# Simplified Procedure for Estimating Approximate Dam Breach Inundation Area for EAP Light Studies

(Developed by CBBEL, July 2009)

This document provides a summary of a simplified methodology developed in July 2009 by Christopher B Burke Engineering, Ltd (CBBEL) for estimating approximate dam breach inundation area for use with Emergency Action Plan of dams in Indiana, when the development of more detailed hydrologic and hydraulic modeling is not financially feasible at this time. The project was done as part of a contract with the Indiana Department of Natural Resources (IDNR).

As part of this effort, CBBEL conducted research to find and briefly evaluate various methods in use by various agencies within the United States to assist in the development of a methodology most appropriate for the IDNR purposes. Based on the noted research, a combination of earlier work done by Dr. David Froehlich (1995), the Washington State Department of Ecology (2007), Bureau of Reclamation (1986), and US Army Corps of Engineers (latest) was determined to be the most appropriate procedure for IDNR purposes. To automate as much as process as possible, CBBEL developed a spreadsheet that incorporates formulas, tables, and graphs associated with Froehlich, Washington State Department of Ecology, and Bureau of Reclamations pieces.

The following are step by step instructions for developing approximate dam breach inundation mapping in accordance with the CBBEL simplified procedure:

## Step1: Determine Dam Height

The following sources can be used to determine the height of the dam:

- National Inventory of Dams
- Inspection records
- Indiana Department of Natural Resources records
- Emergency Action Plans

If no information is available from the sources listed above, estimate the dam height by field measurements or by topographic data from USGS Maps or other reliable sources.

## Step 2: Determine Volume Impounded at Top of Dam

The volume impounded at the top of the dam may be found using the sources listed above. If the volume cannot be found using these sources, then it can be estimated by digitizing contours and using the contour-area method. Lake contour maps can typically be obtained from the Indiana Department of Natural Resources.

## Step 3: Determine the Dam Breach Peak Discharge and Attenuated Peak Discharges in the Downstream Reach

- Input the dam height (feet) and lake volume impounded at top of dam (acre-feet) into CBBEL Simplified Breach Analysis Spreadsheet – Peak Discharge Estimator to obtain peak breach discharge and attenuated peak discharges along downstream reach (peak discharge results are provided at 0.25-mile increments downstream to 2 miles, then every 0.5 miles afterward).
- Methodology and assumptions used within the spreadsheet includes the following:
    - The dam breach peak discharge is computed using an equation developed in 1995 by Dr. David Froehlich [$Q_b = 40.1V_w^{0.295}H_w^{1.24}$]. In the equation, $Q_b$ is the peak breach discharge (cfs), $V_w$ is the volume of water above the breach invert elevation at the time of breach (acre ft), and $H_w$ is the height of water over the base elevation of the breach (ft). For the

purpose of CBBEL simplified approach, the breach is assumed to occur at the top of the dam, with reservoir full to the top of the dam and there is no additional inflow. Therefore, total volume of reservoir at the top of dam is substituted for $V_w$ (in acre-feet) and height of the dam is substituted for $H_w$ (in feet).

- The estimation for attenuation of the dam breach peak discharge as the breach wave travels downstream is based on a family of curves developed in 2007 by the Washington State Department of Ecology for this purpose. The curves depict the relationship of the ratio of downstream discharge to peak breach discharge at the dam versus the distance downstream of the dam for various reservoir storage volumes ranging from 10 to 3,000 acre-feet. If the volume impounded at top of the dam exceeds 3,000 acre-feet, an equation developed in 1986 by the Bureau of Reclamation [$Q = Q_b (10)^{-0.02x}$] is utilized. In the equation, Q is peak discharge (cfs) corresponding to distance x, $Q_b$ is peak breach discharge (cfs), and x is distance downstream from dam (mi).

**Step 4: Obtain Topographic Data and Aerial Photographs for Area of Interest**

- Digital USGS topographic data is preferred to the 2005 Statewide Digital Elevation Model (DEM).
- Utilize more reliable data (i.e. 2-foot or 1-foot contours) if available from the appropriate City or County.
- Obtain the most current aerial photographs from the Indiana Spatial Data Portal, the Indiana Map, or other reliable source.

**Step 5: Perform Breach Wave Modeling and Inundation Mapping**

- Import topographic data and aerial photograph(s) into ArcGIS.
- Utilize the latest version of the US Army Corps of Engineers program HEC-GEORAS to define stream reach, stream banks, flow paths, and to cut cross-sections.
- General rules for cutting cross-sections are as follows:
  1. Cross-sections should be cut whenever there is a significant change in channel geometry or topography or every 500-1000 feet (maximum).
  2. Cross-sections should be perpendicular to the flow path.
  3. At bridges or culverts, assume that the opening is completely blocked with debris from the flood wave. Cut three cross-sections: one along the road profile (ignoring any openings), one approximately 50-100 ft. upstream of the bridge, and one approximately 50-100 ft. downstream of the bridge. Note: The assumption of fully clogged bridge/culvert opening may be too extreme and unreasonable in some cases. Judgment must be used to either assume the crossing to be clogged, explicitly model the bridge opening, or not to model the crossing at all.
- Export geometric data to the latest version of US Army Corps of Engineers Program HEC-RAS that is compatible with the version of HEC-GEORAS being used.
- Input the attenuated peak discharges from Step 3 into the HEC-RAS model.
- Assign Manning's "n" values to each cross-section based on aerial photographs or other recent and reliable site photos.
- Input boundary conditions. Assume normal depth at the downstream end with a friction slope equal to the bed slope between the two most downstream cross-sections.
- Run HEC-RAS steady-state model to determine the water surface profile.

- The study limits should extend downstream to a point at which the depth of flooding is less than two (2) feet, when inundation limits are completely contained within the 100-year floodplain, or when the flood wave reaches a large body of water.
- To be conservative and more accurate, read energy grade line elevation (instead of water surface elevations).
- Export HEC-RAS results to ArcGIS.
- Utilize “Tin Intersect” or HEC-GEORAS to map the inundation area.
- Look up the calculated water surface elevation at the confluence of tributaries entering the downstream reach and the receiving stream within the impact area (including the upstream reach of any receiving stream, if applicable) and map the potential inundation limits along these tributaries assuming level pool inundation in the tributary.

**Alternative Step 5: Estimate Inundation Depths Downstream Without Utilizing Computer Models**

- For very preliminary estimates of potential inundation depth at a downstream location or when using ArcGIS, HEC-GEORAS, and HEC-RAS are not practical for the user, the State of Washington Department of Ecology simplified procedures may be used to determine the flood wave depths. This methodology produces an estimate of cross sectional area at each downstream location through dividing the estimated attenuated peak discharge determined in Step 3 by the representative breach wave velocity estimated based on typical stream bed slope and overbanks cover type. CBBEL automated this procedure into a spreadsheet solution and further modified it by introducing allowance for entering coordinates for typical 8-point cross sections along the stream so that flood wave depth at each discharge location downstream can be estimated. The spreadsheet also allows entry of ditch bottom elevations at quarter mile markers along the stream so that the depths may be translated into elevations. The resultant estimates of breach wave water surface elevations along downstream reach should be treated as an initial estimation tool.
- Utilize the Water Surface Elevation Estimator tab of the CBBEL Simplified Breach Analysis Spreadsheet to determine the water surface depth and elevation at various locations downstream. Additional inputs needed are typical stream bed slope (feet per mile), typical overbank land cover, channel bottom elevations (ft), and typical 8-point cross-section coordinates for one or more typical locations (up to 8 cross sections may be utilized).
- Input a minimum of 1 ft. of freeboard in the spreadsheet to be added to the water surface elevations determined by this method to account for variability in the estimation methods. It is recommended that additional freeboard be added for reaches that have highly variable or irregular cross-sections. The user must use sound engineering judgment when determining the appropriate amount of freeboard.
- If an initial approximate mapping of the estimated elevations is desired, utilize water surface elevations from spreadsheet to manually map the inundation area based on existing topography.