DAM BREACH ANALYSIS FOR URBANIZING BASINS

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INTRODUCTION

Development downstream of old and in many cases deficient, dams is responsible for a growing concern within communities that are transitioning from a rural to suburban environment. There are instances of permitted development being constructed in the shadow of a dam embankment without regard to the potential consequences from a dam failure. Loss of life is a real and sobering risk if a home is built in a potential dam breach zone. In Georgia, many of the dams in formerly rural areas do not fall under the regulatory oversight of the Georgia Safe Dams Program simply because they are smaller than the minimum size necessary by law to bring them into the Program. This does not diminish their potential for causing damage in the event of a breach. It is therefore imperative for development to account for the potential breach zone of even the smallest dams if they present a potential threat to downstream lives and structures. However, many breach zone delineation models are cumbersome and difficult to use, even for the most experienced modelers. It is therefore expensive to contract for that work, and as a result, modeling is often omitted. If a breach zone is delineated by a rough approximation, there is the potential to remove from development projects a substantial, and probably overestimated, portion of the usable land, thereby unnecessarily reducing the investment return for the developer. GIS and HEC-RAS offer a cost-effective and quick method to delineate a reasonable and effective potential dam breach zone. Through the use of a set of simple, but effective techniques, a breach zone can be defined for a reasonable cost that will protect lives and property, but not unduly impact the investment return potential for the development.

HEC-GeoRAS

HEC-GeoRAS is an extension developed by the US Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) for use with Environmental Systems Research Institute (ESRI) ArcGIS products. It consists of a set of tools and procedures for extracting primarily topographic data within the GIS platform and importing directly into a HEC-RAS geometric file. HEC-GeoRAS allows for a quick and seamless conversion of electronic contour data into a cross-section format used by HEC-RAS to facilitate the calculation of water surface elevations.
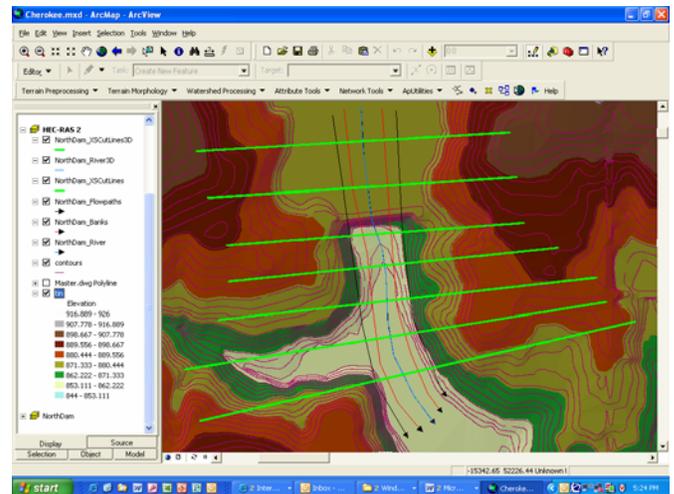

Figure 1 – HEC-GeoRAS GIS Platform

HEC-RAS

HEC-RAS is a steady/unsteady flow model developed by the same USACE HEC facility. It is used to perform one-dimensional hydraulic calculations in natural and constructed open channels. The steady flow algorithm is a derivative of the former HEC-2 programming, one of the primary flood mapping models in use in the late 20th century. The unsteady flow algorithm is derived from UNET, also developed by the USACE HEC facility. The unsteady capability of HEC-RAS includes off-channel and overbank storage, and so can be considered quasi-two-dimensional. This storage modeling capability is also how it is applied to dam breach analysis.

HEC-RAS Inputs

The HEC-RAS geometric file for use in dam breach analysis is the same format that is used for all HEC-RAS studies. Cross-sections are formulated and described in the same way regardless of the flow regime being modeled.
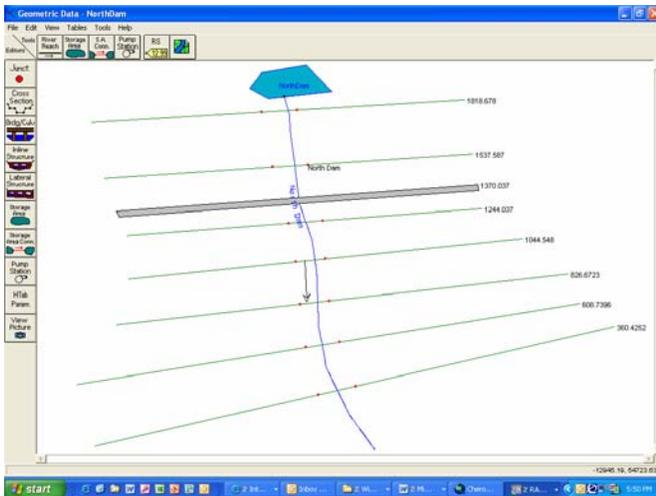
Figure 2 – HEC-RAS Geometric File

The dam is represented in HEC-RAS by an in-line structure and a storage area. The in-line structure requires bracketing by at least two cross-sections upstream and two cross-sections downstream. It is best to substitute within HEC-RAS the cross-section just downstream of the dam for the two upstream of the dam. The breach analysis does not appear to depend on the cross-sectional area of the section for calculative purposes, the storage area inputs account for the reservoir volume. However, the algorithm does appear to require that the lowest elevations in the upstream cross-sections correspond to the lowest elevation in the storage area definition. If this is not the case, the algorithm will become unstable and the profile graphics will not visually represent a dam blocking a stream reach.

Figure 3 – In-line structure and storage area input screens

The breach parameters are input through the in-line structure screen. The Breach (plan data) button will open the breach parameter input screen.
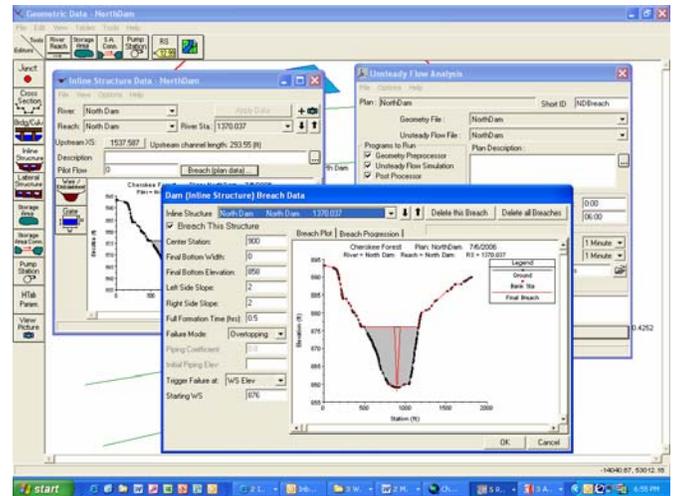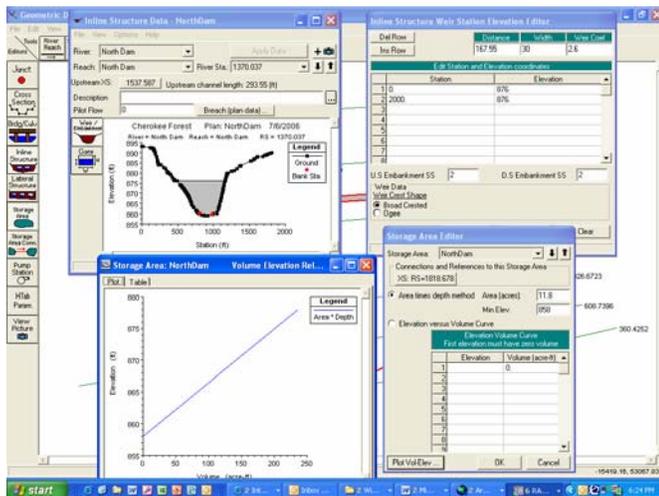

Figure 4 – Dam Breach Input

Upstream and downstream boundary conditions are input in the flow file screen. The downstream boundary condition will typically be a normal depth while the upstream boundary condition is the storage area.
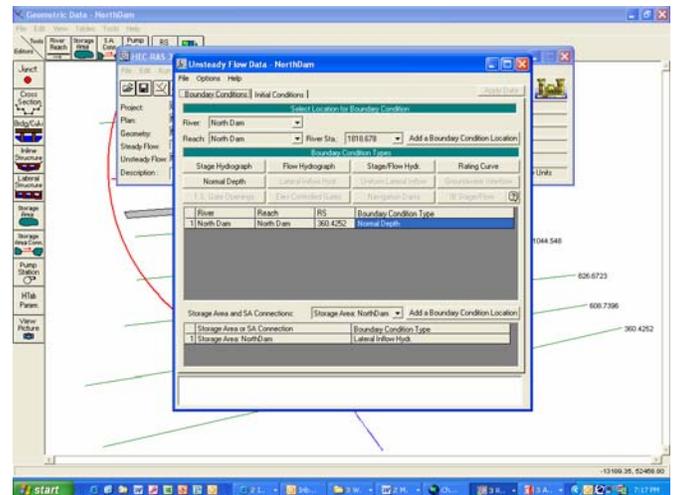

Figure 5 – Upstream/Downstream Boundary Conditions

An initial condition flow of 50 cfs is specified in this example for each cross-section.

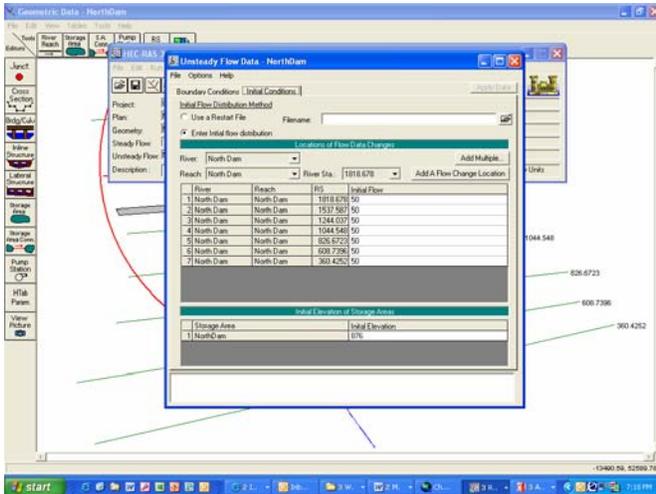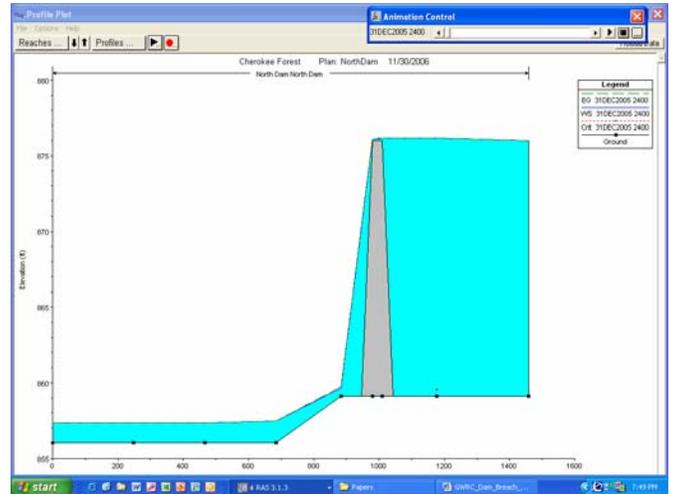Figure 6 – Initial Flow Condition

The unsteady analysis parameters are input in the unsteady plan screen. For this example, there is a 6 hour analysis time frame with a 30 second computational interval and a one minute output interval. This analysis took approximately two seconds to process.
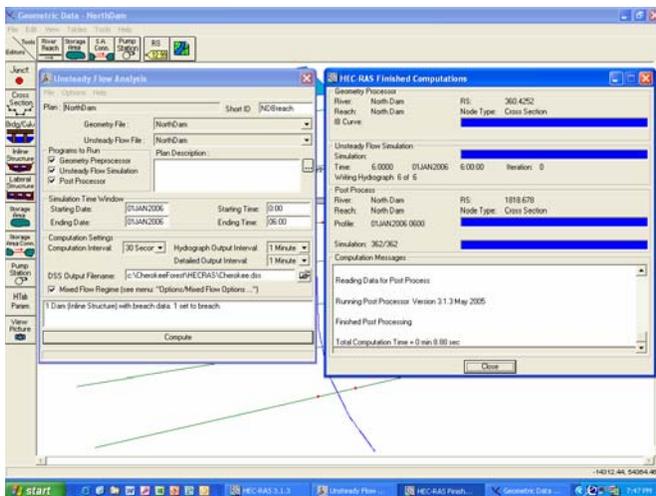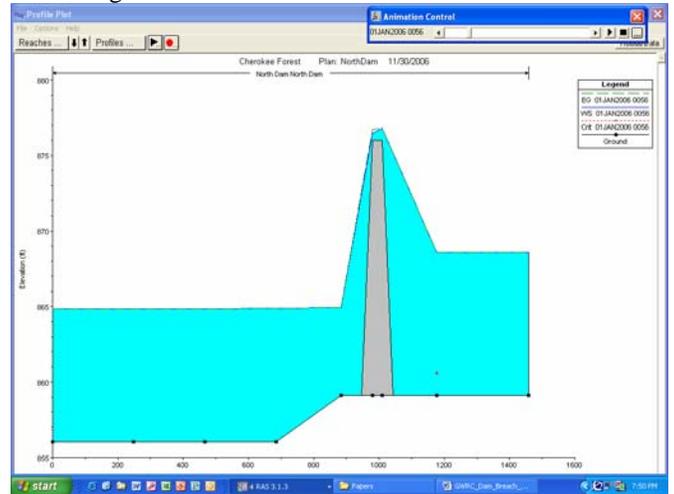

Figure 7 – Unsteady Flow Processing

Results

The results can be reviewed in the profile screen and they can be animated to show the change in water surface elevation throughout the entire analysis. The results can also be reviewed and animated in the three-dimensional screen. Although the program documentation indicates that results can also be viewed and animated in the cross-section review screen, this does not appear to work in this example application.
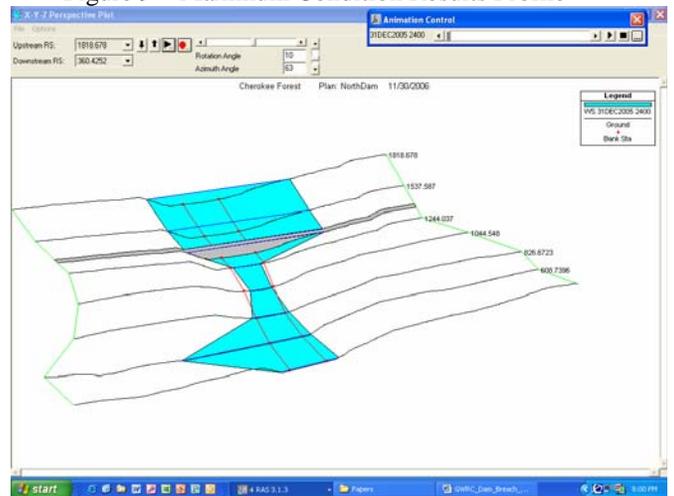

Figure 8 – Initial Condition Results Profile

Figure 9 – Maximum Condition Results Profile

Figure 10 – Initial Conditions Three-Dimensional View

HEC-GeoRAS Post Processing

The results can be imported into the ArcGIS platform for post-processing in the same manner as any HEC-RAS analysis. When exporting from HEC-RAS, any output interval can be selected. Typically, the maximum water surface would be the condition to be mapped. The boundary delineation can then be easily transferred to design plans.
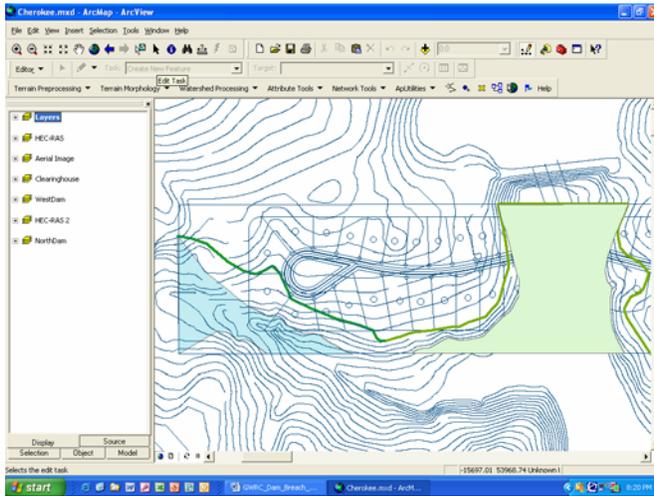
LITERATURE CITED

USACE HEC, *HEC-RAS River Analysis System, User's Manual, Version 3.1*, November 2002.