RESEARCH ARTICLE OPEN ACCESS

GIS-Based Floodplain Mapping as a Component of Flood Early Warning Systems: A Practical HEC-GeoRAS and HEC-RAS Models

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ABSTRACT
Floodplain mapping is an important component of flood-risk assessment and management, requiring the integration of hydraulic modelling with spatial analysis. This report presents a practical GIS-based workflow for integrating HEC-GeoRAS with the HEC-RAS hydraulic modelling system to prepare river geometry, perform steady-state simulations, and delineate flood inundation areas. This demonstrates the main stages of the modelling process, including terrain-data preparation, development of RAS layers, extraction of geometric information, specification of flow conditions and boundary conditions, execution of steady-flow simulations, and transfer of hydraulic results to ArcGIS. The workflow uses GIS layers such as the stream centerline, river banks, flow paths, cross-sections, bridges, ineffective flow areas, and obstructions to construct the hydraulic model. HEC-RAS water-surface profiles are subsequently processed in HEC-GeoRAS to generate flood inundation extent and water-depth maps. The tutorial also emphasizes the importance of reviewing and refining inundation results using the underlying terrain and hydraulic information. The presented workflow provides a practical and structured approach for researchers, engineers, hydrologist, GIS practitioners, and students to integrate hydraulic modelling and GIS for floodplain analysis and visualization.
Keywords- Flood Early Warning, HEC-RAS, HEC-GeoRAS, Floodplain Mapping, Hydraulic Modelling.

Date of Submission: 15-01-2026 Date of acceptance: 30-01-2026

I. INTRODUCTION

Floods are among the most significant natural hazards, with the potential to cause substantial damage to communities, infrastructure, agricultural areas, and natural ecosystems. Accurate floodplain mapping is therefore an essential component of flood-risk assessment, management, and preparedness. Integrating hydraulic modelling with Geographic Information Systems (GIS) provides an effective approach for representing flood behavior and translating hydraulic model outputs into spatially meaningful floodplain information.

This report presents a practical tutorial on the application of HEC-GeoRAS and GIS tools for floodplain mapping through a step-by-step practical example. The approach establishes an integrated workflow between the one-dimensional HEC-RAS hydraulic model and the HEC-GeoRAS extension within the ArcGIS environment. This integration facilitates the preparation of geospatial data required for hydraulic modelling and enables the visualization, processing, and spatial analysis of simulated water-surface profiles and flood extents.

HEC-GeoRAS is a set of procedures, tools, and utilities developed to support the preparation and processing of geospatial data for HEC-RAS modelling within an ArcGIS environment. It provides tools for creating, editing, managing, processing, and visualizing the spatial datasets required for hydraulic analysis. It also facilitates the post-processing of HEC-RAS simulation results for GIS-based interpretation and floodplain delineation (HEC, 2005).

The resulting water surface profiles from HEC-RAS simulations can be transferred to the GIS environment through HEC-GeoRAS and used to delineate flood prone areas and support a range of applications, including floodplain mapping, flood damage assessment, ecosystem restoration, and flood warning and emergency preparedness. The workflow presented in this report intended to provide a practical and accessible guide for researchers, engineers, GIS practitioners, and students interested in integrating hydraulic modelling with spatial analysis for floodplain assessment.

II. OBJECTIVES

The main objectives of this practical tutorial are to:

1. Introduce the basic functions of HEC-GeoRAS for the preparation and post-processing of GIS data and HEC-RAS hydraulic models.
2. Perform steady-state hydraulic simulations and generate water-surface profiles using HEC-RAS.
3. Process the hydraulic model outputs in a GIS environment to delineate and visualize floodplain inundation areas.

III. METHODS AND MATERIALS

The practical tutorial presented in this report requires HEC-GeoRAS Version 4.31, developed by the U.S. Army Corps of Engineers for use with ArcGIS 9.3 and HEC-RAS 4.0 (Hydrologic Engineering Center-River Analysis System). HEC-GeoRAS provides a GIS-based environment for preparing, managing, and processing geospatial data required for hydraulic modelling and floodplain mapping. It utilizes the capabilities of ArcGIS extensions, including Spatial Analyst and 3D Analyst, to support the preparation and visualization of hydraulic modelling datasets.

HEC-RAS is a one-dimensional hydraulic modelling system developed by the U.S. Army Corps of Engineers for simulating water-surface profiles and hydraulic behaviour in river and channel systems. The model requires information describing the channel and floodplain topography, together with flow and boundary condition data for the hydraulic events being investigated. These geometric and flow data are used to calculate water-surface profiles based primarily on energy-loss computations (U.S. Army Corps of Engineers, 1998).

The integration of HEC-GeoRAS with ArcGIS facilitates the preparation of geometric data for import into HEC-RAS and the subsequent processing and visualization of hydraulic simulation results. The geodatabase structure also provides an organized framework for managing spatial datasets and supporting GIS-based hydraulic analysis and floodplain delineation.

3.1 Overview of HEC-GeoRAS

HEC-GeoRAS provides a set of GIS tools that support the preparation of river geometry and the post-processing of HEC-RAS results. The HEC-GeoRAS toolbar includes four main menus: RAS Geometry, RAS Mapping, ApUtilities, and Help. It also provides several tools for preparing and editing hydraulic geometry, including Assign RiverCode/ReachCode, Assign FromStation/ToStation, Assign LineType, Construct XS Cutlines, Plot Cross Section, and Assign Levee Elevation.

These tools provide a structured workflow for preparing the spatial information required by HEC-RAS and for subsequently mapping and visualizing simulated floodplain inundation. Figure 1 illustrates the HEC-GeoRAS toolbar and its principal tools.

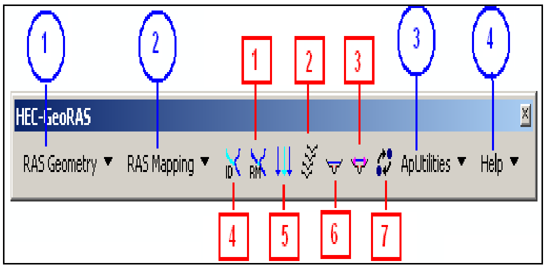


Figure 1: HEC-GeoRAS toolbar

The RAS Geometry menu provides functions for the pre-processing of GIS data required for input to HEC-RAS. The RAS Mapping menu is used for the post-processing of HEC-RAS simulation results and the generation of flood inundation maps. The ApUtilities menu provides tools primarily related to data management and project organization, while the Help menu provides supporting information and guidance on the available functions.

The following sections describe the main functions associated with these menus and tools and demonstrate their application through the practical workflow. Table 1 provides a summary of the principal RAS layers and their roles in developing the hydraulic model.

Table 1: Summary of HEC-GeoRAS layers and corresponding output for HEC-RAS.

RAS layer	Description
Stream Centerline	Used to identify the connectivity of the river network and assign river stations to computation points.
Cross-Sectional Cut Lines	Used to extract elevation transects from the DTM at specified locations and other cross-sectional properties.
Bank Lines	Used in conjunction with the cut lines to identify the main channel from overbank areas.
Flow Path	Used to identify the

ISSN: 2248-9622, Vol. 16, Issue 1, January 2026, pp 71-82

Centerlines	center of mass of flow in the main channel and overbanks to compute the downstream reach lengths between cross sections.
Land Use	Used to assign flow roughness factors (Manning's n values) to the cross sections.
Levee Alignment	Used to identify the location and elevation of high ground on a cross section that limits flow from going out into the floodplain.
Ineffective Flow Areas	Used to identify the location of non-conveyance areas.
Blocked Obstructions	Used to identify obstructions to flow
Bridges/Culverts	Used to extract the top-of-road data from the DTM at specified locations.
RAS layer	**Description**
Inline Structures	Used to extract the weir profile from the DTM for inline structures (dams).
Lateral Structures	Used to extract the weir profile from the DTM for structures the pass flow perpendicular from the main channel.
Storage Areas	Used to define the extent of detention areas and develop the elevationvolume relationship from the DTM.
Storage Area Connections	Used to extract the weir profile from the DTM for connections between storage areas

- **Documentation and Practical Example**
  - **Example: Building a River Hydraulic Model and Mapping Floodplain Extents**

HEC-GeoRAS provides a GIS-based framework for supporting hydrologic and hydraulic modelling and floodplain mapping. The overall workflow consists of three main stages: (1) pre-processing of spatial and hydraulic data, (2) execution of the hydraulic model, and (3) post-processing and visualization of the simulation results.
To create the HEC-RAS import file, an existing Digital Terrain Model (DTM) of the river system is required in Triangulated Irregular Network (TIN) format within the ArcGIS environment. Based on the terrain model, the user creates a series of GIS layers or feature classes that represent the geometric characteristics of the river system and are subsequently used to develop the HEC-RAS hydraulic model. These primary RAS layers include the Stream Centerline, Flow Path Centerlines, Main Channel Banks, and Cross-Section Cut Lines**.** Depending on the requirements of the hydraulic analysis, additional RAS layers can also be created to provide further geometric information.
Additional layers may include Landuse, Levee Alignment, Ineffective Flow Areas, and Storage Areas**.** These datasets provide supplementary information that can be incorporated into the hydraulic model to improve the representation of channel and floodplain characteristics.
The practical example presented in this report guides the user through the main stages of the analysis in a clear and systematic manner:

1. Extraction of geometric data and creation of RAS layers.
2. Execution of steady-state hydraulic simulations to generate water-surface profiles for specified flow conditions.
3. Export of HEC-RAS simulation results to ArcGIS for processing, visualization, and delineation of floodplain inundation areas.

The following sections describe these procedures in detail.

- **Extraction of Geometric Data and Creation of RAS Layers**

The creation of RAS layers and the extraction of geometric information constitute the **pre-processing stage** of the workflow. This stage uses the **Triangulated Irregular Network (TIN)** terrain model within the ArcGIS and HEC-GeoRAS environment to derive the spatial information required for the HEC-RAS hydraulic model.
The extracted geometric information is organized into the appropriate RAS layers, which are subsequently used to generate the hydraulic model

geometry and prepare the data for import into HEC-RAS.

- **Data Preparation**

HEC-GeoRAS is supported by user documentation, tutorials, and example datasets that provide guidance on the preparation and processing of data for hydraulic modelling. The primary dataset required for HEC-GeoRAS is a Digital Terrain Model (DTM)**,** provided in either Triangulated Irregular Network (TIN) or raster/grid format. Additional spatial datasets, such as aerial imagery and land-use information, may also be used to support model development, interpretation, and visualization.
HEC-GeoRAS facilitates the automated preparation of geometric data for import into HEC-RAS. It can extract elevation information from DTMs represented in either TIN or grid format. For the practical example presented in this report, a TIN representing the river channel and surrounding floodplain is required. The terrain model provides the elevation information needed to define the channel and floodplain geometry and to identify the areas available to convey flood flows downstream, as illustrated in **Figure 2**.
Before beginning the geometric-data extraction process, the terrain dataset should be checked to ensure that it adequately represents the river channel and surrounding floodplain and is suitable for the scale and objectives of the hydraulic analysis.

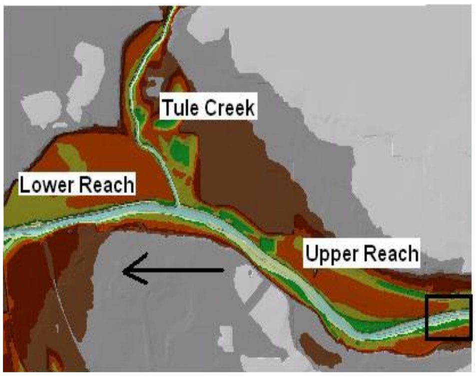


Figure 2: TIN as a basic layer taken for small scale of the targeted river

- **Creating RAS Layers**

The HEC-RAS geometry file contains the spatial and hydraulic information required to represent the river system, including the stream centerline, cross-sections, river banks, hydraulic structures, and other physical characteristics of the channel and floodplain.
The creation of additional RAS layers is generally optional and depends on the characteristics of the river system, the available spatial data, and the specific requirements of the hydraulic model. HEC-GeoRAS provides a GIS-based environment for creating and editing these layers prior to their export to HEC-RAS.
The following sections describe the main RAS layers prepared using HEC-GeoRAS within the ArcGIS environment.

- **Creating the Stream Centerline**

The stream centerline is a fundamental RAS layer used to define the river-reach network and establish the direction of flow for the HEC-RAS hydraulic model.
In the example dataset, the Baxter River flows from east to west, with Tule Creek entering the system as a tributary. Accordingly, the river system consists of three reaches: Upper Baxter River, Lower Baxter River, and Tule Creek Tributary, as illustrated in **Figure 3**.
To create the stream centerline, a separate line feature is digitized for each river reach. Each feature should approximately follow the centre of the main channel and be digitized in the downstream direction of flow. Correct identification of the reach network and flow direction is essential for establishing the hydraulic connectivity of the river system in HEC-RAS.

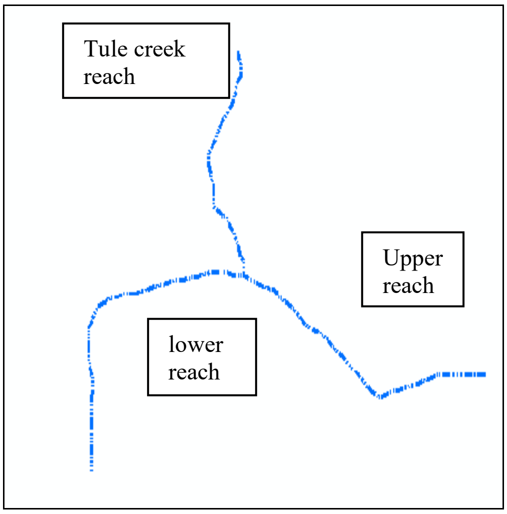


Figure 3: Stream centerline layer for small scale of the targeted river

Creating the River Banks Layer

The riverbanks layer used to distinguish the main channel from the adjacent overbank floodplain areas**.** This information is important for assigning hydraulic properties to different portions of the cross-sections. For example, the main channel and overbank areas may assign different Manning's roughness coefficients (n) to account for variations in surface characteristics, vegetation, and flow resistance.
The creation of the riverbanks layer follows a procedure similar to that used for the stream

centerline. However, unlike the stream centerline, the bank lines do not require a specific orientation or connectivity. They may be digitized either in the downstream or upstream direction**,** depending on the user's preference. Similarly, bank lines may be represented as continuous or separate line features**,** provided that they adequately identify the locations of the left and right banks along the river reach.
The river banks should be digitized carefully to represent the transition between the main channel and the surrounding floodplain, as illustrated in **Figure 4**.

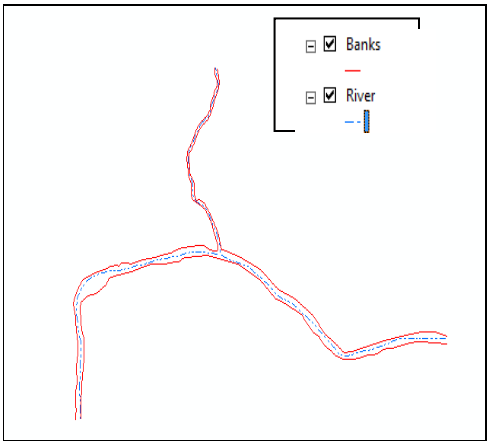


Figure 4: River Banks layer for small scale of Baxter River

- **Creating the Flow Paths Layer**

The flow paths layer represents the principal pathways followed by floodwater through the main channel and the adjacent overbank areas. It consists of three types of flow-path lines: the main-channel centerline, left overbank flow path, and right overbank flow path**.**
These flow path lines used by HEC-GeoRAS to determine the downstream reach lengths between successive cross-sections for the main channel and the left and right overbank areas. Accurate delineation of the flow paths is therefore important for representing the hydraulic characteristics of the river and floodplain.

When the previously created stream centerline approximately follows the centre of the main channel, it can also be used as the main-channel flow-path centerline. In this case, there is no need to create a separate centerline for the main channel. The left and right overbank flow paths are then digitized within the corresponding floodplain areas, following the expected direction of floodwater movement.

Figure 5: Flow path layer for small scale of targeted river

- **Creating the Cross-Sections Layer**

Cross-sections are among the most important geometric inputs required by HEC-RAS. Cross-section cutlines are used to extract elevation information from the terrain model and generate ground profiles across the river channel and floodplain. The intersections of the cross-section cutlines with other RAS layers, such as the stream centerline, river banks, and flow paths**,** are used by HEC-GeoRAS to derive important hydraulic attributes, including bank stations, downstream reach lengths, and Manning's roughness coefficients**.**
Therefore, an adequate number and appropriate distribution of cross-sections are essential for accurately representing the channel geometry and floodplain topography. When creating cross-section cutlines, the following guidelines should be followed:

1. Cross-sections should be digitized approximately perpendicular to the direction of flow**.**
2. Each cross-section should extend sufficiently across the entire floodplain area expected to be inundated**.**
3. Cross-sections should be digitized consistently from left to right when looking downstream**.**

Although uniform spacing is not mandatory, maintaining reasonably consistent spacing between cross-sections is recommended where channel and floodplain conditions are relatively uniform, as illustrated in **Figure 6**.
During digitization, each cross-section should be sufficiently wide to encompass the potential floodplain. The Cross-Section Profile tool can be used to examine the terrain profile and verify that

the cross-section adequately covers the channel and surrounding floodplain, as illustrated in **Figure 7**.
After the cross-section cutlines have been created, the required HEC-RAS attributes should be assigned. These may include the river and reach names, stationing along the river centerline, bank stations, and downstream reach lengths**.** Because these attributes are derived from the intersections between the cross-sections and other RAS layers, each cross-section should properly intersect the stream centerline, river banks, and relevant overbank flow paths**.**

- **Creating the Bridges and Culverts Layer**

Hydraulic structures such as **bridges and culverts** can significantly affect flow conveyance and water-surface elevations and should represent in the hydraulic model.
When a bridge or culvert is present along the river channel, cross-sections should define immediately upstream and downstream of the structure to provide the geometric information required for hydraulic modelling. The locations of such structures can be identified using the aerial imagery provided with the tutorial dataset. (Bridge location is shown in red):

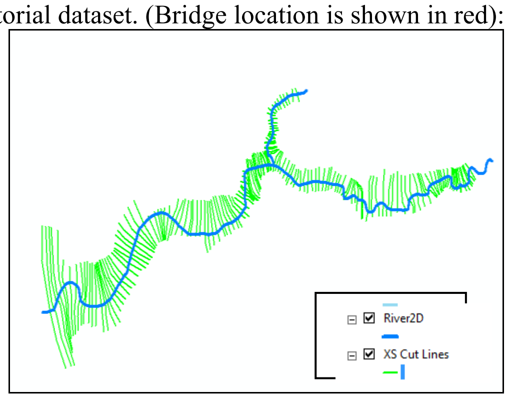


Figure 6: cross sections layer along the large scale of the river with adequate number of cross sections and spacing

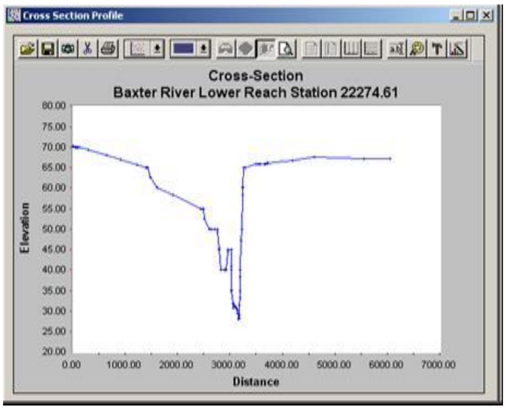


Figure 7: adequate definition of cross-section

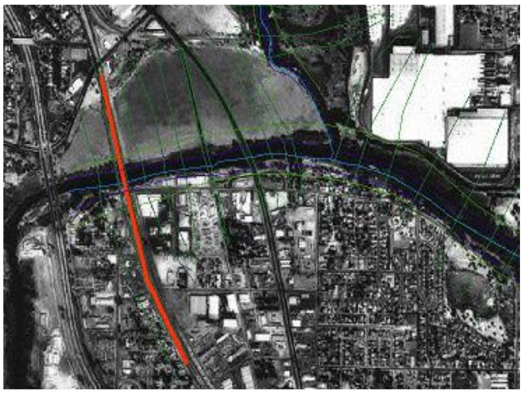


Figure 8: location of the bridge structure

- **Creating the Ineffective Flow Areas Layer**

Ineffective flow areas used in HEC-RAS to identify portions of the floodplain where water may be present but contributes little or no effective conveyance to the flow. These areas represent as having zero or negligible flow velocity under the specified modelling conditions. Ineffective flow areas are commonly associated with local hydraulic features that limit flow conveyance. For example, areas located behind bridge abutments may become hydraulically ineffective because of flow contraction and expansion around the structure. Identifying these areas helps provide a more realistic representation of floodplain flow behaviour and the hydraulic effects of structures, as illustrated in **Figure 9**.

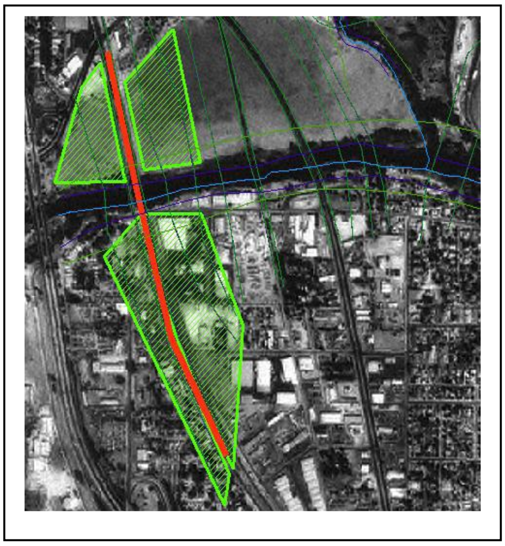


Figure 9: An example of an ineffective area located on the aerial photograph

- **Creating the Obstructions Layer**

Obstructions represent areas within the floodplain that block or restrict the passage of floodwater and are therefore assumed to have no effective flow

conveyance under the modelled conditions. Typical examples include buildings, levees, embankments, and other structures that physically obstruct floodwater.In this practical example, blocked obstruction areas identified using the available aerial photograph. In the upper reach of the Baxter River**,** immediately upstream of the Tule Creek confluence, two buildings are located within the floodplain. These buildings represented as obstructions in the hydraulic model, as illustrated in **Figure 10**.
Including obstruction features provides a more realistic representation of floodplain conditions by accounting for areas that are unavailable for floodwater conveyance.

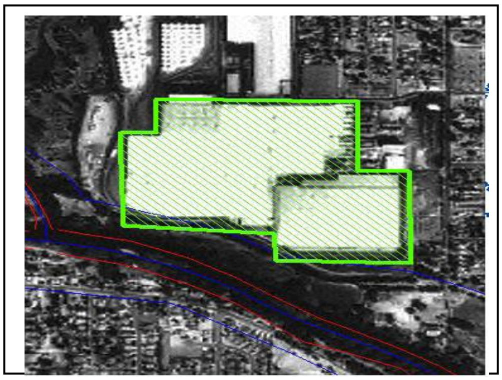
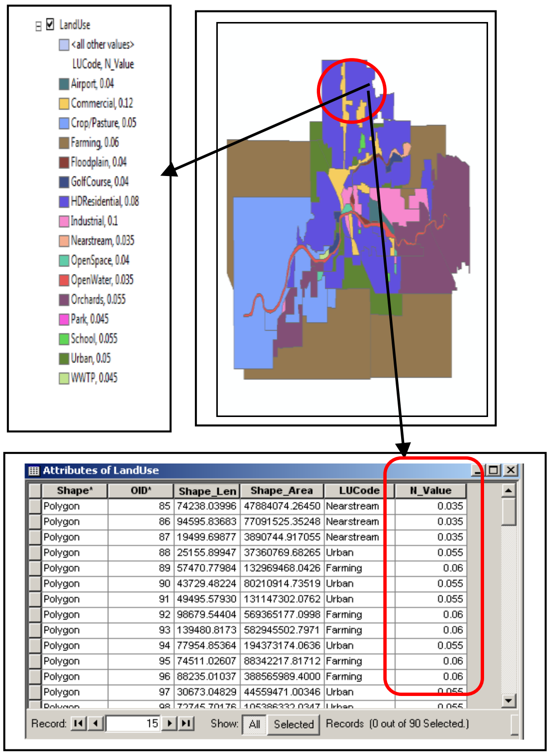


Figure 10: Obstruction layer located on the aerial photograph.

- **Assigning Manning's *n* to Cross-Sections**

The Manning's roughness coefficient (***n***) is an important hydraulic parameter used to represent the resistance to flow across the channel and floodplain. In HEC-GeoRAS, Manning's *n* values can be assigned to individual cross-sections using a landuse feature class in which each land-use category is associated with an appropriate roughness coefficient.
The land-use layer is first prepared and added to the ArcGIS map, with the corresponding Manning's ***n*** value stored for each land-use type. HEC-GeoRAS then uses the spatial intersection between the land-use layer and the cross-sections to determine the appropriate roughness values for different portions of each cross-section.
This approach allows different Manning's *n* values to be assigned to the main channel and overbank areas according to their surface characteristics, such as water, vegetation, agricultural land, and developed areas. The resulting roughness assignments for the cross-sections are illustrated in **Figure 12**.



Shape*	OID*	Shape_Len	Shape_Area	LUCode	N_Value
Polygon	85	74238.03996	47884074.26450	Nearstream	0.035
Polygon	86	94595.83683	77091525.35248	Nearstream	0.035
Polygon	87	19499.69877	3890744.917055	Nearstream	0.035
Polygon	88	25155.89947	37360769.68265	Urban	0.055
Polygon	89	57470.77984	132969468.0426	Farming	0.06
Polygon	90	43729.48224	80210914.73519	Urban	0.055
Polygon	91	49495.57930	131147302.0762	Urban	0.055
Polygon	92	98679.54404	569365177.0998	Farming	0.06
Polygon	93	139480.8173	582945502.7971	Farming	0.06
Polygon	94	77954.85364	194373174.0636	Urban	0.055
Polygon	95	74511.02607	88342217.81712	Farming	0.06
Polygon	96	88235.01037	388565989.4000	Farming	0.06
Polygon	97	30673.04829	44559471.00346	Urban	0.055

Figure 11: Land use layer with relevant descriptive information (i.e Manning n values) for small scale of the targeted river

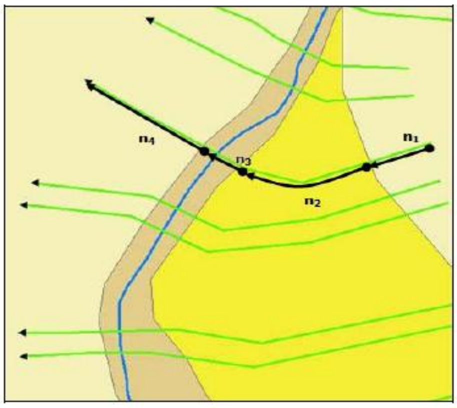


Figure 12: Manning's n value to individual cross-sections

- **Data Processing and Interpretation**
- **Running Steady-State Simulations and Generating Water-Surface Profiles**

Following the preparation of the GIS-based RAS layers and extraction of the required geometric information, the next stage is to execute the hydraulic model in HEC-RAS. This stage involves importing the prepared geometry into HEC-RAS, defining the required flow conditions, and performing steady-state simulations to generate water-surface profiles.
The following procedures describe the main steps involved in model execution.

- **Importing Geometry Data into HEC-RAS**

Developing the RAS Import File

The RAS layers created and edited during the GIS pre-processing stage are used to extract the geometric information required by HEC-RAS. HEC-GeoRAS converts this information into an exchange file that can be imported directly into the HEC-RAS hydraulic model.

First, HEC-RAS 4.0 is launched and a new project is created and saved using the Project File (*.prj) format. To import the GIS-derived geometry, open the Geometric Data editor and select the option for importing geometry data in GIS format. The *.RASImport.sdf file generated by HEC-GeoRAS during the GIS processing stage is then selected for import.

The RAS import file contains the principal geometric information required to establish the hydraulic model, including:

- river, reach, and station identifiers;
- cross-section cut lines and surface information;
- left and right bank stations; and
- downstream reach lengths for the left overbank, main channel, and right overbank areas.

The import file primarily contains geometric information. Parameters such as Manning's roughness coefficients and hydraulic structure data are not included in the RAS import file and defined separately within HEC-RAS. The geometry import process illustrated in **Figure 13**.

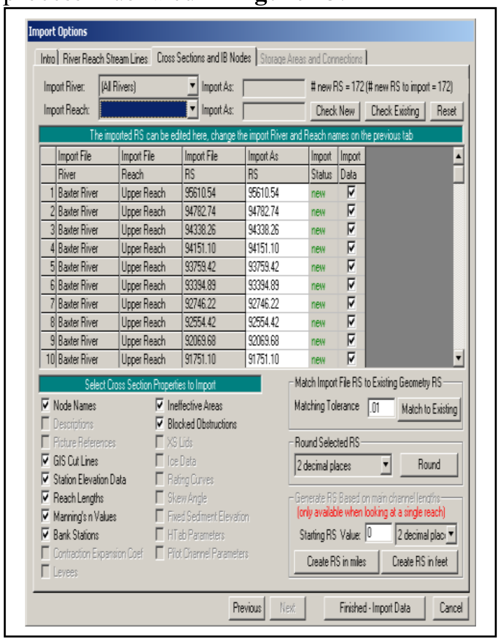


Figure 13: the import options for HEC RAS model

- **Checking and Editing the Imported Hydraulic Geometry**

Before running steady-state simulations and computing water-surface profiles, the imported hydraulic geometry should carefully review and, where necessary, edited within HEC-RAS. This quality-control step helps ensure that the geometric data extracted from the GIS environment have transferred correctly and are suitable for hydraulic modelling.

The imported hydraulic data can be visualized in HEC-RAS to inspect key model components, including cross-sections, the stream centerline, riverbanks, flow paths, and hydraulic structures such as bridges**.** The geometric data should check for consistency, connectivity, and correct spatial representation. Where inconsistencies or errors identified, the corresponding geometry should correct before proceeding with the hydraulic simulation.

Figure 14 illustrates the visualization of the imported hydraulic geometry in HEC-RAS. Careful checking and, when required, editing of the input geometry helps improve the consistency of the hydraulic model and supports reliable generation of water-surface profiles.

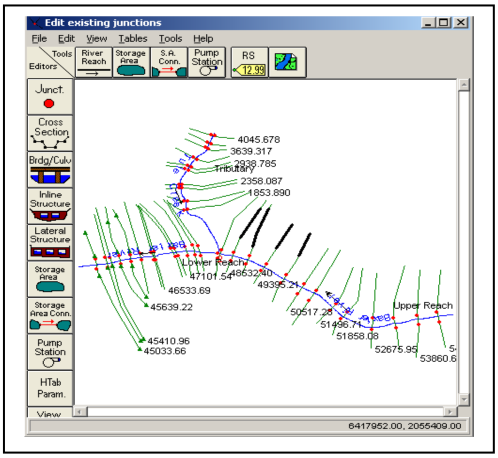


Figure 14: Functions in HEC RAS

- **Entering Flow Data and Boundary Conditions**

To perform steady-state hydraulic simulations, the required flow data and boundary conditions specified in HEC-RAS. Flow values typically entered at the upstream end of each river reach or tributary and, where appropriate, at river junctions. Additional flow locations may be required depending on the complexity of the river system and the available hydrological information.

In HEC-RAS, each set of flow conditions to be simulated is represented as a profile. For the practical example presented in this tutorial, three hypothetical flow profiles are defined to demonstrate the procedure for entering flow data and establishing the corresponding boundary conditions, as illustrated in **Figure 15**.

The flow values and boundary conditions should be selected consistently with the purpose of the hydraulic analysis and clearly document.

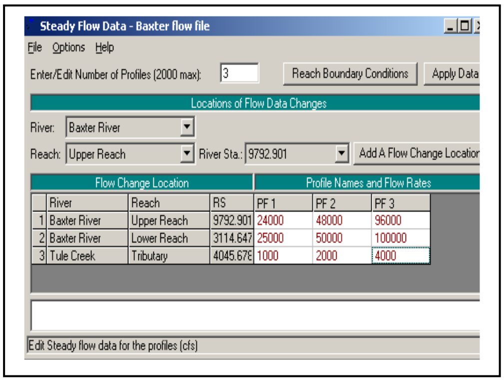


Figure 15: Creation of three hypothetical profiles in HEC RAS

- **Running HEC-RAS**

The hydraulic simulations are performed using the Steady Flow Analysis option in HEC-RAS. For the present example, the subcritical flow regime is selected, as illustrated in **Figure 16**. The model is then executed for the defined flow profiles to calculate the corresponding water-surface elevations and hydraulic characteristics along the river system.

After completing the simulations, the resulting water-surface profile data are prepared for export from HEC-RAS to the GIS environment. These results are subsequently processed using HEC-GeoRAS and ArcGIS to support the delineation and visualization of the floodplain inundation extent.

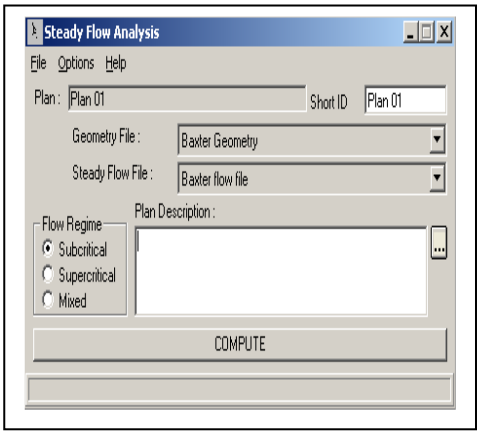


Figure 16: Run a Steady Flow Analysis with subcritical Flow Regime

- **Exporting HEC-RAS Results to ArcGIS and Creating Floodplain Maps**

Following completion of the HEC-RAS simulations, the model results are transferred to the GIS environment for post-processing, interpretation, and floodplain mapping. This stage uses HEC-GeoRAS to convert the hydraulic simulation results into spatial datasets that can be analyzed and visualized in ArcGIS.

- **Exporting HEC-RAS Results**

The simulated water-surface profile results are exported from HEC-RAS using a GIS data-exchange file. Similar to the geometry exchange process, the HEC-RAS results are written to a RAS export file (RASExport.sdf)**,** which is subsequently processed for use in the GIS environment. HEC-GeoRAS provides the tools required to transfer the hydraulic results from HEC-RAS to ArcGIS and to generate spatial representations of the simulated flood conditions.

During the post-processing stage, the water-surface elevations obtained from HEC-RAS are combined with the underlying Digital Terrain Model (DTM/TIN)**.** The comparison between the simulated water-surface elevation and the terrain elevation allows the flood inundation extent and water depth to be determined across the modelled area. Areas where the simulated water surface is higher than the ground elevation are identified as potentially inundated areas.

The post-processing procedure generates GIS datasets representing the simulated water surface, inundation extent, and inundation depth. These datasets can be stored as geodatabase feature classes and raster depth grids**,** providing a spatial basis for visualization and further floodplain analysis.

For the present example, the water-surface profile corresponding to the maximum simulated flow is selected to demonstrate the floodplain mapping procedure.

IV. RESULTS AND DICUSSION

- **Mapping of Flood Inundation**

Flood inundation datasets generated from the water-surface elevation information calculated at the cross-section locations and extended across the modelled floodplain. A bounding polygon used to define the area within which inundation evaluated and to account for hydraulic features repress

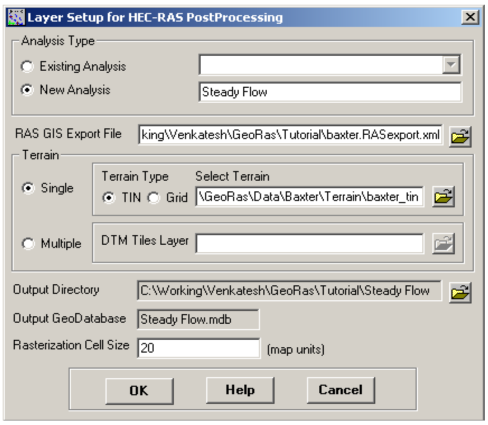


Figure 17: post processing for steady flow output

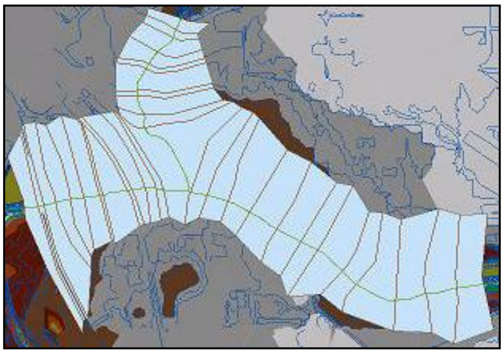


Figure 18: The extent of inundation bounding polygons

Finally, the flood inundation extent map is generated from the water-surface elevation corresponding to the maximum simulated flow **(**Profile PF3**),** as shown in **Figure 18**. The inundated area is identified by comparing the simulated water-surface elevation with the underlying terrain elevation. Cells with positive values, indicating that the water-surface elevation exceeds the terrain elevation, are classified as potentially inundated, whereas cells with negative values are considered dry.
The cells with positive values in the resulting water-surface difference grid are subsequently converted into a polygon feature, producing the final flood inundation polygon. This polygon represents the spatial extent of the floodplain under the maximum flow condition simulated in the example.

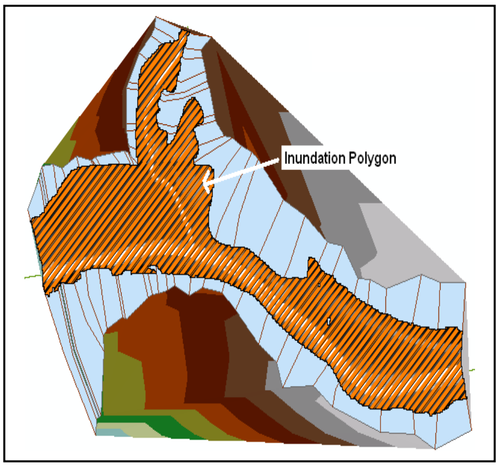


Figure 19: Inundation map extent for pf3 for small scale of Baxter River

- **Water Depth Mapping and Classification**

A second example illustrates the spatial distribution and classification of water depth within the inundated area**.** The water-depth values are classified into appropriate depth classes to facilitate interpretation and visualization of flood severity, as shown in **Figure 20**.
For this example, Profile PF1 is used to generate the inundation depth map. The calculated water-depth values are then combined with the corresponding inundation polygon to identify and represent the spatial distribution of flood depths within the affected area, as illustrated in **Figure 21**.

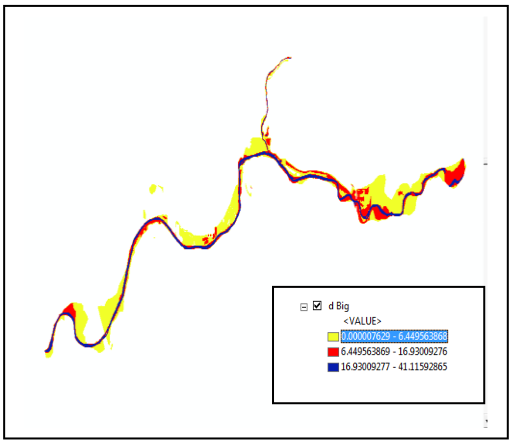


Figure 20: Inundation map depths extent for pf1 for large scale of the targeted river

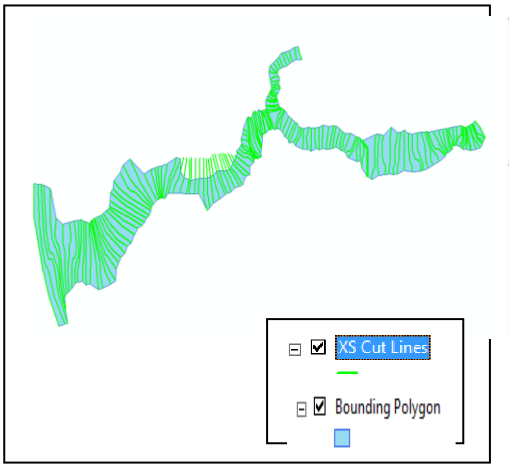


Figure 21: Inundation map polygons depths extent for pf1 for large scale of the target river

- **Quality Control of Flood Inundation Results**

After generating the flood inundation map, the resulting inundation polygon should review for quality and consistency. The polygon examined in relation to the underlying terrain and other relevant spatial features to identify and correct possible inconsistencies or errors in the delineated flood extent.
Refinement of the flood inundation results may require an iterative process between the GIS environment and HEC-RAS, particularly where the terrain representation, hydraulic geometry, or boundary conditions require adjustment. This may involve several cycles of model modification, simulation, and GIS-based review before obtaining a satisfactory hydraulic representation of the inundated area.
The ability to assess the quality of the terrain representation and flood inundation results depends on a good understanding of the study area, terrain characteristics, hydraulic behaviour, and modelling principles. Expert interpretation and familiarity with the physical characteristics of the river system are therefore important for evaluating and refining the results.

V. CONCLUSIONS

HEC-GeoRAS provides an effective GIS-based framework for integrating spatial data processing with HEC-RAS hydraulic modelling. The integration facilitates the preparation, management, and refinement of geometric data required for river hydraulic analysis and enables the spatial visualization and interpretation of hydraulic simulation results within the GIS environment.
Through the workflow presented in this tutorial, GIS data can be used to develop the geometric components of a hydraulic model, while HEC-RAS can be used to simulate water-surface profiles under specified flow conditions. The resulting hydraulic outputs can subsequently be transferred back to the GIS environment to delineate flood inundation extents and water-depth distributions.

The integration of GIS and hydraulic modelling provides a practical environment in which spatial information can be prepared, examined, visualized, and refined throughout the modelling process. This integration is particularly useful for identifying inconsistencies in model geometry, interpreting hydraulic results in their spatial context, and supporting informed decisions during floodplain analysis.

Overall, the HEC-GeoRAS and HEC-RAS workflow demonstrated in this report provides a structured approach for river hydraulic modelling, floodplain delineation, and visualization of flood-related information, while highlighting the importance of appropriate terrain data, accurate geometric preparation, and careful quality control of the final inundation results.

APPENDICES

Data Requirement*:
The dataset supplied with this tutorial includes a small portion of the fictional Baxter River available with HEC-GeoRAS users manual.
The dataset supplied with this tutorial includes a small portion of the fictional Baxter River available with HEC-GeoRAS users manual.
The data (11.1 MB) required for this tutorial/example is available at ftp://ftp.ecn.purdue.edu/vmerwade/download/data/georasdata.zip. Download the zip file on your local drive, and unzip its contents. The GeoRASData folder contains two sub-folders, one TIN dataset, and one aerial image (as raster).

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