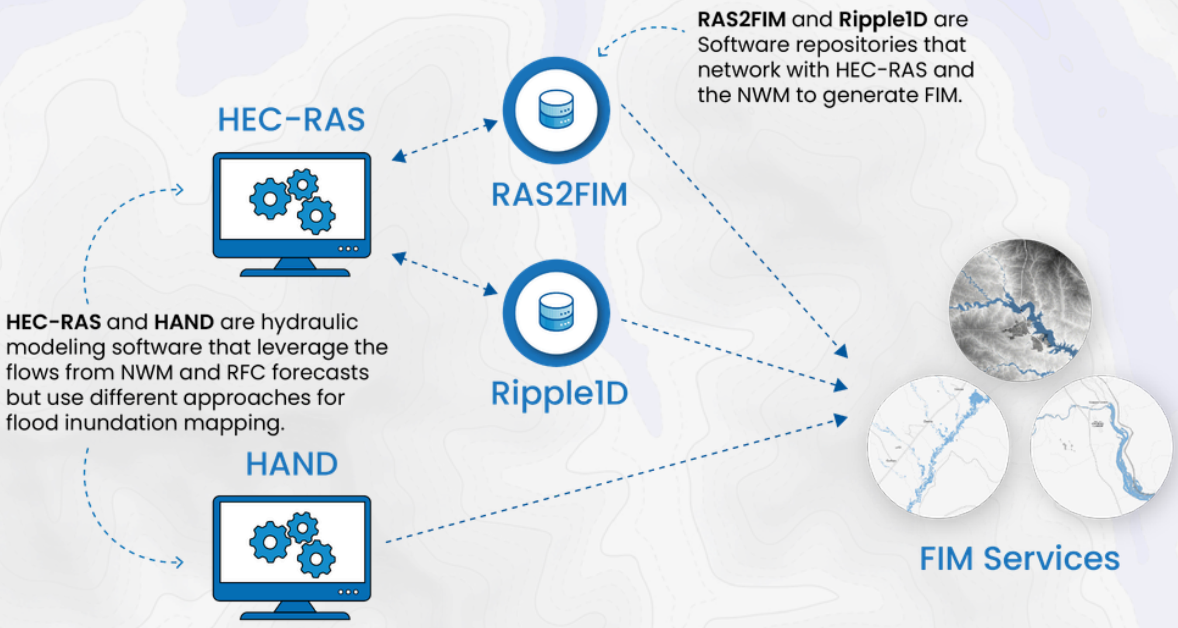
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For detailed information, refer to the National Oceanic and Atmospheric Administration (NOAA) Office of Water Prediction (OWP) HEC-RAS Wiki page or the HEC-RAS Frequently Asked Questions (FAQ) page.

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HEC-RAS Overview

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) is a hydraulic modeling software developed by the U.S. Army Corps of Engineers that performs hydraulic modeling of rivers, streams, and other open channel systems. Hydrologists utilize its ability to solve complex water equations to more accurately estimate the water surface and related Flood Inundation Mapping (FIM). While terrain-based FIM methods such as Height Above Nearest Drainage (HAND) rely on simplified assumptions about flood behavior, HEC-RAS provides a physics-based, dynamic understanding of how water moves through a watershed during flood events. Currently, NOAA utilizes one-dimensional (1-D) HEC-RAS models with plans to utilize two-dimensional (2-D) models in the near future. Refer to the Glossary section to review terminology that is essential in understanding HEC-RAS.



Obtaining HEC-RAS

HEC-RAS works by dividing a river into segments called **reaches**, and then further into **cross-sections**. Users input terrain data, flow data, and roughness

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estimates to represent how the river and its surroundings resist water movement. The software then solves a set of hydraulic equations, specifically the **Saint-Venant equations**, to calculate **Water Surface Elevations (WSEs)**. The calculated elevations are then mapped against terrain data to create inundation extents.

Using HEC-RAS

HEC-RAS is a powerful, detailed tool for understanding flood behavior and creating high-confidence flood inundation maps. It generally performs better in flatter floodplains, multi-channel systems, varying channel widths, and areas where there isn't any data to calibrate HAND synthetic rating curves. It has the ability to represent real world hydraulic dynamics (e.g., backwater effects, channel constrictions, etc.) that simpler methods like the HAND method are unable to fully capture. It's also especially valuable when precision and reliability are critical such as in floodplain mapping, infrastructure risk assessments, and emergency response planning.

Limitations

While HEC-RAS is a powerful tool for the generation of flood inundation maps, there are limitations that should be considered. Building a reliable HEC-RAS model is time and labor intensive as it requires a significant amount of high-quality and detailed input data (e.g., river cross-sections, high-resolution terrains, etc.). Additionally, NOAA currently only utilizes 1-D HEC-RAS models for FIM applications which can oversimplify flooding behavior in complex areas like urban environments or wide floodplains. Furthermore, not all rivers have existing HEC-RAS models, and using different models to develop FIM services may cause continuity issues. While HEC-RAS is ideal for producing high-accuracy flood maps, it may not be ideal for broad, rapid, or resource-limited FIM efforts.

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HEC-RAS vs. HAND

HEC-RAS and the HAND method are both FIM tools that differ based on how the flood inundation is modeled. HEC-RAS is a physics-based modeling method that uses full hydraulic equations whereas the HAND method is a terrain-based flood approximation method that estimates flood extent and depth without full hydraulic equations. HEC-RAS is a powerful and versatile tool for detailed hydraulic modeling, while HAND is a simpler, faster approach for rapid, large-scale flood mapping, particularly when detailed data is limited. The following table provides a high-level overview of the two FIM methods.

Feature	HEC-RAS	HAND
Function	Detailed Hydraulic Modeling	Terrain-Based Flood Inundation Mapping
Complexity	High (1-D and 2-D)	Low
Data Requirements	Detailed topographic, channel, and flow data	DEM and drainage network
Applications	Detailed mapping where available	Estimated mapping for everywhere

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RAS2FIM and Ripple1D

While HEC-RAS provides the hydraulic model of open channel systems and can develop flood inundation maps, tools like RAS2FIM and Ripple1D are used to translate those simulations into FIM products that can be utilized in real-time applications. RAS2FIM is a NOAA software repository that automatically converts Federal Emergency Management Agency (FEMA) Base Level Engineering HEC-RAS models into flood depth and extent grids for a range of given flows. These FIM extents are pre-run, clipped to match NWM reaches, and saved as a "FIM Library" so that HEC-RAS does not have to be run in real-time. During a flood event, HydroVIS uses a forecast (NWM or River Forecast Center (RFC)) for each reach to identify the corresponding flood extent contained within the FIM Library to display in the services.

Ripple1D is similar software that uses FEMA Mapping Information Platform (MIP) HEC-RAS models to build the same FIM Libraries as RAS2FIM. The MIP models are the ones used in FEMA's floodplains and National Flood Hazard Layer (NFHL). Other than model source, the biggest enhancement Ripple1D has over RAS2FIM is the ability to incorporate backwater effects into the FIM. In addition to pre-running multiple flows, Ripple1D is able to run multiple downstream boundary conditions for each flow so that FIMs near confluences can account for higher downstream Water Surface Elevations (WSE) during flood events. It is important to note that, unlike HAND, Ripple1D does not currently account for bridges. Development of this capability is in progress.

Both RAS2FIM and Ripple1D use similar inputs such as 1-D HEC-RAS models, rating curves, cross-section geometry, stage height tables, and water surface elevations (WSE). Their main differences are that RAS2FIM uses 10m DEMs, while Ripple1D uses 5m DEMs and incorporates downstream WSE boundary conditions.

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HAND, RAS2FIM, and Ripple1D Comparison Table

While HAND, RAS2FIM, and Ripple1D are all strong FIM tools, the following table provides a comparison between these methods to help forecasters determine which method is most appropriate to use.

Features	HAND	RAS2FIM	Ripple1D
Use Case	Utilizes only terrain data for quick, consistent mapping across large areas when full models aren't available	Leverages fully developed HEC-RAS models to deliver detailed inundation maps	Leverages fully developed HEC-RAS models to deliver detailed inundation maps that can include backwater effects at confluences
Accuracy	Low to moderate - higher when there is less possibility for backwater effects	Moderate – good for flat or simple terrain	High
Inputs	10m DEM, streamlines	1-D HEC-RAS model, 10m terrain, NWM streamlines, range of possible flows	1-D HEC-RAS model, 5m terrain, NWM streamlines, range of possible flows, range of possible downstream boundary conditions
Data Source	DEM: USGS 3DEP 10m Streamlines: NWM (NHD medium resolution)	DEM: USGS 3DEP 10m HEC-RAS models: FEMA Base-level Engineering	DEM: USGS 3DEP 5m HEC-RAS models: FEMA Mapping Information Platform
Hydraulic Modeling	None – synthetic rating curves are reach-averaged approximations	Based on detailed 1-D hydraulic simulation from HEC-RAS	Based on detailed 1-D hydraulic simulation from HEC-RAS
Backwater Effect Simulation	None	None – normal depth assumption	Yes, WSE at confluences are used as boundary conditions for upstream reaches
Availability	Full NWM domain	12 select HUC-8s in Texas	For select HUCs across the nation

* Ripple1D cannot process all FEMA models, therefore presence of the NFHL is not a definite indicator of availability.
* Bridge representation: Unlike HAND, Ripple1D does not currently account for bridges.

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Glossary

The following section provides terminology and definitions that are essential in understanding HEC-RAS FIM.

Term	Definition
1-D Hydraulic Model	A model that simulates water movement along a single flow dimension (length of the river), assuming uniform flow across the channel cross-section.
Backwater	The increased water surface elevation that occurs upstream of an obstruction, constriction, or confluence.
Boundary Conditions	A set of flow or stage conditions at the upper and lower ends of a HEC-RAS model reach that are used to determine how flow enters and exits the modeled area.
Cross-Section	A slice of the channel and floodplain that define the river's geometry.
DEM	A gridded terrain model of the Earth's surface that shows ground elevation.
Rating Curve	A relationship between river stage (height) and discharge (flow volume), used to estimate water levels for given flows.
Reach	A defined segment of a river between two points (like between cross-sections) used for organizing and modeling flow behavior.
Saint Venant Equation	A set of equations used in HEC-RAS to simulate unsteady open channel flow by conserving mass and momentum. This calculates how water depth and flow change over time and space within a river channel.
Stage-Height Table	A table listing specific WSE (stages) used to generate flood extent and depth grids. Each stage corresponds to a potential flood scenario.
Water Surface Elevation (WSE)	The height of the water surface above a reference point (usually sea level or ground level).

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