

Flood Inundation Mapping using HEC-RAS

Goodell, C.¹; Warren, C.²

WEST Consultants, 2601 25th St SE, Suite 450, Salem, OR 97302.

Abstract

Flood inundation mapping is an important tool for municipal and urban growth planning, emergency action plans, flood insurance rates and ecological studies. Mapping a floodplain requires a forecasting of the behavior of the stream in question for various recurrence interval storm events and the ability to translate the forecasted results into a plan-view extent of flooding. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) has the ability to model flood events and produce water surface profiles over the length of the modeled stream. With the companion GIS utility, HEC-GeoRAS, those water surface profiles can easily be converted to flood inundation maps. This paper will address the steps required to perform a flood inundation mapping study using HEC-RAS and will present a case study, demonstrating the capabilities of HEC-RAS and HEC-GeoRAS.

Key words: flood, hydrologic, inundation, mappings.

1. Introduction

Flood Inundation Mapping is an important tool for engineers, planners, and government agencies used for municipal and urban growth planning, emergency action plans, flood insurance rates and ecological studies. By understanding the extent of flooding and floodwater inundation, decision makers are able to make choices about how to best allocate resources to prepare for emergencies and to generally improve the quality of life. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) is a software package that is well-suited for developing flood inundation maps for a variety of applications. An HEC-RAS model can be used for both steady and unsteady flow, and sub- and supercritical flow regimes. With its companion utility, HEC-GeoRAS and ArcView[®], seamless integration with GIS makes both the construction of the model geometry and the post-processing of the output very easy. This paper presents a case study while addressing the steps taken to construct an HEC-RAS model and to resolve the output into flood inundation maps.

The Cameron Run Watershed is located in eastern Fairfax County, in the Commonwealth of Virginia, USA (Figure 1). Portions of the downstream end of the watershed are located in Alexandria County. The watershed area is approximately 44 sq miles (114 km²) and ranges in elevation from 485 ft (148 m) above mean sea level on the northwest

side of the watershed to about 10 ft (3 m) at the confluence of Cameron Run and the Potomac River. Cameron Run is fed by two main tributary streams: Holmes Run from the northwest and Backlick Run from the west. Holmes Run originates near the northwest area of the watershed along with its major tributary stream, Tripps Run. Turkeycock Run, and Indian Run comprise the two primary tributary streams that flow into Backlick Run.

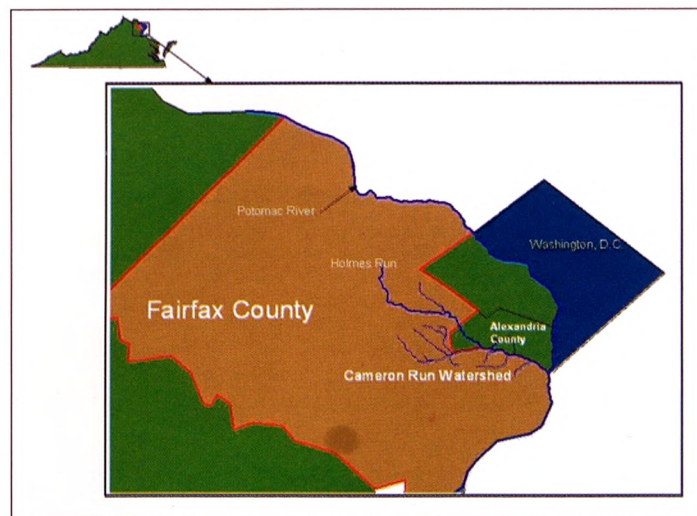


Figure 1. Site Layout

1.1 Background

The Cameron Run Watershed is located in eastern Fairfax

direction. Examples of ineffective flow areas include flow separation zones at constrictions such as bridges and culverts, backwater eddies, overbank areas shadowed by obstructions, etc. The ineffective flow areas were defined in the GIS model using aerial photos to locate zones of potential ineffective flow. A 1:1 contraction ratio and a 2:1 expansion ratio was typically used to define ineffective flow areas bounding bridges and culverts. Ineffective flow areas were also defined where significant infrastructure existed within a cross section and appreciable downstream conveyance was not expected. Once these areas were defined in the GIS model, they were intersected with the cross sections and exported to the HEC-RAS model via HEC-GeoRAS.

2.8 Crossings

In the HEC-RAS model, crossings include bridges, culverts, and inline weirs. Each crossing was input as a structural element in the RAS models. At the time of this study there was no way to import crossings to HEC-RAS from GIS; the crossings had to be entered into the HEC-RAS geometry after the base geometry data was imported. There are a total of 98 crossings in the Cameron Run Unnamed Tributary #2 and the Cameron Run HEC-RAS models.

In the HEC-RAS model, bridges are defined by station-elevation points of the high and low chords, piers, the overflow weir coefficient, and the modeling approach. The high and low chords were determined using a combination of field survey data for the structure and points taken from the TIN for the roadway elevation. Weir coefficients were initially set to the default value of 2.6 (English units based on $Q = CLH^{1.5}$), which represents a relatively inefficient broad-crested weir. Some of the coefficients were adjusted on a case-by-case basis, using photographs and survey notes.

Culverts are defined by station-elevation points of the embankment, the size and shape of the culvert, and its energy loss coefficients. Most of the culverts in the Cameron Run Watershed were box culverts, frequently consisting of multiple boxes in parallel. The watershed also has some circular pipes, pipe arches, and conspan structures. All the culverts are lined with concrete or corrugated metal. Loss coefficients were set for each culvert based on its entrance and exit conditions, its shape, and the degree of blockage. Severely blocked culverts were assigned entrance loss coefficients as high as 1.0. Very efficient, unblocked culverts

had entrance coefficients as low as 0.2. Exit loss coefficients were normally left at the default value of 1.0. When a culvert was partially blocked with sediment along its length, an average blockage depth was used and the roughness of the sediment was considered in selecting coefficients to define the culvert bottom roughness.

One inline weir was entered into the model. This weir is located at the downstream end of Holmes Run, just upstream of its confluence with Backlick Run. The weir is constructed of sheet piling and has a drop of about 7 feet (2.1 m). A discharge coefficient of 3.0 was used to define the structure's rating curve.

Figure 4 presents the geometric schematic in HEC-RAS for Cameron Run with all of the geometric data entered.



Figure 4. HEC-RAS Geometry Schematic for Cameron Run.

3. Hydrology

Once the geometry is complete, the hydrology can be entered into the model. HEC-RAS requires flows to be entered at all upstream boundaries. In addition, flow changes can be specified along any of the streams. Flows were provided to the model for the 1-, 2-, 10-, 25-, and 100-year recurrence interval storm events for both present and future conditions (complete build-out of the watershed).

3.1 Reservoirs

There are two major reservoirs in the Cameron Run

Watershed: Lake Barcroft and Fairview Lake, both on Holmes Run. No bathymetric data was available for these reservoirs, so defining them with cross sections was not possible. It was possible to model the reservoirs as storage areas; however, the storage area element in HEC-RAS was developed for use in unsteady flow applications, and was not originally intended for steady flow modeling. For the Cameron Run Watershed, the reservoirs were modeled using a single cross section, with a specified water surface for a given flow. In other words, the reservoirs are treated as internal boundary conditions. The water surface elevations are programmed into the flow files and are taken from existing storage elevation curves.

3.2 External Boundary Conditions

For steady flow models, upstream boundary conditions are input as discharges. Downstream boundary conditions can be set to normal depth, a rating curve, a known water surface elevation, or critical depth. Since no gage data information was available at the downstream end of the model, normal depth was selected for the Cameron Run Watershed model downstream boundary condition. The normal depth option requires an energy slope be entered by the user and the program then back-calculates a starting water surface elevation using Manning's equation. The error involved in the selection of the energy slope is normally minimized by placing the downstream boundary far from the area of

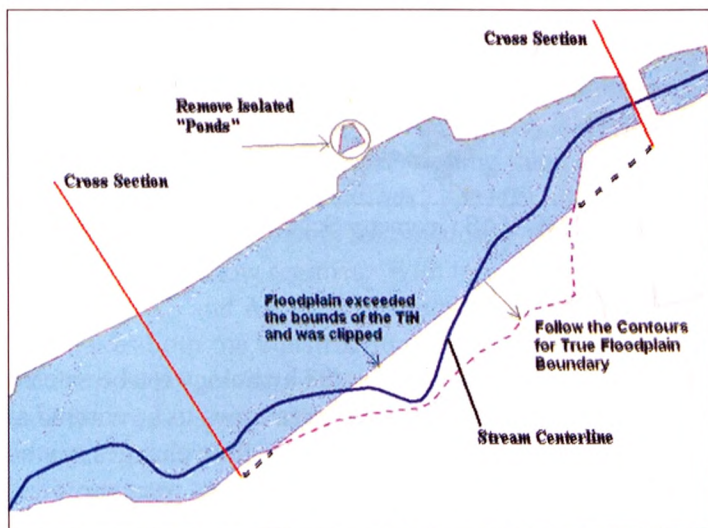


Figure 5. Manual Adjustment of Floodplain Delineation.

interest in the model. In this case, the downstream boundary for the Cameron Run Tributary model is about 1800 ft (550 m) downstream of the first tributary and over 1 mile (1.6 km) downstream of the calibration gage.

4. Post Processing

Once the HEC-RAS model was complete, output data was exported to GIS. HEC-GeoRAS was used to compile the data into useful graphical output such as floodplain polygon shape files.

To generate floodplain shape files, the GeoRAS extension is used to first create a water surface TIN for each of the flood events. The water surface TIN is automatically clipped to fall within the bounds of the cross sections (i.e. it does not extend beyond the end points of any cross section), and is completely independent of the terrain TIN. After the water surface TIN is created, the rasterization of the water surface TIN and the terrain TIN takes place and the floodplain is delineated where the water surface exceeds the terrain elevations.

Because the resulting floodplain shape file is only as good as the quality of the TINs that are used to create it, some manual adjustment of the floodplain boundary is necessary for the final product. Isolated "ponds" are removed from the floodplain shape file if it is determined that water cannot get there as surface flow. Also, there were areas where the floodplain extended beyond the extent of some of the cross sections. Because the water surface TIN is clipped at the end of the cross sections, manual extension of the floodplain was necessary. This process involved starting at a point within the water surface TIN bounds and tracing the floodplain boundary outside the TIN along a consistent contour elevation. This is continued until floodplain boundary returns within the bounds of the water surface TIN (Figure 5).

5. Results and Conclusions

HEC-RAS and its companion GIS extension HEC-GeoRAS can aid in the development of flood inundation maps. HEC-RAS is a powerful, yet easy-to-use software package for determining water surface profiles in a wide variety of streams. GeoRAS can post-process the HEC-RAS data into polygon shape files that define the extents of flooding for a given flood.

The resulting flood inundation maps are useful for municipal planning purposes, emergency action plans, flood insurance rates and ecological studies. Figures 6 through 8 present example flood inundation maps created by HEC-RAS for the 1- and 100-year flood events.

County, in the Commonwealth of Virginia, USA (Figure 1). Portions of the downstream end of the watershed are located in Alexandria County. The watershed area is

approximately 44 sq miles (114 km^2) and ranges in elevation from 485 ft (148 m) above mean sea level on the northwest side of the watershed to about 10 ft (3 m) at the confluence of Cameron Run and the Potomac River. Cameron Run is fed by two main tributary streams: Holmes Run from the northwest and Backlick Run from the west. Holmes Run originates near the northwest area of the watershed along with its major tributary stream, Tripps Run. Turkeycock Run, and Indian Run comprise the two primary tributary streams that flow into Backlick Run.

Barcroft is the biggest reservoir with a storage volume of about 2270 acre-ft (2.8 million m^3). It is fed by Holmes Run from the west and Tripps Run from the northwest. Fairview Lake is located on Holmes Run about 4 miles (6.5 km) upstream of Lake Barcroft and has a storage volume of about 130 acre-ft ($160,000 \text{ m}^3$).

Both present and future conditions were modeled for the 1-, 2-, 10-, 25-, and 100-year recurrence interval storms. The objective of this study was to use HEC-RAS to produce flood inundation coverage and velocity profiles for all of the major streams in the Cameron Run Watershed.

2 Model Development

2.1 Survey Data

A digital terrain model (DTM) was constructed using a compilation of 2-ft (0.6-m) contour plots from Falls Church, Alexandria County, and the portion of Fairfax County that falls within the Cameron Run Watershed. The DTM was compiled in the form of a Triangular Irregular Network (TIN) for use in HEC-RAS model development. In addition to the DTM, field surveyed cross sections were collected near many of the crossings in the watershed. The contour plots were developed from aerial photogrammetry and do not include bathymetry. Therefore, the TIN does not provide coverage for “submerged” terrain. Most of the streams in the watershed are very small, and an absence of bathymetric data will make little difference in the results. However, the larger streams such as Cameron Run, and the lower Holmes Run may show results that skew towards higher water surface elevations. Where taken, field survey cross sections were merged with DTM-generated cross sections to capture

the bathymetry.

2.2 Geometry

The Cameron Run Watershed was broken into three HEC-RAS models. One model defines the geometry of Pike Branch. The second model encompasses the Cameron Run Unnamed Tributary # 2, and the third model captures the rest of the watershed (called Cameron Run). Figure 2 illustrates the scope of the three models. The Pike Branch model was completed earlier and is not discussed in this Technical Memorandum.

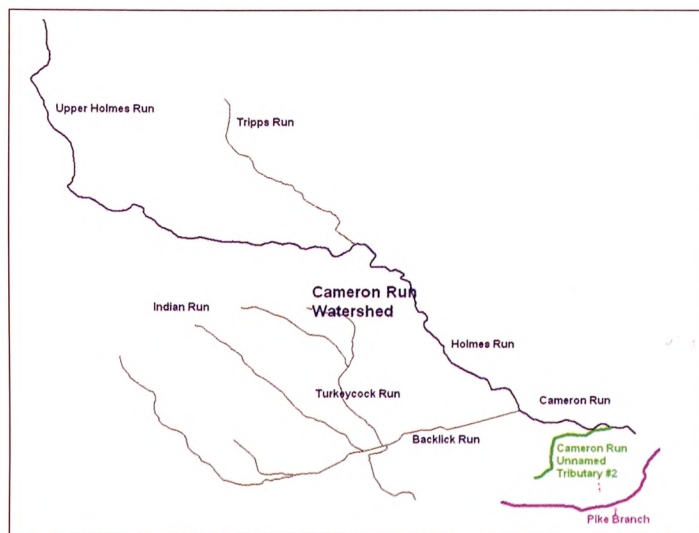


Figure 2. Scope of the three HEC-RAS Models.

2.2 Stream Lines

To define the path of the various streams, stream lines were drawn into the GIS, using an aerial photograph and contours for delineation. The stream line is used to define the location of the invert of the stream and its planform layout for import to HEC-RAS.

2.2 Bank Lines and Flow Paths

Bank lines were then drawn along the approximate location of the top-of-bank on both sides of all of the streams. HEC-RAS requires the bank stations to be specified for each cross section. By drawing in the bank lines that intersect the cross sections, the GeoRAS utility is able to determine where that bank station falls on each cross section. Flow lines were also delineated to approximate the flow paths of the center of mass of the main channel, the left overbank and the right overbank. The flow paths are used to determine the reach lengths between cross sections for the main channel

and overbanks (floodplains).

2.5 Cross Sections

Cross sections are used to define the shape of the stream and its characteristics, such as roughness, expansion and contraction losses, and ineffective flow areas. Typically, cross sections are drawn into the GIS perpendicular to the approximated flow lines. Over 1000 cross sections were drawn on the DTM to define the terrain in the Cameron Run Watershed. Additionally, fifty cross sections were surveyed in the field. The field cross sections were typically taken near crossings and include bathymetric data. Where possible, these cross sections were merged with DTM cross sections to produce composite cross sections that include terrain as well as bathymetric survey points. Figure 3 shows a sample section of Holmes Run with the stream line, bank lines, flow lines and cross sections included.

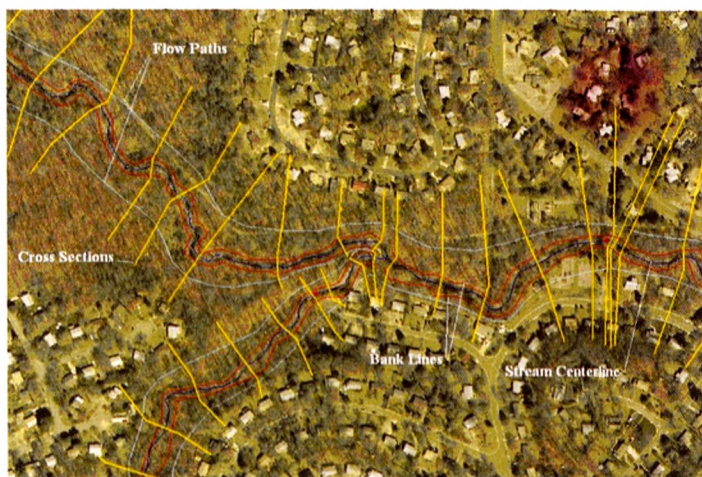


Figure 3. Stream Lines, Flow Paths, Bank Lines, and Cross Sections.

2.6 Roughness Values

Manning's n values were used in the model to define roughness for each cross section. The n -values were assigned in two steps: The first step involved defining land-use characteristics for common areas throughout the watershed.

Each land-use characteristic was given an n -value based on published values for similar conditions (Chow, 1959; Barnes, 1967) and on engineering judgment and experience. The in-stream n -values for small streams were not assigned in the first step. Once the land-use was defined for the entire watershed, the representative n -values were assigned to the portion of each cross section that intersects the respective land-use area (defined in a polygon shape file in the GIS).

These n -values were then exported to the HEC-RAS model using HEC-GeoRAS.

Table 1 presents the land-use and corresponding n -values that were used in the GIS model.

The second step involved entering the in-stream n -values. These n -values are based on field inspections and hydraulic properties and range from 0.015 for some of the concrete-lined channels to 0.07 for the steep, cobbly streams with a lot of overhanging vegetation and debris.

2.7 Ineffective Flow Area

Ineffective flow areas define portions of a cross section in which water does not move effectively in the downstream

Land-Use Characteristic	n Value
Backlick Run	0.045
Lower Backlick Run	0.045
Lower Cameron Run	0.035
Concrete Canal	0.018
Field 1, Open and maintained fields. Parks.	0.030
Field 2, Open fields with scattered brush. Not mowed.	0.045
Field 3, Fields with thick vegetation. Not maintained.	0.065
Forest 1, Light trees and underbrush.	0.070
Forest 2, Medium trees and dense underbrush.	0.085
Forest 3, Thick trees and very dense underbrush.	0.120
Industrial	0.100
Pavement	0.015
Railways	0.020
Reservoirs	0.030
Residential, typically landscaped backyards.	0.050
Sparse Residential, forested backyards	0.085

Table 1. Land-use and Corresponding Mannings n Values

Teniendo en cuenta las leyes de transporte es posible generar ecuaciones diferenciales de equilibrio, capaces de describir en manera acertada los mecanismos de transporte y almacenamiento dominantes.

2.1. Temperatura

Los mecanismos físicos que provocan el transporte de calor se distinguen entre: radiación, conducción y convección. La conducción propiamente dicha, solo tiene lugar en los medios continuos, mientras que en los medios porosos se efectúa a su vez un intercambio de calor por radiación, en el espacio de poros ocupado por aire.

La ecuación de equilibrio que permite la descripción del fenómeno se basa en el principio de conservación de la energía, y plantea, que la suma de todos los cambios de energía dentro de un elemento diferencial en forma de calor o trabajo, deben ser intercambiadas con el medio [11]. Despreciando los términos termomecánicos acoplados [6], tenemos:

$$\dot{\Psi} = \bar{Q}_T - \text{div}(\mathbf{q}_T) \quad (1)$$

Lo que se traduce en que la tasa de cambio de la energía calorífica específica $\dot{\Psi}$ es provocada, por un lado por la variación espacial de la densidad de flujo calórico $\mathbf{q}_T$ y por otro por una fuente de calor interna $\bar{Q}_T$ (de aporte o de retención).

2.2. Contenido de Humedad

Los tres procesos hídricos de interacción entre un cuerpo (medio poroso) y su entorno, pueden dividirse en: adsorción (entrada de moléculas de agua del entorno que se acumulan en el cuerpo), desorción (salida de moléculas de agua hacia el entorno) y permeación (migración de moléculas de agua a través del medio poroso).

El proceso de transporte, acontece siempre que exista un desequilibrio hídrico dentro del cuerpo, o entre el cuerpo y el entorno. El espacio dentro del cual se dará el mismo, es el contenido dentro de los vacíos formados por los poros. Los distintos mecanismos que pueden producirse dependen básicamente de la cantidad, tipo, forma y distribución de los poros, y del estado del agua (líquido o gaseoso), logrando que se forme un flujo másico dentro del cuerpo. El espacio

de vacíos sirve además como lugar de almacenamiento de agua. Para alcanzarse el equilibrio térmico e hídrico, se almacenarán o bien entregarán moléculas de agua en o desde la superficie de los poros, según las condiciones de temperatura y humedad relativa. Por lo tanto el flujo de humedad a través del medio poroso es el resultado de la interacción entre el transporte y el almacenamiento de humedad.

Para la descripción numérica del problema, se formula una ecuación diferencial de equilibrio basada en el principio de conservación de la masa, según la cual, la variación del contenido de humedad $\dot{w}$ es producto de la variación espacial del flujo $\mathbf{q}_H$ y del aporte o retención de una fuente $\bar{Q}_H$. Específicamente

$$\dot{w} = \bar{Q}_H - \text{div}(\mathbf{q}_H) \quad (2)$$

3. Ecuaciones de Equilibrio

Tomando como base las ecuaciones (1) y (2), y teniendo en cuenta, relaciones de transporte y almacenamiento descritas en [16, 17]. Se obtiene finalmente un sistema de ecuaciones diferenciales no lineales acopladas, en términos de la temperatura T y la humedad relativa del aire en los poros H , que tiene la siguiente forma:

$$\begin{aligned} c_T^T \dot{T} + c_T^H \dot{H} - \text{div}[\lambda_T^T \nabla T] - \text{div}[\lambda_T^H \nabla H] - \bar{Q}_T &= 0 \\ c_H^T \dot{T} + c_H^H \dot{H} - \text{div}[\lambda_H^T \nabla T] - \text{div}[\lambda_H^H \nabla H] - \bar{Q}_H &= 0 \end{aligned} \quad (3)$$

Las ecuaciones anteriores no son suficientes para describir completamente el problema, es necesario a su vez definir las condiciones iniciales y las condiciones de borde.

Denotando el interior del medio poroso como Ω y el borde de este como Γ , las condiciones iniciales definen los campos de temperatura y humedad en cada punto para el tiempo inicial t_0 :

$$\left. \begin{aligned} T - T_0 &= 0 \\ H - H_0 &= 0 \end{aligned} \right\} \text{ en } \Omega \cup \Gamma \quad (4)$$

En cuanto a las condiciones de borde, estas se dividen comúnmente en tres clases: Dirichlet, Neumann y Neumann-

Robin. En las primeras, la condición es impuesta directamente. Las segundas imponen un flujo normal a la superficie, mientras que las terceras representan el transporte por convección y radiación, teniendo en cuenta los valores de las variables independientes en el entorno. Dichas condiciones de borde se pueden resumir en:

▪ Dirichlet:

$$\left. \begin{array}{l} T - \bar{T} = 0 \\ H - \bar{H} = 0 \end{array} \right\} \text{ sobre } \Gamma \quad (5)$$

▪ Neumann/Neumann-Robin:

$$\begin{aligned} (\lambda_T^T \nabla T + \lambda_T^H \nabla H) \cdot \mathbf{n} + \alpha_c^T (T - \bar{T}_\infty) + \sigma \varepsilon (T^4 - \bar{T}_\infty^4) - \bar{q}_{nT} &= 0 \\ (\lambda_H^T \nabla T + \lambda_H^H \nabla H) \cdot \mathbf{n} + \alpha_c^H (H - \bar{H}_\infty) - \bar{q}_{nH} &= 0 \end{aligned} \quad \text{sobre } \Gamma \quad (6)$$

Las ecuaciones (3) a (6) permiten la descripción completa del problema, donde las incógnitas son la temperatura T y la humedad relativa en los poros H . La fuerte no linealidad del problema viene dada por la condición de borde Neumann-Robin, según la ley de Radiación de Stefan-Boltzmann y por la dependencia funcional de los términos c_i^j y λ_i^j , (para $i,j=T,H$), respecto a las propias variables independientes. Cabe hacer notar que, para el análisis posterior, las fuentes Q se consideran independientes de T y H .

Debido a la complejidad del problema, no se conoce una solución analítica para el caso general, por lo que en adelante se planteará la solución del problema para el caso unidimensional utilizando el método de los elementos finitos, para ello se comenzará con la forma débil del problema.

3.1. Forma débil

Para hallar la forma débil del sistema de ecuaciones, se toman individualmente cada una de las ecuaciones de equilibrio (3), con sus correspondientes condiciones de borde (5) y (6), se realiza la sumatoria de las mismas, y seguidamente se las premultiplica por ciertas funciones de peso δT y δH correspondientemente. Las ecuaciones así obtenidas se integran en el dominio Ω y finalmente, mediante la aplicación del teorema de Gauss se obtiene la forma débil del problema.

3.2. Forma semidiscreta

Teniendo el problema en su forma débil, se realiza posteriormente la discretización espacial de este mediante elementos finitos. Con esto se aproximan las variables principales en función de sus valores nodales y utilizando las clásicas funciones de forma dadas por polinomios lineales de Lagrange, se tiene entonces que para un determinado elemento e , conectado a los nodos $e1$ y $e2$, la temperatura y humedad, reunidas en el vector $\mathbf{v} = [T \ H]^T$, se aproximan como:

$$\begin{aligned} \mathbf{v}_{(x)} &\cong \mathbf{N}_{(x)} \mathbf{v}^e & \delta \mathbf{v}_{(x)} &\cong \mathbf{N}_{(x)} \delta \mathbf{v}^e \\ \dot{\mathbf{v}}_{(x)} &\cong \mathbf{N}_{(x)} \dot{\mathbf{v}}^e & \nabla \delta \mathbf{v}_{(x)} &\cong \mathbf{B}_{(x)} \delta \mathbf{v}^e \\ \nabla \mathbf{v}_{(x)} &\cong \mathbf{B}_{(x)} \mathbf{v}^e \end{aligned} \quad (7)$$

donde $\mathbf{v}^e$ se define en (13), $\mathbf{N}_{(x)}$ es la matriz de las funciones de forma y $\mathbf{B}_{(x)}$ es la matriz de las derivadas de las funciones de forma.

Ensamblando finalmente el aporte de todos los elementos a la forma débil se obtiene la forma general de un problema no lineal, semidiscreto, de primer orden, con valores iniciales, que escribimos a continuación:

$$\delta W = \delta \mathbf{v} \cdot [\mathbf{r}_{int(\dot{\mathbf{v}}, \mathbf{v})} - \mathbf{r}_{ext(\mathbf{v})}] = 0; \quad \mathbf{v}_{(t=t_0)} = \mathbf{v}_0 \quad (8)$$

Donde $\mathbf{r}_{int}$ viene dado por:

$$\begin{aligned} \mathbf{r}_{int(\dot{\mathbf{v}}, \mathbf{v})} &= \bigcup_{e=1}^{NE} \mathbf{r}_{int(\dot{\mathbf{v}}^e, \mathbf{v}^e)} \\ \mathbf{r}_{int(\dot{\mathbf{v}}^e, \mathbf{v}^e)} &= \int_{x^{e1}}^{x^{e2}} \mathbf{N}^T \mathbf{C}_{(v)} \dot{\mathbf{v}} A dx + \int_{x^{e1}}^{x^{e2}} \mathbf{B}^T \boldsymbol{\lambda}_{(v)} \nabla \mathbf{v} A dx \\ \mathbf{C}_{(v)} &= \begin{bmatrix} c_T^T & c_T^H \\ c_H^T & c_H^H \end{bmatrix}; \quad \boldsymbol{\lambda}_{(v)} = \begin{bmatrix} \lambda_T^T & \lambda_T^H \\ \lambda_H^T & \lambda_H^H \end{bmatrix} \end{aligned} \quad (9)$$

mientras que para $\mathbf{r}_{ext}$ se tiene:

$$\begin{aligned} \mathbf{r}_{ext(\mathbf{v})} &= \mathbf{r}_{ext}^{(q)} + \mathbf{r}_{ext}^{(B)} \\ \mathbf{r}_{ext}^{(q)} &= \bigcup_{e=1}^{NE} \mathbf{r}_{ext}^{(q)e} \quad \text{y} \quad \mathbf{r}_{ext}^{(B)} = \bigcup_{e=1}^{NE} \mathbf{r}_{ext}^{(B)e}(\mathbf{v}^e) \end{aligned} \quad (10)$$

$$\mathbf{r}_{ext}^{(q)e} = \int_{x^{e1}}^{x^{e2}} \mathbf{N}^T \mathbf{Q} A dx \quad (11)$$

At relatively low recurrence interval floods (1- and 2- years), Holmes Run just downstream of Arlington Boulevard comes out of bank, creating a large flood plain. The majority of the overbank of this reach is forested and reserved as park land (Figure 6).

Significant flooding occurs for the 100-year event on the lower Backlick Run and its confluence with Holmes Run. As shown in Figure 7, this is mostly industrial and a substantial area is inundated. Comparisons between different

flood frequency events can easily be compared by overlaying multiple floodplain polygons on the same background image, as shown in Figure 8. In this case, the 1-yr flood is compared with the 100-yr flood on Holmes Run. The cross sections used to construct the HEC-RAS model are shown on this figure as well.

The results presented in the form of ArcView[®] shapefile polygons and lines were generated in the steady flow version of HEC-RAS, which is a one-dimensional model. Because the steady flow version of HEC-RAS was used, no time-dependant hydrodynamic effects are captured in the calculated water surface profiles, such as flow attenuation and lag times. However, flow attenuation was simulated by manually including lateral inflows throughout the watershed based on the results from the hydrologic study, which does provide a method for estimating flow attenuation and lag time.

Being a one dimensional model, HEC-RAS computes single water surface elevations for each cross section. In other words, the water surface elevation presented in the HEC-RAS results will not vary along the length of a cross section;

the overbanks and the main channel will have the same water surface elevation. In reality, the overbanks typically have a higher water surface elevation than the main channel.

As a result, flow will come out of bank earlier than in reality and the water surface elevation in the overbanks will be slightly lower than in reality. The errors due to the one-dimensionality of HEC-RAS are typically inconsequential for watershed-level analyses, and the results are generally accepted for use in planning and design.

¹Senior Hydraulic Engineer,
WEST Consultants,
Tel: (503) 485-549
cgoodell@westconsultants.com
²Hydraulic Engineer,
WEST Consultants,
Tel: (503) 485-549
cwarren@westconsultants.com

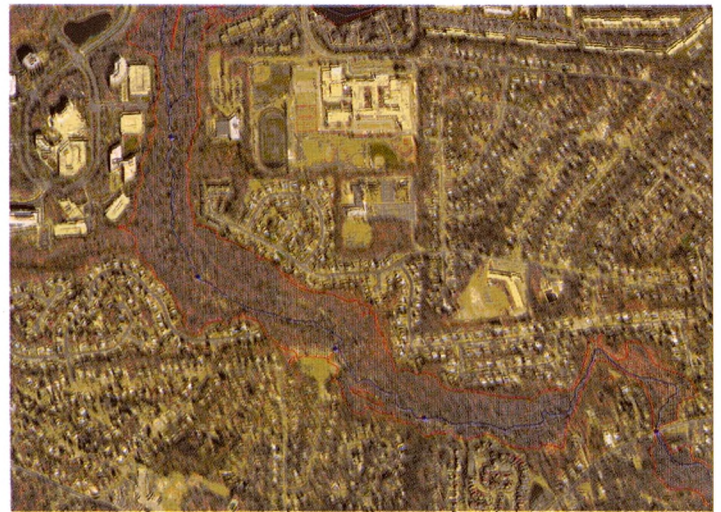


Figure 6. 1-year Flood Event on Holmes Run Downstream of Arlington Boulevard.



Figure 7. 100-year Flood Event on the Lower Backlick Run.

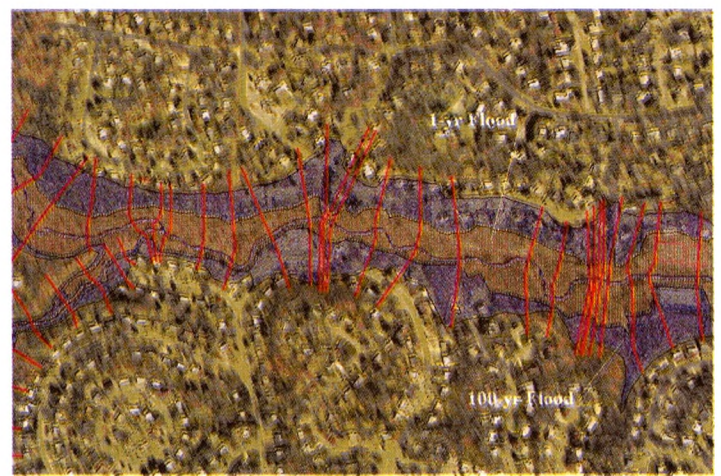


Figure 8. 1-yr vs. 100-yr Flood on Holmes Run