2 INTRODUCTION TO HEC-RAS

Welcome to the U.S. Army Corps of Engineers River Analysis System (HEC-RAS) developed by the Hydrologic Engineering Center. This software allows you to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling.

The HEC-RAS modeling system was developed as a part of the Hydrologic Engineering Center's "Next Generation" (NexGen) of hydrologic engineering software. The NexGen project encompasses several aspects of hydrologic engineering, including: rainfall-runoff analysis (HEC-HMS); river hydraulics (HEC-RAS); reservoir system simulation (HEC-ResSim); flood damage analysis (HEC-FDA and HEC-FIA); and real-time river forecasting for reservoir operations (CWMS).

This chapter discusses the general philosophy of HEC-RAS and gives a brief overview of the capabilities of the modeling system. Documentation for HEC-RAS is discussed, as well as an overview of this manual.

General Philosophy of the Modeling System

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface (GUI), separate analysis components, data storage and management capabilities, graphics, mapping and reporting facilities.

The HEC-RAS system contains the following river analysis components for: (1) one dimensional steady flow water surface profile computations; (2) one-dimensional and/or two-dimensional unsteady flow simulation; (3) Quasi unsteady or fully unsteady flow movable boundary sediment transport computations (1D and 2D); and (4) one dimensional water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be invoked once the water surface profiles are computed. HEC-RAS also has an extensive spatial data integration and mapping system (HEC-RAS Mapper).

Overview of Program Capabilities

HEC-RAS is designed to perform one-dimensional and two-dimensional hydraulic calculations for a full network of natural and constructed channels, overbank/floodplain areas, levee protected areas; etc… The following is a description of the major capabilities of HEC-RAS.

User Interface

The user interacts with HEC-RAS through a graphical user interface (GUI). The main focus in the design of the interface was to make it easy to use the software, while still maintaining a high level of efficiency for the user. The interface provides for the following functions:

- File management
- Data entry/editing and geospatial data interfaces
- River analyses
- Tabulation and graphical displays of input and output data
- Inundation mapping and animations of water propagation

- Reporting facilities
- On-line help

River Analysis Components

- **Steady Flow Water Surface Profiles.** This component of the modeling system is intended for calculating water surface profiles for steady gradually varied flow. The system can handle a full network of channels, a dendritic system, or a single river reach. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles.
  The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions).
  The effects of various obstructions such as bridges, culverts, dams, weirs, and other structures in the flood plain may be considered in the computations. The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments. Also, capabilities are available for assessing the change in water surface profiles due to channel modifications, and levees.
  Special features of the steady flow component include: multiple plan analyses; multiple profile computations; multiple bridge and/or culvert opening analysis; bridge scour analysis; split flow optimization; and stable channel design and analysis.
- **Unsteady Flow Simulation**. This component of the HEC-RAS modeling system is capable of simulating one-dimensional; two-dimensional; and combined one/two-dimensional unsteady flow through a full network of open channels, floodplains, and alluvial fans. The unsteady flow component can be used to performed subcritical, supercritical, and mixed flow regime (subcritical, supercritical, hydraulic jumps, and drawdowns) calculations in the unsteady flow computations module.
  The hydraulic calculations for cross-sections, bridges, culverts, and other hydraulic structures that were developed for the steady flow component were incorporated into the unsteady flow module.
  Special features of the unsteady flow component include: extensive hydraulic structure capabilities Dam break analysis; levee breaching and overtopping; Pumping stations; navigation dam operations; pressurized pipe systems; automated calibration features; User defined rules; and combined one and two-dimensional unsteady flow modeling.
- **Sediment Transport/Movable Boundary Computations**. This component of the modeling system is intended for the simulation of one-dimensional and two-dimensional sediment transport/movable boundary calculations resulting from scour and deposition over moderate to long time periods.
  The sediment transport potential is computed by grain size fraction, thereby allowing the simulation of hydraulic sorting and armoring. Major features include the ability to model a full network of streams, channel dredging, various levee and encroachment alternatives, and the use of several different equations for the computation of sediment transport.
  The model is designed to simulate long-term trends of scour and deposition in a stream channel that might result from modifying the frequency and duration of the water discharge and stage, or modifying the channel geometry. This system can be used to evaluate deposition in reservoirs, design channel contractions required to maintain navigation depths, predict the influence of dredging on the rate of deposition, estimate maximum possible scour during large flood events, and evaluate sedimentation in fixed channels.
- **Water Quality Analysis.** This component of the modeling system is intended to allow the user to perform riverine water quality analyses. The current version of HEC-RAS can perform detailed temperature analysis and transport of a limited number of water quality constituents (Algae, Dissolved Oxygen, Carbonaceuos Biological Oxygen Demand, Dissolved Orthophosphate, Dissolved Organic Phosphorus, Dissolved Ammonium Nitrate, Dissolved Nitrite Nitrogen, Dissolved Nitrate Nitrogen, and Dissolved Organic Nitrogen). Future versions of the software will include the ability to perform the transport of several additional water quality constituents.

Data Storage and Management

Data storage is accomplished using "flat" files (ASCII and binary), the HEC-DSS (Data Storage System), and HDF5 (Hierarchical Data Format, version 5). User input data are stored in flat files under separate categories of project, plan, geometry, steady flow, unsteady flow, quasi-steady flow, sediment data, and water quality information. Output data is predominantly stored in separate binary files (HEC and HDF5). Data can be transferred between HEC-RAS and other programs by utilizing the HEC-DSS.
Data management is accomplished through the user interface. The modeler is requested to enter a single filename for the project being developed. Once the project filename is entered, all other files are automatically created and named by the interface as needed. The interface provides for renaming, moving, and deletion of files on a project-by-project basis.

Graphics, Inundation Mapping, and Reporting

Graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and inundation mapping. A three-dimensional plot of the terrain and many of the simulation results are now available. Inundation mapping is accomplished in the HEC-RAS Mapper portion of the software. Inundation maps can also be animated, and contain multiple background layers (terrain, aerial photography, etc…). Tabular output is available. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer (or plotter), or passed through the Windows Clipboard to other software, such as a word-processor or spreadsheet.
Reporting facilities allow for printed output of input data as well as output data. Reports can be customized as to the amount and type of information desired.

HEC-RAS Documentation

The HEC-RAS package includes several documents. Each document is designed to help the modeler learn to use a particular aspect of the modeling system. There are three major pieces of documentation:

Documentation	Description
User's Manual	This manual is a guide to using HEC-RAS. The manual provides an introduction and overview of the modeling system, installation instructions, how to get started, a simple example, entering and editing geometric data, detailed descriptions of each of the major modeling components, and how to view graphical and tabular output.
2D User's Manual	This document describes how to use the 2D modeling capabilities that are included in this version of the software. It also describes how to use RAS Mapper in support of 2D modeling (mesh generation) and inundation mapping for models containing 2D flow areas.
HEC-RAS Mapper	This document describes how to use HEC-RAS Mapper to do the following: establish a horizontal coordinate system; develop an HEC-RAS terrain model; layout the geometric data model and extract terrain data; visualize results in the form of maps, plots, and tables.

Sediment Transport User's Manual	This manual describes how to perform sediment transport modeling. The document describes 1D quasi unsteady; 1D unsteady flow, and 2D sediment transport modeling. Additionally sediment impact analysis (SIAM) and bank stability using BSTEM is also described.
Hydraulic Reference Manual	This manual describes the theory and data requirements for the hydraulic calculations performed by HEC-RAS. Equations are presented along with the assumptions used in their derivation. Discussions are provided on how to estimate model parameters, as well as guidelines on various modeling approaches.
Applications Guide	This document contains a series of examples that demonstrate various aspects of HEC-RAS. Each example consists of a problem statement, data requirements, and general outline of solution steps, displays of key input and output screens, and discussions of important modeling aspects.

Overview of this Manual

This user's manual is the primary piece of documentation on how to use the HEC-RAS system. The manual is organized as follows:

- Chapters 1-2 provide an introduction and overview of HEC-RAS, as well as instructions on how to install the software.
- Chapters 3-4 describe how to use the HEC-RAS software from an overview perspective. Understanding how this system works with projects is also discussed, including defining all the file types that are used.
- Chapters 5 explains how to enter and edit geometric data to represent the river, floodplain, and hydraulic structures.
- Chapters 6 and 7 explain in detail how to perform the different types of hydraulic analyses that are available, such as 1D steady flow modeling and 1D Unsteady Flow Modeling
- Chapter 8 provides detailed discussions on how to view graphical and tabular output, as well as how to develop user-defined tables.
- Chapter 9 describes how to perform a floodway encroachment analysis.
- Chapter 10 provides discussions on "Trouble Shooting" and understanding the most common Errors, Warnings, and Notes.
- Chapter 11 describes how to perform bridge scour computations from within HEC-RAS.
- Chapter 12 describes how to perform channel modifications within HEC-RAS.
- Chapter 13 describes how to use the Hydraulic Design Functions in HEC-RAS for performing stable channel design and analysis, as well as sediment transport potential calculations, and rip rap sizing.
- Chapter 14 contains topics on advanced uses of the unsteady flow simulation capabilities, including: mixed flow regime for unsteady flow; dam break analysis; levee overtopping and breaching; modeling pump stations; navigation dams; and user defined rules for controlling gate operations.
- Appendix A contains a list of references.
- Appendix B contains a detailed description of the file formats used for importing and exporting GIS data to and from HEC-RAS.
- Appendix C contains a description of all the output variables available from the HEC-RAS program.
- Appendix D discusses how to import HEC-2 data into HEC-RAS