A GENERAL DISCUSSION OF DAM BREACH ANALYSES

Natural Resources and Environmental Protection Cabinet

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER

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DIVISION OF WATER
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BACKGROUND

KRS 151.295 requires the regular safety inspection of dams within the Commonwealth. It further states that the Secretary of the Department for Natural Resources and Environmental Protection may establish different inspection intervals, thereby permitting more frequent inspection of dams which are important due to their function and/or hazard classification.

The hazard classification is determined, in part, by consideration “given to the damage, which might occur to existing and future developments downstream resulting from a sudden breach of the earth embankment and the structures, themselves.” Until recently, the hazard classification has been based exclusively on the judgement of the engineer. In many instances, this has been entirely adequate. Many dams are obviously high hazard structures and designs have conformed to the appropriate criteria. Although future developments must be anticipated in assigning the hazard classification, actual developments may cause the hazard classification to change after construction. Any owner must recognize this possibility and his resulting liability.

Problems of design have not generally been encountered on high hazard dams built since 1967. The primary problems are being experienced on dams, which were initially low or significant hazard structures or built prior to 1967. Recent inspections are indicating that some of these dams are now high hazard structures. As such, many are deficient when compared to the minimum design criteria of the Commonwealth.

In order to better assess the hazard potential of a dam in a systematic and equitable manner, one may employ an analytical approach termed a dam breach analysis. The dam breach analysis has two primary goals. The first goal is to provide information to the engineer about the appropriate hazard classification for the dam. The hazard classification dictates minimum design criteria for either new dams or dams which are being modified or restored.

The second goal is to identify areas which would possibly be affected should a failure occur. Applications of the analysis for this purpose are envisioned primarily on existing dams with identified deficiencies. Many dams perform necessary function, such as impounding water supply reservoirs, and hazardous conditions cannot readily be corrected. The identification of possible affected areas should allow for the development and implementation of emergency preparedness and evacuation plans. Such plans coupled with frequent inspection and conscientious maintenance work could minimize the loss of life resulting from a failure.

Many types of dam breach models exist. The objective of each is to model a simulated failure of a dam. Some procedures can readily be preformed by hand, while others require computers. In general, the hand worked methods are simplified and more conservative versions of the more rigorous mathematical solutions.

A realistic estimate of the outflow hydrograph from a breached dam which is routed downstream to delineate affected areas is the objective of a dam breach analysis. The outflow hydrograph development will, of course, be affected by numerous items. The height of the dam, impounded volume, type of dam, strength of materials, quality of construction, and other physical parameters will all have an effect on any failure analysis. Engineering judgement plays a large part in quantifying the parameters used and assessing their importance in an analysis.

The use of a dam breach analysis is expected to expand significantly. Public awareness with respect to dams and the consequences of failures has been highlighted by periodic failures. The growth of population areas downstream of dams requires an analytical tool to protect the public's safety and welfare. Some states are now requiring this analysis as a routine part of design and inspection procedures.

The purpose of this paper is to set forth in a broad manner and scope, the type of information required to perform a dam break analysis, the suggested range of major parameters, and the types of assumptions inherent in such an analysis.

As an initial step, a definition of the term sudden breach is required. A sudden breach is interpreted to mean a rapid failure, which essentially approximates an instantaneous breach. It is a structural failure in which a portion of the embankment is removed in a relatively short period of time. The cause of this structural failure is not presumed. Since such a breach could occur at any time, the level of the reservoir can significantly affect a dam breach analysis. For the purpose of hazard classification, it is the policy of this division to assume that the reservoir is at the level of the uncontrolled, non-clogging spillway unless other considerations make a lesser (or greater) level of water the more crucial situation. The engineer is expected to determine if other, more critical situations are more applicable for an analysis. In most cases, the reservoir will be assumed at the crest of the emergency spillway and the dam breach analysis will be performed with minimal inflows at the time failure is assumed. (i.e. a non-flood inflow condition).

INFORMATION REQUIRED

1. Dam Geometry
   A. Length
   B. Height
   C. Elevation of Crest of Dam
2. Reservoir Characteristics
   A. Length of Reservoir
   B. Storage-Stage Relationship
   C. Elevation-Crest of Spillway
3. Downstream Area
   A. Cross-Sections at:
      1.Points of Interest
      2.Major Obstructions
      3.Changes in Direction
      4.Changes in Channel (floodplain) Configuration
   B. Manning in Estimates
   C. Distances Between Sections

ESTIMATED RANGE OF MAJOR PARAMETERS

While much of the information required to perform a dam breach analysis is simply a measurement of physical parameters, the analysis requires that parameters, which have major effects on the outflow hydrograph, be estimated. These major parameters include the width of the breach, the side slope of the breach and the time required for the breach to form. The estimated values presented in Table 1were estimated by Dr. Danny L. Fread of the National Weather Service's Hydrologic Research Laboratory for use in dam break analysis.

As a means of determining the validity and reliability of the breach analysis a method of comparing the peak flow from the breach analysis with expected outflows in needed. Figure 1 depicts three methods, which relate the outflow peak to the height of the dam. Th results from a dam breach analysis should be compared to this figure as a method for ascertaining the correctness of the assumptions in the breach width, side slopes, and time to fully form the breach.

The peak outflow is obviously influenced by many considerations other than the height of the dam; nevertheless, the information contained in Figure 1 has been substantiated by observed flows during failures of record.

The calculated peak outflow should be reasonably close to values depicted on Figure 1. Otherwise, the parameters should be adjusted to render a more reasonable peak value of outflow, or the engineer should check his assumption and parameters closely to justify his selection.

FIGURE

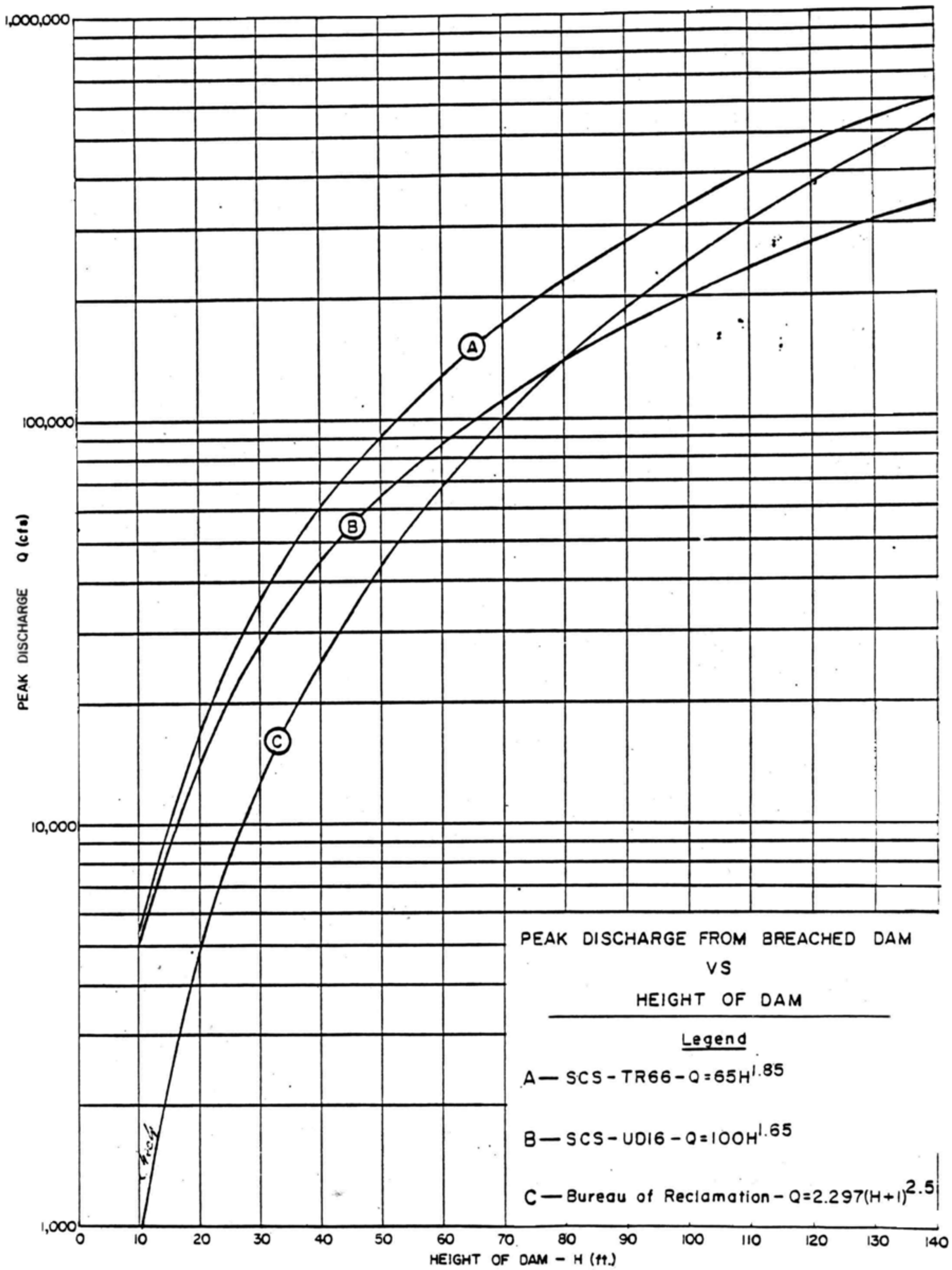
1,000,000
100,000
10,000
1,000
PEAK DISCHARGE Q (cfs)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
HEIGHT OF DAM – H (ft.)
A
B
C
PEAK DISCHARGE FROM BREACHED DAM
VS
HEIGHT OF DAM
Legend
A — SCS - TR66 - Q = 65H^1.85
B — SCS - UD16 - Q = 100H^1.65
C — Bureau of Reclamation - Q = 2.297(H+1)^2.5

TABLE 1

ESTIMATION OF BREACH PARAMETERS

Parameter	Value	Type of Dam
Average width of Breach	HD/2 ≤ BB ≤ 3HD	Earthen, Rockfill
	BB = 0.8 x Crest Length	Slag, Refuse
	BB = Crest Length	Concrete, Arch
	BB = Width of 1 or more Construction Joints	Masonry, Gravity
Side Slope of Breach (Z)	0 ≤ Z ≤ 2	ALL
	Z=0	Masonry, Gravity
	1/4 ≤ Z ≤ 2	Earthen (Engineered, Compacted)
	1 ≤ Z ≤ 2	Slag, Refuse (Non-Engineered)
Time to Failure (TFH) (In Hours)	0.1 ≤ TFH ≤ 3	ALL
	0.1 ≤ TFH ≤ 0.3	Masonry, Concrete
	0.3 ≤ TFH ≤ 3.0	Earthen (Engineered, Compacted)
	0.1 ≤ TFH ≤ 0.5	Earthen (Non-Engineered, Poor Construction)
	0.1 ≤ TFH ≤ 0.3	Slag, Refuse

Definition:

Assumptions (General)

Pursuant to the hazard classification criteria set forth in Engineering Memorandum 5, a sudden failure of the dam must be assumed in determining the proper minimum design criteria. The assumed breach, which results in the failure being analyzed, includes many parameters, which require a significant degree of engineering judgement and expertise. Estimated ranges of parameters are presented herein.

No attempt will be made to detail specific assumptions on the hydraulic computations. Various methods have been developed by many federal agencies including the National Weather Service, the Soil Conservation Service, TVA and the Corps of Engineers. The use of dam breach analysis has been expanded greatly in recent years, both in terms of capabilities and reliability. The methodology is developed to a point where applications can efficiently and consistently be performed. Regardless of the modeling method employed, the engineer must be aware of and comfortable with the hydraulic assumptions necessary in that method.

The basic assumption is that a failure and the resulting flood wave can reasonably be modeled using analytical techniques. Existing computer models have been used to recreate actual failures with a close representation to observed crests. However, unrealistic results can be obtained without a careful analysis. The judgement and expertise of the engineer plays an important role in the interpretation of the results.

The welfare and safety of the public requires that efforts be continued to identify and correct hazardous dams. A dam breach analysis provides a tool to adequately and objectively assess the hazard classifications. Such an analysis can reasonably predict affected areas and possibly lead to the development of emergency warning and evacuation plans and their implementation in the event of a failure.