THE VARIABILITY OF FLOODWAY ENCROACHMENT DETERMINATION

J. F. Harp
The University of Oklahoma
Norman, Oklahoma

R. J. Hayes
Hydrologic Engineering Center

Introduction

Designated floodways may be determined by any of several methods. This paper will treat the designated floodways as they can be determined from Corps of Engineers computer program HEC-2, Water Surface Profiles. This program is very powerful, well documented, and supported, which exemplifies why it is probably the most widely used backwater program in the world. Other commonly used computer methods are deemed to be similar to at least one of the several encroachment algorithms programmed into HEC-2.

The purpose of this paper is to elucidate the variability of designated floodways that might be determined by different investigators. The aspects of the nonuniqueness of designated floodways must be critically addressed since property values, land use, and municipal building permits are affected by the exact delineation of the left and right encroachment stations, which define the designated floodway.

Methods of Floodway Determination

The Hydrologic Engineering Center (HEC) has developed six different methods for establishing floodway encroachment stations using HEC-2. These may be briefly summaried below as:

METHOD ONE: An encroachment procedure which allows the program user to specify directly the desired encroachment stations (left and right). With this method, HEC-2 will determine the water surface elevation and other hydraulic data with the given fixed encroachment stations.

METHOD TWO: This procedure utilizes a fixed top width of encroachment whereby the left and right encroachments are made equidistant from the channel centerline, which is delineated by the left and right overbank stations. This method is useful to simulate the hydraulic effect of ordinances which provide a uniform flow easement centered on the stream.

METHOD THREE: This algorithm provides for a specified reduction (in percent) in the natural conveyance which is to be removed from the overbank areas. Normally, half of the specified conveyance reduction is eliminated from each side of the cross-section. There is also provision to reduce the conveyance in proportion to the distribution of the natural conveyance which occurs on each overbank. With this method HEC-2 determines encroachment stations as well as the resultant hydraulic properties of the floodway.

METHOD FOUR: This method computes encroachment stations so that the conveyance within the encroached cross-section (at a higher elevation) is equal to the conveyance of the unencroached (natural) cross-section (for the same discharge) at the natural water level. The encroachment stations are determined so that an equal or proportional loss of conveyance occurs on each overbank. A desired rise in the water surface elevation is specified, in this method.

METHOD FIVE: This method has the same goals as method four (i.e., determine encroachment stations given a target rise in the water surface elevation) except that a different algorithm is used. Method five uses the percentage reduction in conveyance as an objective function, which is optimized to determine encroachment stations. Equal or proportional conveyance reduction may also be specified.

METHOD SIX: The procedure is much like method five except, the energy grade elevation change is the targeted difference which is optimized. Method six was initially developed for applications involving steep streams in which encroachments by methods four and five often resulted in an encroached profile which has elevation lower than the unencroached (natural) profile.

A Critical Review of Each Method

Method one will provide a water surface elevation consistent with the conveyance that will be computed by the encroachment limits that are subjectively provided by input left and right encroachment stations. If a target increment of one unit above the natural water surface is desired, a trial and error procedure is necessary before an elevation difference of that one unit is ever achieved with method one. Actually, it is not likely that an exact targeted difference of any specified precise value is ever feasible even though possible. A better concept is to view any target-difference as a maximum value rather than an exact value that must be achieved. A tolerance, or range of values, would be more logical. Method one does not require that an initial unencroached profile be computed prior to the profile using specified method one encroachment stations. Actually, however, when determining floodway encroachments, an initial run using one of the automatic methods (methods four, five or six) should be made, and must be made if a known targeted water surface increment is to be achieved. It must be remembered, that no targeted increment is actually an objective method one algorithm, but exists only in the mind of the user. Sometimes, method one is the sole procedure which will yield the results at all cross sections that engineering judgement dictates to be reasonable and prudent in light of all the considerations. Method one does not require, nor is it restricted to, encroachment stations exterior to the left and right overbank stations. Most of the other methods (three thru six) are "overbank constrained" as will be seen later in this paper. It is obvious to even casual users of method one that an infinite number of answers are possible. This procedure does not require equal or portional removal of conveyance from either side. In fact, some of the channel itself can be used. However, the spirit of floodway designation is that logic and engineering judgement be applied. Unreservedly, any percentage of the conveyance can be removed from either side. Therefore, selfish, ruthless, or unethical application of method one procedures would favor a landowner on either side of the stream. Also, any changes in the floodway width at one cross-section will cause changes at cross-sections upstream. These changes may be adjusted until the desired result is achieved. Guidelines will be presented later in this paper to provide for this and other situations. Finally, method one can be prudently utilized to provide cessation of encroachment by one of the automatic methods, as may be necessary, or desired.

Method two makes sense in that if a floodway width could be somehow specified, estimated, or even legislated, then each encroachment station would be located at the same distance from the computed streambed centerline, as set up based upon the location of the left and right overbank stations. Method two is not overbank constrained, that is, the encroachment stations could properly be set within the channel itself, as far as the procedure itself is concerned. Thus, no provision is made that all of the channel area is retained as flow area. This method makes use no particular increment in the water surface elevation. In any flood study where an unimproved channel is studied, simply setting the top width seems inconsistent with consideration of the natural conveyance, flow distribution, or associated topographic features which must form a basis for delineating a logical floodway. In an improved channel or prismatic configuration, method two seems most appropriate. Simply setting the floodway at the upper channel overbank stations, even if they are high and dry, is most logical and has been used by the authors with acceptable results to everyone concerned.

Method three is perhaps a logical choice if the user has an estimate of the conveyance reduction percentage that might be appropriate. If the user had properly called for the HEC-2 flow distribution option, then an educated estimate of conveyance reduction and its division between left and right sides could be made. This method is infrequently used by most investigators but could be a valuable tool once experience in its utilization and application is achieved. Method three is one of the automatic methods in that encroachment station are uniquely set by the program.

Method four is perhaps the most widely used and most popular of all of the methods available for floodway encroachment determinations. This is so due to the output which is produced. Even though, a target water surface rise, of say, one foot, or any amount, is called for, experience shows that it will rarely be achieved at precisely that value. This is explained in the basic algorithm assumption that conveyance is a parabolic function of distance between data points in the overbank. This is appropriate as long as depth is constant, but is less exact as depth changes with station distance across the channel segments. Due to this inexactness, several profiles are usually computed with varying targeted water surface increments until the water surface rise computed is the one desired. Sometimes, there is just no solution available that will achieve the target water surface elevation rise at a particular cross-section. In this event default encroachment stations would be set at the overbank stations. Method four is overbank constrained in that the encroachment stations can never be set within the channel. From a practical engineering point of view, this is highly desirable, and is in conformance with the floodway determination guidelines for flood insurance studies of the Federal Emergency Management Agency (FEMA). Thus, when an improved channel has been created, the encroachment stations are logically set at exactly the left and right overbank stations. Informed users of any encroachment techniques will realize, early, that some aspects of floodway designation are logical while others are simply a matter of engineering judgement.

Method four is deemed automatic in that no top width, or specified encroachment stations are specified. Realistically, one might take the best results from several runs using method four, and make a few final runs with method one to really sharpen the results numerically. A criteria for this procedure is set out later in this paper.

Method five has most of the characteristics of method four. It was developed later in the evolution of HEC-2 and is deemed by many to be a better procedure than method four. For riverine corridors where channel geometry is radical and topographically varying, perhaps this procedure is an improvement over method four. Experience will quickly show that sometimes this is so, and sometimes not so in striving for the target water surface elevation increment. Method five, like method four, requires an initialization (natural) profile to establish the natural conveyance prior to the floodway computation profile. Since method five employes an optimization procedure the length of time for computations and hence computer cost can be significantly greater than method four.

Method six operates similar to method five except that the optimization is based upon an incremental rise in the energy grade elevation rather than the water surface itself. The concept is that the energy grade line is a more stable criteria to meet. This might be particularly useful for larger energy gradients in high velocity streams. A natural profile is also required prior to the profile applying method six. Equal or proportional conveyance reduction may be specified for both methods five and six. A judicious application of method six will elucidate the fact that several runs may be required to achieve a targeted increment. Users should be aware that with any of these methods, floodway velocities can increase significantly and water surface profiles may decrease. Decreases in water surface elevation are deemed unacceptable to most governing agencies, but are in fact a possibility in the real world.

General Guidelines for Prudent Establishment of Encroachment Stations

The general guidelines to be followed for establishing floodway encroachment stations which delineate the designated floodway are few in number, but important in scope and concept. A suggested compilation of essential criteria factors might be as follows:

1. That the hydrology and hydraulics be based upon existing conditions.
2. That the discharges be based upon one percent exceedance frequency.
3. That the flood plain will be divided into a central designated floodway and a floodway fringe area on each side of the designated floodway.
4. The designated floodway will pass the flood discharge without causing the water surface to rise by more than one foot (acceptable rise may be less in some states or communities) above the natural water surface elevation.
5. The floodway fringes are assumed filled solid for purposes of hydraulic computation.
6. That there should not be a significant increase in stream velocity.
7. That there should not be unreasonable depths in the floodway fringes.
8. That there should not be undulating top widths.
9. That the floodway should be consistent with local needs.
10. That the results should be consistent with engineering judgement.
11. That in improved channels where the capacity of that channel will carry the one percent exceedance discharge, the encroachment stations can be set at the channel overbanks where they will be high and dry, and meet all agency rules and regulations.

Conclusions

Whenever the natural floodway elevations have been determined by one of the preferred methods, the outer fringe lines can be drawn onto contour maps by those with engineering experience. The designated floodway stations cannot, however, be drawn in by the same procedure because no contour interpolation is possible. To mitigate some of the problems in accurately drawing the floodway onto maps a greater number of cross-section can be used, or engineering judgement be judiciously applied. In radically changing topography, this becomes virtually impossible and some of the above criteria must be applied. Certainly rugged topographic features and constancy of widths should be recognized. At any rate, these designated floodway encroachment stations are often a matter of opinion, and that opinion is hopefully rendered by competent engineers with great experience and good engineering judgement.

References

Federal Emergency Management Agency
1983 FEMA Publication 37, Flood Insurance Study, Guidelines and Specifications for Study Contractors. Washington D.C.

U.S. Army Corps of Engineers
1982 HEC-2 Water Surface Profiles, Users Manual. Hydrologic Engineering Center, Davis, California

NASA/ERL TECHNOLOGY APPLIED TO FLOODPLAIN MANAGEMENT

Susan A. Howard
NASA/NSTL Earth Resources Laboratory

Optimal development of the floodplain requires information based on the integration of land use, topographic, socioeconomic, and hydro- meteorologic data. In most communities these data are stored on hard copy maps, graphs, and charts. The floodplain manager is faced with the complex task of keeping these data up to date, and also with converting these data into usable information. Today I am speaking about a technology for rapidly building and updating a community's floodplain information system.

The technology of which I speak is a product of NASA's Earth Resources Laboratory (ERL) at the National Space Technology Laboratories (NSTL) near Bay St. Louis, Mississippi. Since the early 1970's, ERL has been developing a software technology designed for the analysis of data collected by multispectral scanners flown on board Landsat satellites. The software modules are grouped in a broad package called ELAS, the acronym for Earth Resources Laboratory Applications Software.[1] Satellite scanners are optical-mechanical devices which record the reflection of light energy from the earth's surface, and in doing so, produce an image. Multispectral scanners record data in two or more spectral bands, such as in the visible and infrared.

In support of NASA's scanning system research, ERL builds and tests simulator scanners to fly aboard aircraft. As a result, software designed specifically for integrating aircraft scanner data into a digital data base has been created.

In order to incorporate aircraft data into a digital data base, it must be accurately georeferenced. Because of the difficulties in maintaining an aircraft along a steady and even course, such a georeferencing program has to correct for data errors caused by flightline and altitude deviations. The ELAS module Rubber Sheeting, or RUBS for short, addresses these deviations.

Prior to running the RUBS module, the investigator selects an evenly spaced network of control points. Map coordinates and digital scan line and element coordinates are identified for each control point. RUBS joins these control points into a network of triangles and georeferences within each triangle. Following georeferencing, the individual flightlines are ready for joining into one data plane.

This data plane can be viewed on a cathode ray monitor for land use and land cover analysis. For example, the Southwestern Division of the U.S. Army Corps of Engineers has recently collected 5- and 10-meter resolution aircraft scanner imagery over a number of study areas. The Corps is utilizing this imagery for multi-purpose planning applications, such as flood control, lakeshore management, agricultural crop production, and documenting land use change over time.[2]

For the past two years ERL has investigated equipment which could be used to rapidly digitize map and photographic data. ERL recently obtained an Eikonixscan Model 78/99. This is a laboratory image digitizer which has a push-broom array scanner mounted behind a camera lens. For color scanning, color filters are placed in front of the lens. The array scans 2048 elements per scan line, advancing down the image one scan line at a time. The array configuration precludes skewing of the data, a problem common to video digitizers. By varying the size of the image scanned, the technician can vary the spatial resolution of the resulting data file. For example, if a 1:24,000 scale topographic map were scanned at one setting, the resulting data file would contain 2048 elements for each scan line. If the same topographic map were quartered, with each quarter scanned separately, the resulting data file can be subdivided into 4096 elements per scan line.

The image digitizer will be utilized in four ways. It will be used to digitize aerial photography, which can then be georeferenced with the RUBS module. These photographic data files will be used at ERL as a base for testing the accuracy of multispectral scanner classification software. The image digitizer will also be used to digitize isolines, such as mapped elevation data. Supporting software has been developed to classify these contour lines and to interpolate between these lines. A third use for the data will be to create digital areal imagery such as soil maps. Line-dividing software will blend the outlines which occur on published soil survey maps into the soil data file. A fourth use will be to digitize polygonal data. If, for example, the investigator required outline data, but not the areal data within the polygons, that areal data would be subtracted out.

While ERL is not in the business of mapping the nation's floodplains per se, spinoffs of ERL technology are directly applicable for that purpose. And, as private industry is rapidly developing micro-systems which are affordable at the community level, this spinoff technology will find wide application. The message I want to leave you with is that the technology now exists for building and updating your community's floodplain information system. Land use maps can be rapidly updated and overlaid on Flood Hazard Boundary Maps, contour maps, zoning maps, and socioeconomic maps. These data files can be rapidly integrated to provide such information as the current land use within the 100 year floodplain.

References

NASA Earth Resources Laboratory
1980 ELAS Earth Resources Laboratory Applications Software

Earls, G.
1985 "SWD Applications of Remote Sensing Technology to Resource Management." In Wildlife Resource Notes Information Exchange Bulletin. Washington D.C. U.S. Army Corps of Engineers. March 31.