COMPARATIVE STUDY OF FLOODWAY ANALYSIS
USING WSPRO AND HEC 2

By

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CHAPTER I

INTRODUCTION

A floodplain is defined as the land area that adjoins a river, stream, or watercourse and that has a strong probability of flooding during a high water flow (Bhowmik and Demissie,1982). Because the floodplains of rivers are the most productive lands for agriculture and provide desirable locations for factories and other structures, man generally uses this land to its fullest extent. The possibility of its being flooded is ignored until such a catastrophe occurs. The floodplain, however, is basically a conveyance channel for flood water. The river will occasionally overflow onto its floodplain and destroy the properties in its way.

The need for fast and accurate evaluation of floodway characteristics, at a minimum cost, has become important because of the increased interest in floodplain information reports, floodplain zoning, local protection projects, and the effects of urbanization. It is also important for use in bridge waterway design and in the study of the alternatives for channel improvements.

The main purpose of my research is to develop a comparative study of floodway analysis using a computer modeling technique. I have compared the performance of two computer models in the simulation of river flow.

To make an accurate assessment of what the water surface profile will be during the passage of a flood wave one must have an adequate simulation using available models. Problem solvers are generally reluctant to devote sufficient time for learning how to use the computer model. Extreme care in the preparation of input data is not sufficient to assure reasonable results (Eichert, 1970). Continual use, a good understanding of the procedures adopted in the programs, and a thorough review of intermediate answers are all needed to acquire proficiency in more complicated applications.

The second objective of the study is to evaluate the sensitivity of two models to the main parameters involved in the stream-flow computation including the roughness factor, reach length, backwater effect, channel slope, friction-slope-averaging technique and floodplain geometry. A benchmark test is also performed for model comparison and for hardware performance.

This study was conducted using HEC 2 and WSPRO, computer programs developed to calculate water surface profiles in natural or man-made channels and to consider the backwater effects caused by the presence of various obstructions in the floodplain, such as bridges, culverts, weirs, spur dikes, and relief structures. The main characteristics and special features of each model are compared. Actual field data from three sites in the state of Oklahoma are used for the application and sensitivity analyses.

Computer runs are provided for each application as well as illustrations of floodplain shapes, bridge geometry, and cross-section locations for each model studied.

CHAPTER II

REVIEW OF LITERATURE AND HYDRAULIC BACKGROUND

Almost all open-channel flows are both unsteady (depth varies with time at a point) and non-uniform (depth changes from point to point along the channel). Estimations of the flow rates or water levels at different times and locations in the channel can be obtained by the solution of the complete Saint-Venant equations.

In the computation of flood flow, the water level is important because it will delineate the floodplain and determine the required height and other dimensions of hydraulic structures, such as bridges, culverts, levees, and overflow structures. The computation of velocity is also important because velocity determines the safety of structures, and affects scouring at bridge piers and the eroding of approach and exit sections of the bridge openings.

In the solution of the energy equation for the flood flow a steady uniform flow is considered. The assumption of the steadiness is justified by the fact that at peak flows the discharge hydrograph flattens out and flow approximates steady conditions. Another assumption made in the evaluation of the friction losses is that Manning's equation for uniform flow applies to a gradually varied flow. The uniformity of flow is evaluated by the degree that the water surface profile and the energy gradient are parallel to the streambed. In the computation, the uniform flow can be achieved by dividing channels into shorter reaches that are considered to have reasonably uniform flow between upstream and downstream cross sections.

The computation of a gradually-varied flow-profile has been the subject of intensive study for some time. Attempts have been made to generalize the problem and to try to formulate a concept of how the geometric and physical factors affect the water surface profile in the open channel.

Standard Step Method

The Standard Step Method, presented by Chow (1959) is used to determine the water surface profile by solving the energy equation in a series of sub-reaches. The total energy head at the upstream end of the reach must be equal to the total energy head at the downstream end plus any energy losses that occur along the sub-reach. In the solution of the energy equation the following assumptions are considered:

1. Flow is steady;
2. Flow is at the same regime at both ends of the cross sections (supercritical or subcritical). Flow must be critical at an end that serves as a control point;

3. Slopes are small enough so that normal depth can be approximated vertically;
4. Water surface does not vary across a cross section;
5. All losses presented are adequately evaluated (such as friction losses, transition losses and bridge losses related to weir shape, pier configuration, and pressure flow).

Reach Length

The distance between cross-sections, also known as the reach length,is determined by the hydraulic detail required and the financial resources available (French, 1985). This distance, therefore, is dependent upon the stream size, slope, uniformity of cross-sectional shape and the selected method for friction slope calculation. The reach length can vary from 200 ft for steep mountain streams to 0.5 to 2 miles for large uniform streams with small slopes (Feldman, 1981). A longer reach is always desired because of the high cost and the time required for the surveying needed to determine the hydraulic properties of cross sections.

The type of study being performed also has an impact on reach-length determination. For example, navigation studies, which require information on local conditions during periods of minimum flow, require the shortest reach lengths. Longer reaches may be used if the profile is hydraulic type M_1 and the average friction slope equation is used, or if the profile is type M_2, and a harmonic mean equation is used (Feldman, 1981).

Transition Curves

Transition curves are formed not only in constricted sections of the channel, but also when flow passes from one reach into another that has different characteristics and different heights of normal depth lines.

When the water level is changing in a channel carrying a subcritical flow, effects of these changes propagate back upstream. Various types of backwater curves for gradually varied flow are described by Chow (1959). Of the many possible curves, those for subcritical flows on mild slopes are of the most concern because almost all natural streams carry subcritical flow, with only occasional stretches of supercritical condition.

The M_1 profile occurs when the steady flow in a mildly sloping channel is checked by a downstream control that increases the water-surface profile above its normal depth (Vallentine, 1967).

The M_1 curve could be formed upstream of a dam or constrictions, such as a highway bridge or overflow structure that obstructs the floodplain. It can also be observed in a tributary that is flowing into a flooded main stream. Yet, the M_1 curve is presented in the transition between a mild and a milder slope, or on a mild slope having the roughness factor of Manning's n changed to a high value. The M_2 curve could be formed from a drop structure located downstream, where the water surface drops below the critical depth line and the flow changes from the subcritical to the supercritical regime. This curve type is found also in the transition from a mild to a steeper slope, or in a mild slope that has a high roughness upstream and a low value in the downstream reach.

For both M_1 and M_2 profiles, it is convenient to fix the control section at the downstream end of the reach and to make computations in the upstream direction, because of the subcritical regime of the flow. For a long channel reach away from a control point, these curves would asymptotically approach to the normal depth line upstream. As adjacent subreaches are not identical in channel dimensions, roughness, or bed slope, the normal depth in each subreach is different. A natural water surface profile would be a series of curves that relate to the normal depth in each subreach. However, there is continuity in water surface profiles over the entire length of a stream.

Friction Slope Evaluation

Vallentine (1964) examined factors affecting the shape of the M_1 type profile. Graphs showing the length of non-dimensional M_1 profiles in a rectangular channel provide a guide to the form of the profile and the manner in which it is affected by variations in channel form, roughness, and slope. They can be of use as approximate guidelines for preliminary design purposes, eliminating computations where precise values are not required. Using these findings, Rao and Sridharan (1966) studied the nature of the nondimensional M_1 profiles considering several channel shapes.

Vallentine (1967) demonstrated that a pattern of similarity exists for all M and S type profiles and that the non-dimensional form of these profiles depends on the normal-flow Froud number.

Rao and Sridharan (1971) studied the effect of channel shape, roughness, slope, and Froude number on several types of profiles where profile lengths might be needed for different normal depths and downstream control depths.

Tavener (1973) studied the variation of reach-lengths in the computation of the backwater effect using the standard step method, and compared the accuracy of the use of the hydraulic loss equations with particular types of water surface profiles. The standard of comparison was the profile obtained by dividing the channel into very short sub-reach lengths. This procedure would help minimize the differences between slopes of reach ends and, therefore, differences in the average slope to be used in the computation of the water surface profile.

Tavener showed that a parabola with a vertical axis can be used to represent the hydraulic gradient at the ends of the reach under an M_1 water surface profile. Under an M_2 condition he found that a parabolic curve having a horizontal axis located below the water surface would better fit the shape of the total energy line.

Tavener stated that a significant improvement in accuracy is obtained if one takes into consideration the shape of the vertical profile of the energy line. He also found that the arithmetic mean of the reach-end friction slope was a suitable equation for evaluating the average friction slope under M_1 type profiles. For the M_2 type, he presented a new equation based on the harmonic mean of reach-end friction slopes.

In his study, Tavener tried to define an allowable reach length for backwater computation based on the hydraulic characteristics of the starting section (downstream section for subcritical profile). He pointed out that a maximum reach length should be carefully selected to avoid a difference in the water surface greater than one foot. In order to prevent such a situation an interpolated cross-section should be used.

Reed and Wolfkill (1976) compared seven different energy gradient averaging techniques in direct step computations of gradually varied flow profiles with those determined by numerical quadrature using Simpson's method of short steps. Their study, including profiles type M_1, M_2, M_3, S_1, S_2 and S_3, was more comprehensive than Tavener's.

A graphical representation of the results was produced showing the percent variation of each method in relation to the number of incremental steps. Figures showed all solutions converging to the same value as the number of steps increased. The best method is selected by looking for the one which produces the lowest error for the single step computation of the entire reach.

Reed and Wolfkill's conclusion agrees with Tavener's suggestion to use the arithmetic average of end-section energy slopes for M_1 profiles and others such, as the S_2 profile, having approximately the same shape. For the convex-upward-type profiles such as M_2 and S_1, they confirmed that Tavener's proposed equation of the harmonic mean of the reach-end friction slope produced fewer errors.

Chadderton and Miller (1980), proposed a new friction-slope-averaging equation for the M_2 profile based on the shape of the friction-slope curve. The equation is expressed as:

$$S_f = C_1 S_{f1} + C_2 S_{f2} \tag{1}$$

where S_f is the representative average friction slope for the reach and S_{f1}, S_{f2} are friction slopes at the reach-end cross sections. Coefficients C_1 and C_2 were derived assuming a parabolic and elliptical shape of the friction slope curve. When the restriction of gradually-varied flow is met, the equation gives more accurate results than the recommended harmonic equation.

Laureson (1986) studied the application of four different methods to approximating the average slope in irregular channels; previous investigations had been conducted for a prismatic channel. For an irregular channel, the friction-slope line in a given reach was approximated by a third-degree polynomial, the simplest curve to fit different slopes at the reach ends.

Laureson concluded, as previous authors had for prismatic channels, that the arithmetic mean of reach-end friction-slopes produces the lowest maximum error and that it is the safest and the best single method to be used. He suggested the use of this method and occasionally, the use of the geometric mean with a systematic selection of cross-section location, as being an adequate procedure for minimizing errors in the computation of the water-surface profile.

Carrying Capacity of Floodplain

The carrying capacity of floodplains depends upon many factors including size, shape, width, depth and nature of the flood zone, and the main stream. Bhowmik and Demissie (1982) studied the distribution of flow in the main channel and in the floodplains. They concluded that when the return period is about 40 years or more, the floodplain and the main channel appear to behave as a single unit carrying a proportionate share of the discharge.

Sometimes the estimation of a flood elevation for an anticipated flood flow can be difficult because of different man-made restraints, such as obstructions that increase the flood-stage for a given return-period flow. Data on actual flood-flow are hard to obtain because usually the flood passes at a time when no one is around to measure the discharge and water levels.

To compare the flow in a composite section one can use a number of techniques:

a) Treat the entire cross section as a single unit and assume a single roughness value.

b) Treat the floodplain as a storage reservoir and the main channel as the conveying stream.

c) Divide the floodplain and the main channel into two conveyance channels with uniform hydraulic properties where the roughness can be different.

d) A combination of the above techniques (Chow 1959).

Knight and Demetriou (1983) conducted laboratory experiments on discharge characteristics, the boundary shear stress, and boundary shear-force distribution in a complex cross-section comprising one rectangular main channel and two symmetrically disposed floodplains. This study was an attempt to understand better the many practical situations in which the natural cross-section is irregular in shape as, for example, in a river channel with a wide floodplain. Although the results of the experiments apply to the case of the floodplains having the same roughness of the main channel and being symmetrically disposed, they found that the apparent shear force acting on the vertical interface between the floodplain and main channel is strongly depth dependent. It also increases for situations in which the floodplain width is much larger than the width of the main channel. They also concluded that the ratio of the total discharge in various sub-areas differs from that given by simple area ratios because of the retarding influences of the floodplains.

Standard methods for computing backwater at width constrictions of floodplains usually underestimate backwater values when the floodplain is wide and heavily vegetated (Schneider et al.,1977). The energy-loss term for the approach reach is computed using the average streamline length in the reach. In standard one-dimensional-step backwater procedures, the average streamline is approximated by the length of the approach reach. Thus a more accurate estimate of the average streamline length would improve the calculation of the energy loss in the approach section.

Solution of the Energy Equation

The total energy loss is computed as:

$$H_T = h_f + h_e \qquad (2)$$

where: H_T = total energy loss

h_f = energy loss due to friction of boundaries of flow in the reach

= $S_f \times L$

S_f = representative friction slope for a reach

L = discharge weighted reach length

h_e = eddy losses expressed in terms of change in the velocity head

$= C\ (h_{v1} - h_{v2})$

C = contraction/expansion coefficient

h_{v1}, h_{v2} = velocity head at respective sections.

Four alternative expressions are available for S_f:

a) Average Conveyance Equation

$$Sf_a = \frac{(Q_1 + Q_2)^2}{K_1 + K_2} \qquad (3)$$

b) Average Friction-Slope Equation

$$Sf_b = \frac{(S_{f1} + S_{f2})}{2} \qquad (4)$$

c) Geometric Mean Friction-Slope Equation

$$Sf_c = (S_{f1} \cdot S_{f2})^{1/2} \qquad (5)$$

d) Harmonic Mean Friction Slope Equation

$$Sf_d = \frac{(2\ S_{f1} \cdot S_{f2})}{S_{f1} + S_{f2}} \qquad (6)$$

where: Q_1, Q_2 = flow at the ends of the channel reach

K_1, K_2 = conveyance for cross sections at the ends of the reach

S_{f1}, S_{f2} = Q/K at the respective sections.

It should be noted that:

(i) Since 1971, Equation 3 has been used in the HEC 2 model as the default equation (Corps of Engineers, 1982);

(ii) Equation 4 was used as a default value for HEC 2 prior to 1971, and is suitable for M_1 profiles (Corps of Engineers, 1982);

(iii) Equation 5 is used as the default in the WSPRO model (FHWA, 1986); and

(iv) Equation 6 is suitable for M_2 profiles (Laureson, 1986).

The energy equation for a channel reach shown in Figure 1, can be expressed as:

$$h_1 + h_{v1} = h_2 + h_{v2} + h_f + h_e \tag{7}$$

where: h_1, h_2 = water surface elevation at the upstream and downstream sections above a common datum

h_{v1}, h_{v2} = velocity head at the respective sections = $\alpha V^2/(2g)$

$h_f + h_e$ = total energy loss as defined in Equation 2

The steps in the solution of Equation 7 through subreaches are described below.

1. Select a discharge for which the Water Surface Profile (WSP) is to be determined.
2. Obtain all necessary channel geometry and roughness information in the lateral, longitudinal, and vertical directions. Choose a distance between cross-sections and compute reach-length.
3. Select a value for the Water Surface Elevation (WSE), h_2 at the downstream section (control section) based on a starting condition.
4. Compute cross section values of area, conveyance,

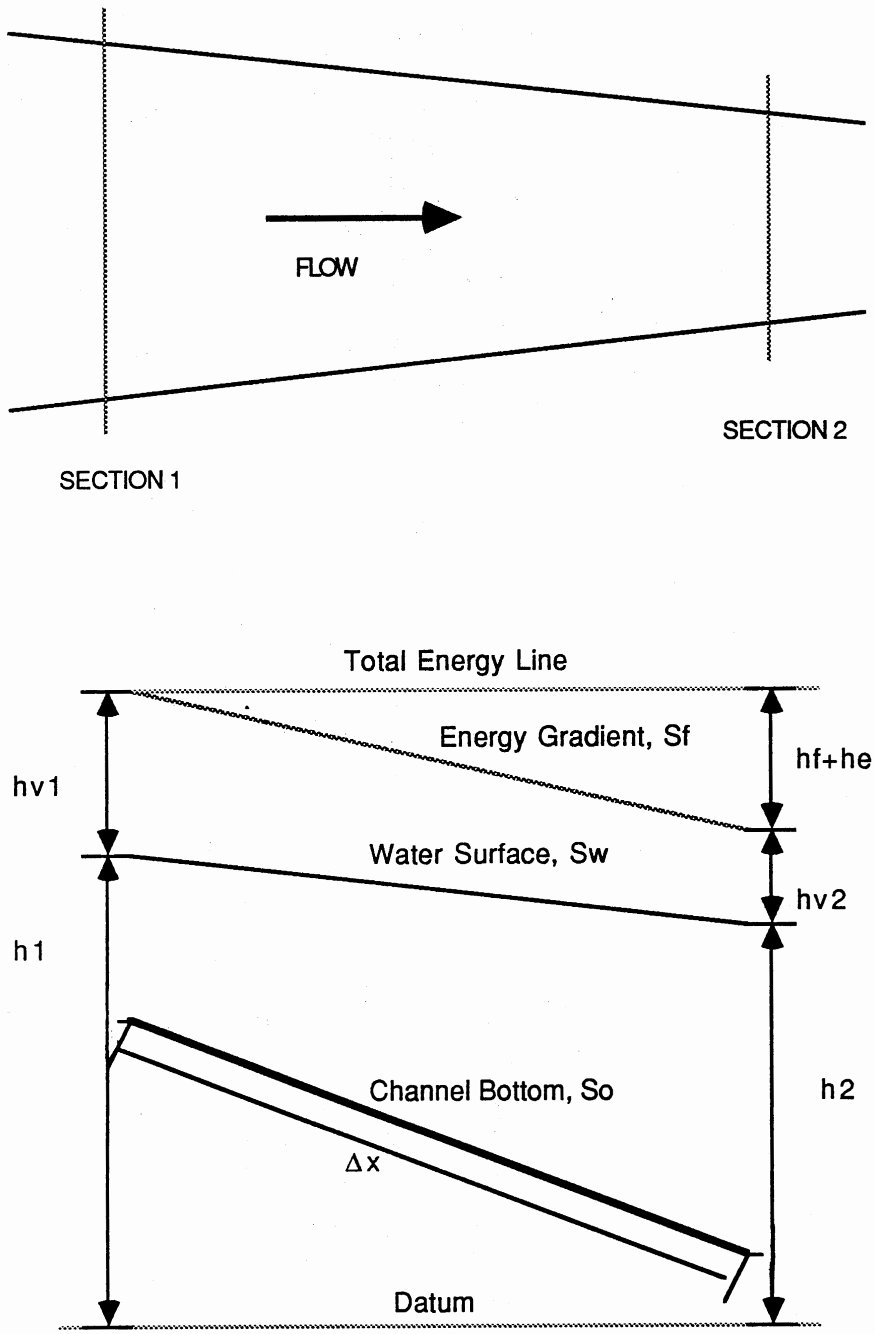


Figure 1. Definition of Terms for the Energy Equation

velocity head, and alpha coefficient at the downstream section for the value of h_2 selected in Step 3.

5. Assume a WSE h_1 for the upstream section.
6. Compute corresponding area, conveyance, velocity head, and alpha values at the upstream section for the value of h_1 assumed in Step 5.
7. Compute energy loss between sections 1 and 2.
8. Solve the energy equation for the reach, equating both sides of Equation 7. If the equation is balanced within an acceptable tolerance, go to Step 11.
9. Choose a new value for h_1.
10. Repeat Steps 5 through 8 until the energy equation is satisfactorily balanced.
11. Select the channel length upstream. The value of h_1 at the upstream end of the first or previous reach is now used as a known value at the downstream end of the new reach.
12. Repeat Steps 4 through 11 for each reach until the WSP of the entire reach has been computed.

Velocity Head Coefficient

Variations in velocity from point to point in a cross section are caused by numerous factors, including the channel roughness, non-uniformities in geometry, bends, and obstructions upstream (Davidian, 1984).

The average velocity head V, in a cross-section is defined as the discharge-weighted mean of the velocityheads in its constituent subsections. The ratio of the true velocity head to the velocity head computed on the basis of the mean velocity is the coefficient alpha (α), computed as:

$$\alpha = \frac{\int Q\ (v^2/2g)\ dQ}{Q\ (V^2/2g)} \tag{8}$$

where v = mean velocity in a subsection

V = mean velocity in a cross section

Q = total discharge

g = acceleration due to gravity.

Considering each of the subdivisions of the cross section having uniform velocity, the distribution of discharge can be represented by the distribution of conveyance. According to Davidian (1984), the equation is reduced to:

$$\alpha = \frac{\Sigma\ (k^3/a^2)}{K^3/A^2} \tag{9}$$

where: k, K = subsection and total conveyances

$k = (1.486/n)\ a\ r^{2/3}$

r = hydraulic radius

a, A = subsection and total flow areas.

Multiple Opening Waterways

Kindsvater and Carter (1955), in a first comprehensive study of flow in channel constrictions, developed the solution of a discharge equation for flow through a single opening. The backwater effect of single-opening constriction in open channels was studied by Tracy and Carter (1955). The backwater was defined as the difference in elevation between the normal and the constricted water-surface profiles at a given approach section. The results of the experiments were presented in the form of a backwater ratio, which expressed the ratio of the backwater to the water-surface drop through the constriction.

Subsequently, Liu, Bradley, and Plate (1957) studied the effect of many variables on the maximum backwater. Laboratory studies were conducted to describe the variation in backwater ratio related to variations in channel slope, channel roughness, Froude number, and contraction shape. They found that both channel shape and roughness can be eliminated as variables if the normal depth and the Froude number of the normal flow are used.

The term, multiple-opening constriction, is associated with a series of independent, single-opening constrictions, each having distinct geometric and hydraulic characteristics. The method for computing backwater, in such a situation, requires the location of pseudo-boundaries in the upstream and downstream sides of the constricted section so that it forms pseudo-channels flowing through each individual opening.

Davidian et al. (1962) conducted laboratory experiments and analyses of flow patterns at constrictions with two to seven openings. A method that considered each opening separately was developed for computing the discharge and predicting the maximum backwater caused by a constriction. It was concluded that the relation developed for the constriction having a single opening is valid for each opening of a multiple-opening constriction when the boundaries of the flow channel approaching each opening are established.

In a wide valley, a large fraction of the flood can be flowing on the floodplain. The embankment of the valley crossing acts as a barrier and the overbank flow must move laterally to the bridge opening, and then back again to the valley. Laursen (1970) studied the bridge backwater in wide valleys with the river reach near the constricted valley divided into four zones: accretion, contraction, expansion, and abstraction. He analyzed the flow pattern in these regions and the interaction of flow between the main channel and the floodplain.

Lee (1976) collected field data in single and multiple bridge openings to check the method of distribution described by Davidian et al. (1962). He found that the difference between the computed discharge and the measured discharge ranged between -20 and +6 percent for the two major sites studied. For the third site an error of +100 percent was observed at one opening and that might be attributed to an incorrect location of the stagnation points at the approach section. The technique of determining the individual channel widths, their match sections, and the way to apportion the total flow through each opening is well described by Davidian et al. (1984).

The flow boundaries are located in direct proportion to the gross-flow areas of the openings on either sides of the embankment. The areas are computed on the basis of the depths corresponding to the water surface elevation at the downstream side of the embankment for the full-valley cross-section. The flow boundaries are then projected upstream and downstream of the embankments and they provide an adequate means of dividing the constriction into independent single-opening units.

CHAPTER III

DESCRIPTION OF THE MODELS

Two computer programs were selected for the present study: HEC 2 and WSPRO. Micro-computer versions of the above models were used because they are generally the choice in the majority of government and private agencies.

HEC 2 Model

The HEC 2 computer program was developed by the Hydrologic Engineering Center to compute water surface elevations for specific discharges in natural or man-made channels to aid the U.S. Army Corps of Engineers in the floodplain-management program (Feldman, 1981). The model uses the standard step method in the solution of the one dimensional energy equation with the energy loss due to friction evaluated by Manning's equation.

The main application of HEC 2 has been in:

a) determining inundated areas associated with various flood discharges for the assessment of damages;

b) studying the effects of land use in the floodplain;

c) comparing the benefits of various channel improvements in attenuating flood damages (French,1985).

Program Limitations

The program is limited by the strictures of the standard step method discussed in Chapter II (pp. 5), and the following:

1. Flow is steady (constant in time);
2. Flow is gradually varied (hydrostatic distribution of pressure exists);
3. Flow is one-dimensional (velocity component only in the direction of the flow);
4. River channel has small slope ($So < 10$ %) (Corps of Engineers, 1982);
5. HEC 2 does not have the capability to determine the location of the hydraulic jump;
6. HEC 2 cannot handle multiple bridge openings;
7. HEC 2 cannot deal with movable boundaries (i.e. sediment transport);
8. Variations of Manning's n with water depth is applicable to the main channel only.

Optional Capabilities

Some of the capabilities available to the user are listed below:

1. Can handle English or metric units;
2. Can perform multiple profile analysis (up to 14);
3. Can calculate both subcritical and supercritical flow profiles;

4. Can consider the effects of obstructions such as bridges, culverts, weirs, and structures present in the floodplain;
5. Can select output parameters;
6. Can estimate average friction slope for a reach using one of four equations selected by the user;
7. Can select an average friction-slope equation based on profile type and previous reach characteristics;
8. Can handle ice-covered streams;
9. Can compute bridge backwater at cross-sections located by channel constrictions rather than bridge openings.

WSPRO Model

The Water Surface Profile model (WSPRO) was developed by the U.S. Geological Survey (USGS) for the Federal Highway Administration (FHWA). The program is based on the conventional step standard method. Reflecting the policy of the FHWA, WSPRO is designed for determining the impact of encroachment alternatives on the floodplain. It is equally suitable for water-surface-profile computations without regard to highway design (B.W.A.M., User's Manual, 1986).

The objectives of WSPRO are as follows:

1. Compatibility with conventional techniques for step-backwater analysis and incorporation of desirable features from existing methods;
2. A more flexible data-input scheme, adequate for studying

alternative design options with minimal data changes;

3. Use of recent developments and methodology for computation of flow through bridges and embankments;
4. Inclusion of a procedure for analyzing a multiple-opening waterway crossing (Tyagi et al., 1988).

Main Features

Basically, with a few exceptions, WSPRO has the same limitations listed for the HEC 2 program. The computation direction is the same as that used by HEC 2, upstream for subcritical flow and downstream for supercritical flow. Some of the capabilities of the model are:

1. Has most of the input data in free format;
2. Uses card types similar to those of HEC 2;
3. Uses template cross-section to fabricate valley sections that are similar in shape;
4. Initializes coefficients with adequate default values;
5. Performs multiple profile analysis (up to 20 profiles);
6. Handles up to 100 cross sections in a single job;
7. Permits building of spur dikes in the model;
8. Defines road grades by either horizontal coordinate or vertical curve data;
9. Permits analysis of several alternative designs in a single job submission;
10. Uses the average length of the approximate streamlines to compute friction losses immediately upstream from the bridge opening;

11. Has four equations available for estimation of friction slope;
12. Uses the geometric mean slope equation as a default for the computation of the average friction slope.

WSPRO has a simple and objective instruction process involving three parts: (a) an overview of the overall input data requirements regardless of data arrangement; (b) discussion of the typical data sequence without detailed discussion of each parameter; and (c) an overview of the model output.

Comparison of the Models

The comparative study showed that the results obtained by both models agreed in the majority of the situations and that each model has particular features.

The main advantages observed in HEC 2 are listed below.

1. Effective flow option (confine flow to main channel only);
2. Six methods of encroachment;
3. Automatic performance of channel improvements;
4. Interpolation of cross sections capability;
5. Computation of tributary stream profiles;
6. Estimations of roughness coefficient by discharge elevation data;
7. Global variation of roughness factor making calibration procedures easier;
8. More detailed output (up to 90 variables can be listed per cross-section);

The main improvements of WSPRO are listed below.

1. Handles multiple waterway openings;
2. Minimizes the code of repetitive data;
3. Skews angle for cross-sections that are not surveyed normal to the flow direction;
4. Has a bridge modeling approach with a more realistic situation (no need of approximation to a trapezoidal area);
5. Has two methods for modeling the bridge: design mode and fixed geometry mode;
6. Uses an effective flow length from the approach section to the bridge section, considering the average stream lines;
7. Permits selection of the minimum conveyance as a representative conveyance for the subreaches in the vicinities of the bridge-opening section;
8. Can use vertical and horizontal variations of the roughness coefficient simultaneously;
9. Computes the friction losses in the vicinity of the bridge based on relatively recent developments in bridge backwater analysis, and recognizes the influence of bridge geometry variations;
10. Computes natural profile first making the evaluation of the total backwater easier;
11. Produces computations that help trace intermediate program iterations;

Although not a two-dimensional model, WSPRO's major improvement is an efficient algorithm to analyze sections with multiple waterway openings; such sections are commonly found in wide floodplains. An iterative procedure is used to apportion the flow among the individual openings and to compute a water surface profile for each individual opening. The valley is divided into strips on the basis of stagnation points that are computed from the relative flow areas of adjacent openings. The discharge is apportioned on the basis of the flow area of the openings and conveyance of the floodplain.

The WSPRO program includes the latest hydraulic researches in the computation of the head losses in the vicinities of the bridge and other special structures, considering also the geometry of the opening. WSPRO models the bridge in a simpler way than HEC 2 does and it is easy to learn and simple to use, which are important features always sought by users. Conversely, the Corps program has been widely used and one of its advantages is the capability to automatically interpolate cross-sections when limitations of change in the total conveyance are imposed. HEC 2 also has six options for channel encroachments and performs channel improvements automatically.

CHAPTER IV

APPLICATION

The application of HEC 2 and WSPRO in the computation of the water surface profile for three sites in the State of Oklahoma is presented in this chapter. An attempt was made to select different sites with representative flood plain characteristics and stream sizes. The sites, named Site 1, Site 2, and Site 3, represent examples of a small, medium, and large stream and floodplain problems.

The first objective is to illustrate the application of the models in the real case simulation, exemplify the preparation of the input deck, and present the output of results. A second objective is to obtain results from both models and compare the results of the sensitivity analysis as described in Chapter V. Computer configurations used to run the simulations are described in the Benchmark Tests in Chapter VI.

Twin Spring Creek in Alfalfa County is the first site under study. The Industrial Bypass of Posey Creek in Tulsa County was selected as Site 2. Site 3 is located in the Caney River at the intersection of US-75, south of Bartlesville in Washington County. Geographical location of the sites is presented in Figure 2.

Figure 2. Site Locations in the State

Site 1 - Twin Spring Creek

Site 1 in Alfalfa County is referred as No. 16 by the Oklahoma Department of Transportation. It is an example of a small floodplain having a single bridge opening. For this site, simulations were performed for the 10, 25, 50 and 100 years flood. Flow discharges for those recurrence intervals include 850, 1300, 1650, and 2100 cubic feet per second respectively. The slope of the river bed in the vicinity of the bridge is 4.6 feet per mile which is considered an average for mild slopes in the state of Oklahoma.

A particular surveyed cross-section located at a Section Reference Distance (SRD) equal to zero was used to prepare the input deck. The valley was divided into seven strips and appropriate roughness coefficients given by Manning's n were assigned to each of them in an attempt to represent the friction factor as closely as possible to reality. The surveyed cross-section was propagated upstream at SRD equal to 45 ft to model the Full Valley Section, and at SRD equal to 127 ft to delineate the Approach Section. Station elevations were corrected in the propagation to reflect the actual slope of the site.

A single opening bridge 45 ft long and 27 ft wide is presented. The bridge deck is at 1258 ft and the low chord elevation is at 1254.5 ft above mean sea level. The bridge has sloped embankments and sloped abutments without wingwalls. A road grade was coded to allow computations of weir flow in case of overtopping of the bridge deck.

Floodplain shapes at Exit and Bridge Sections can be seen in Figures 3 and 4. Model requirements for the location of cross sections for backwater computations are presented in Figure 5. Figure 6 shows the required parameters for the bridge modeling. Computer runs from HEC 2 and WSPRO can be found in Appendices A and B.

Water surface elevations obtained from the simulations by both methods are summarized in Table 1. The maximum difference in the WSE computed by HEC 2 and WSPRO is 0.25 ft, for the Q_{100} flow discharge, corresponding to 2.7 percent of the water depth.

Site 2 - Posey Creek

The Industrial Bypass of Posey Creek is used in the application of the models to illustrate a medium-size site. Characteristics of floodplain shape, flow discharges, cross-section locations, roughness factor, starting conditions and bridge geometry are described below.

The floodplain geometry is an example of a uniform concave shape with the main stream appearing in the center. The constricted section has a single bridge opening. The slope of the river bed near the bridge site is 0.005427 ft/ft or 28.6 ft/mi, characterizing a steep slope. Floodplain shapes are shown in Figures 7 and 8.

The flow discharge of interest for this site is a 100-

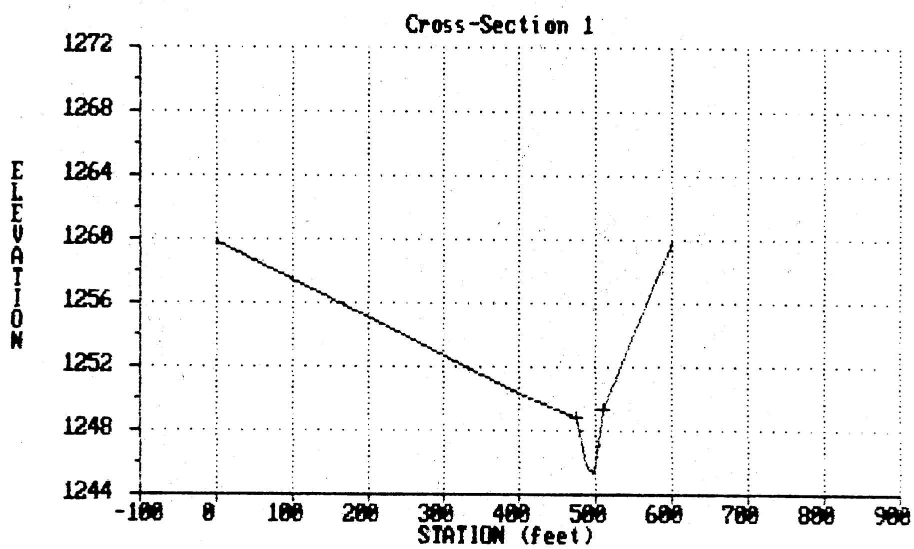


Figure 3. Exit Section - Site 1

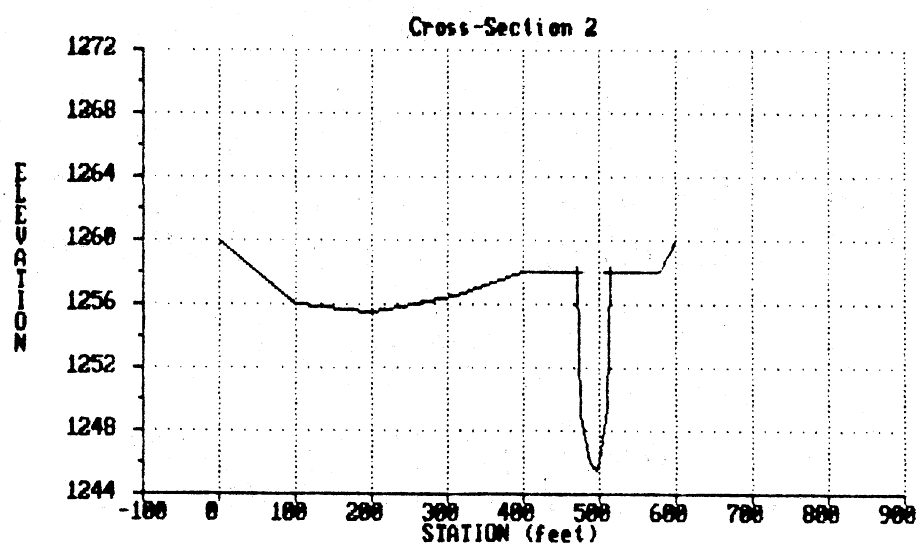
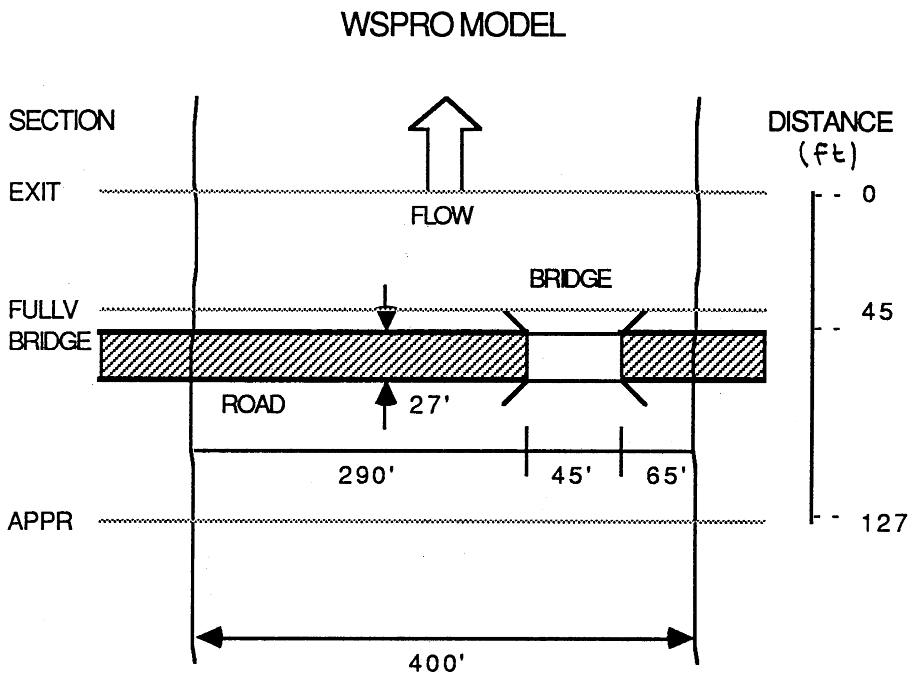


Figure 4. Bridge Section - Site 1



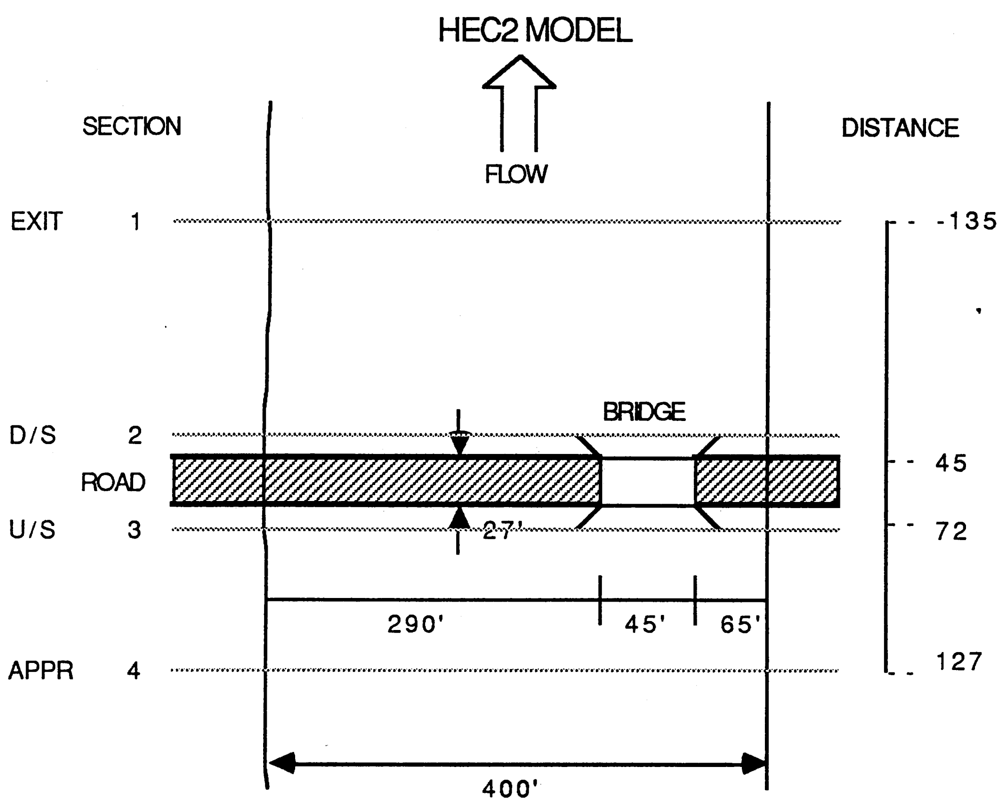


Figure 5. Cross Section Locations - Site 1

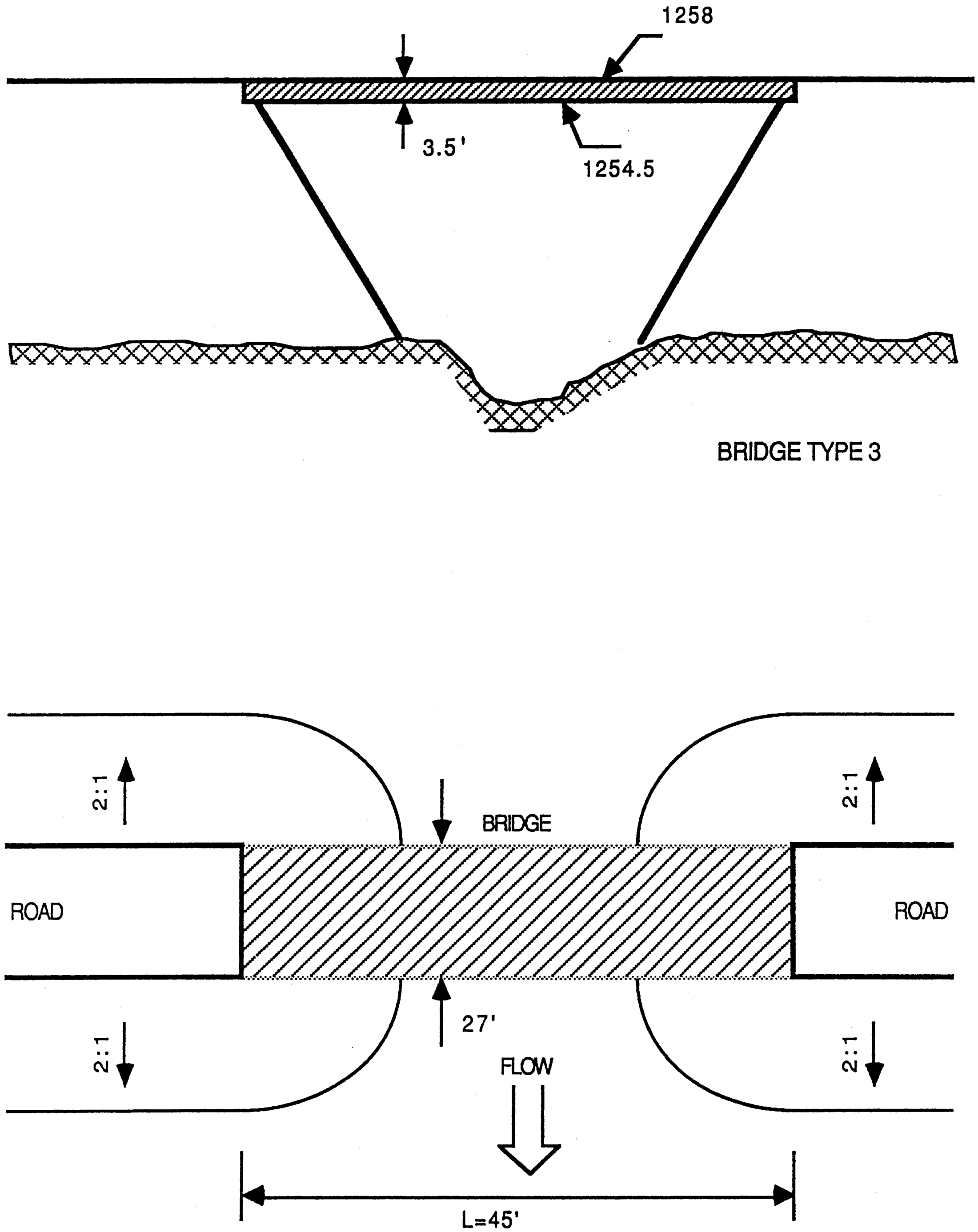


Figure 6. Bridge Modeling - Site 1

TABLE 1

WATER SURFACE ELEVATIONS FOR SITE 1

SECTION	SRD (ft)	WSE WSPRO (ft)	WSE HEC 2 (ft)
..Q_{10} = 850 cfs..			
Exit*	-135		1252.39
Exit**	0	1252.50	
Bridge	45	1252.44	1252.53
Approach	127	1252.83	1252.88
..Q_{25} = 1300 cfs..			
Exit*	-135		1253.32
Exit**	0	1253.45	
Bridge	45	1253.32	1253.41
Approach	127	1254.02	1253.99
..Q_{50}= 1650 cfs..			
Exit*	-135		1253.93
Exit**	0	1254.05	
Bridge	45	1253.86	1253.95
Approach	127	1254.82	1254.72
..Q_{100}=2100 cfs..			
Exit*	-135		1254.58
Exit**	0	1254.70	
Bridge	45	1254.50	1254.51
Approach	127	1255.88	1255.63

* Exit section for HEC 2

** Exit section for WSPRO

year recurrence interval flood with the magnitude of 10,900 cubic feet per second. For WSPRO simulations, cross sections representing Exit, Full Valley and the Approach sections were located at section-reference-distances 0, 100, and 651 ft, respectively. For the HEC 2 run the exit section was located at SRD equal to -50 ft and the approach section at SRD equal to 505 ft to meet the model requirements. Values of the W.S.E. computed were propagated to the same location upstream for comparison purposes. Cross-section locations for both models are shown in Figure 9.

The valley was divided into three strips: main channel, the right, and left overbanks. A roughness coefficient was assigned to each division. The slope-conveyance method was selected for computing the initial elevation of the water surface at the Exit Section. The slope of the energy grade line was estimated to be the same as that of the river bed.

A single bridge opening, 551 ft long exists at this site. The total width is 32 ft and it has slope embankment and vertical abutments without wing walls. The bridge deck is at elevation 623.45 ft and the low chord is at 619.70 ft. Values of 0.5 and 0.3 were used as expansion and contraction coefficients for the computation of transition losses near the bridge. Figure 10 illustrates the bridge parameters. The road grade was coded to permit computation of weir-flow when the water-surface elevation is higher than the embankment elevation.

Computer printouts for HEC 2 and WSPRO runs are

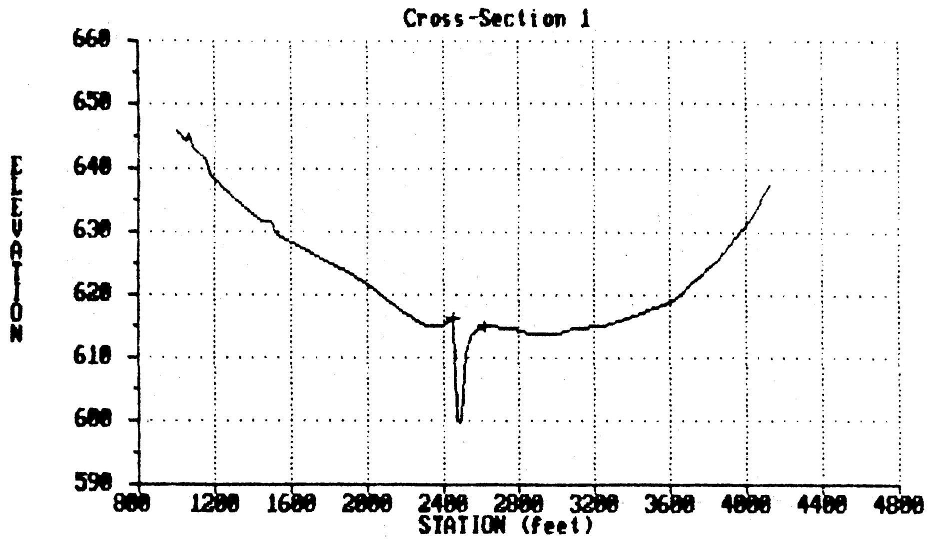


Figure 7. Exit Section - Site 2

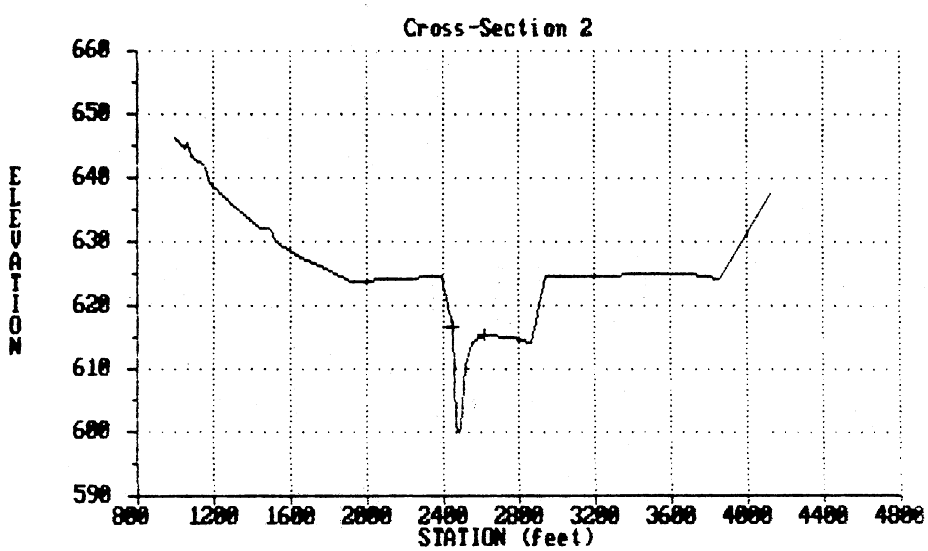
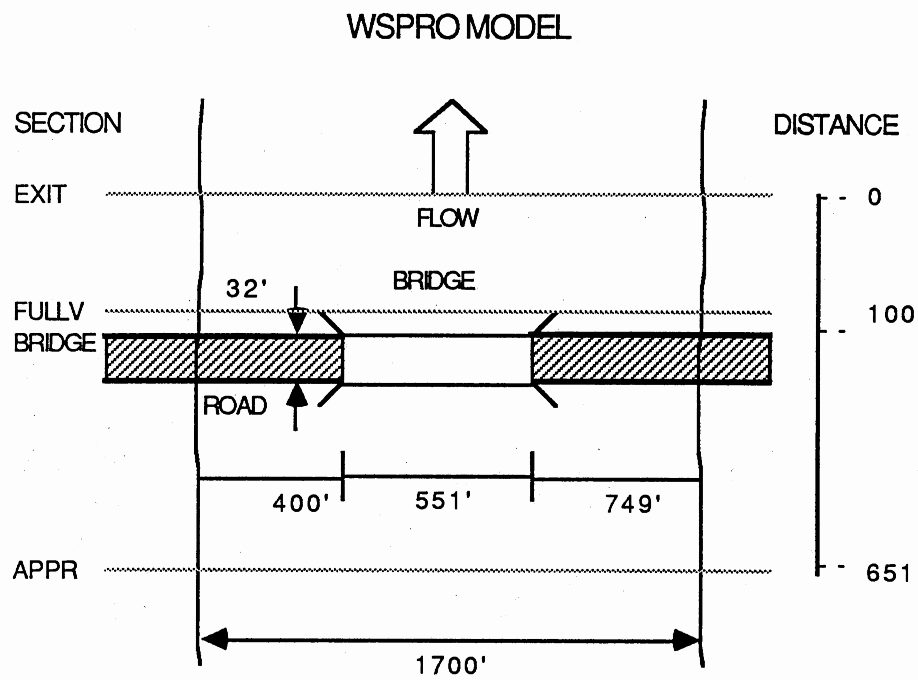


Figure 8. Bridge Section - Site 2



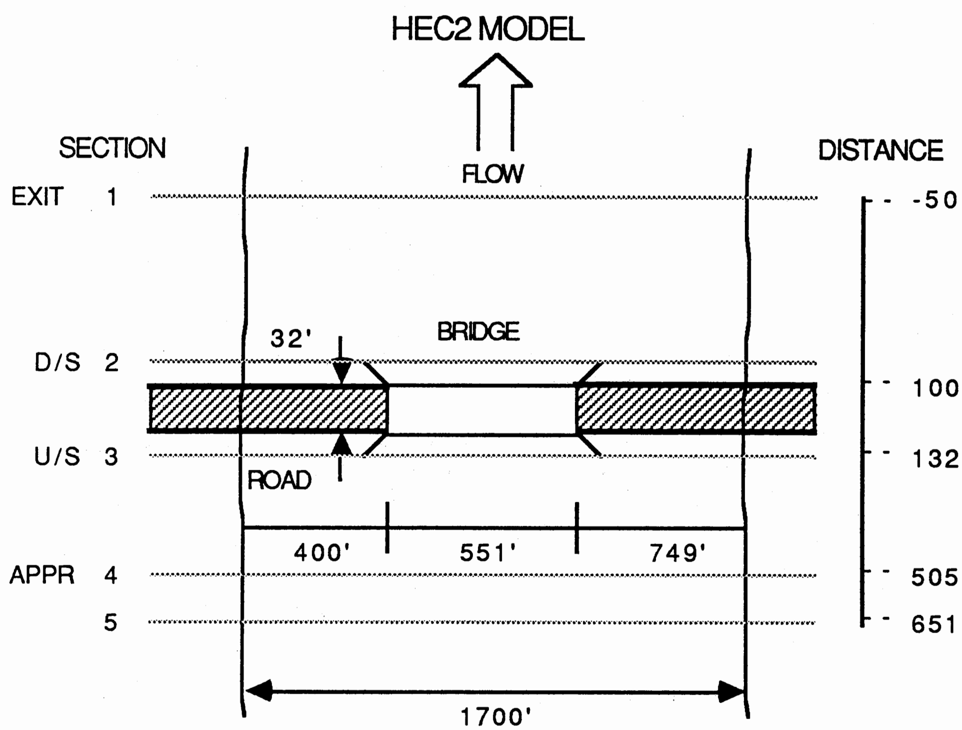


Figure 9. Cross Section Locations - Site 2

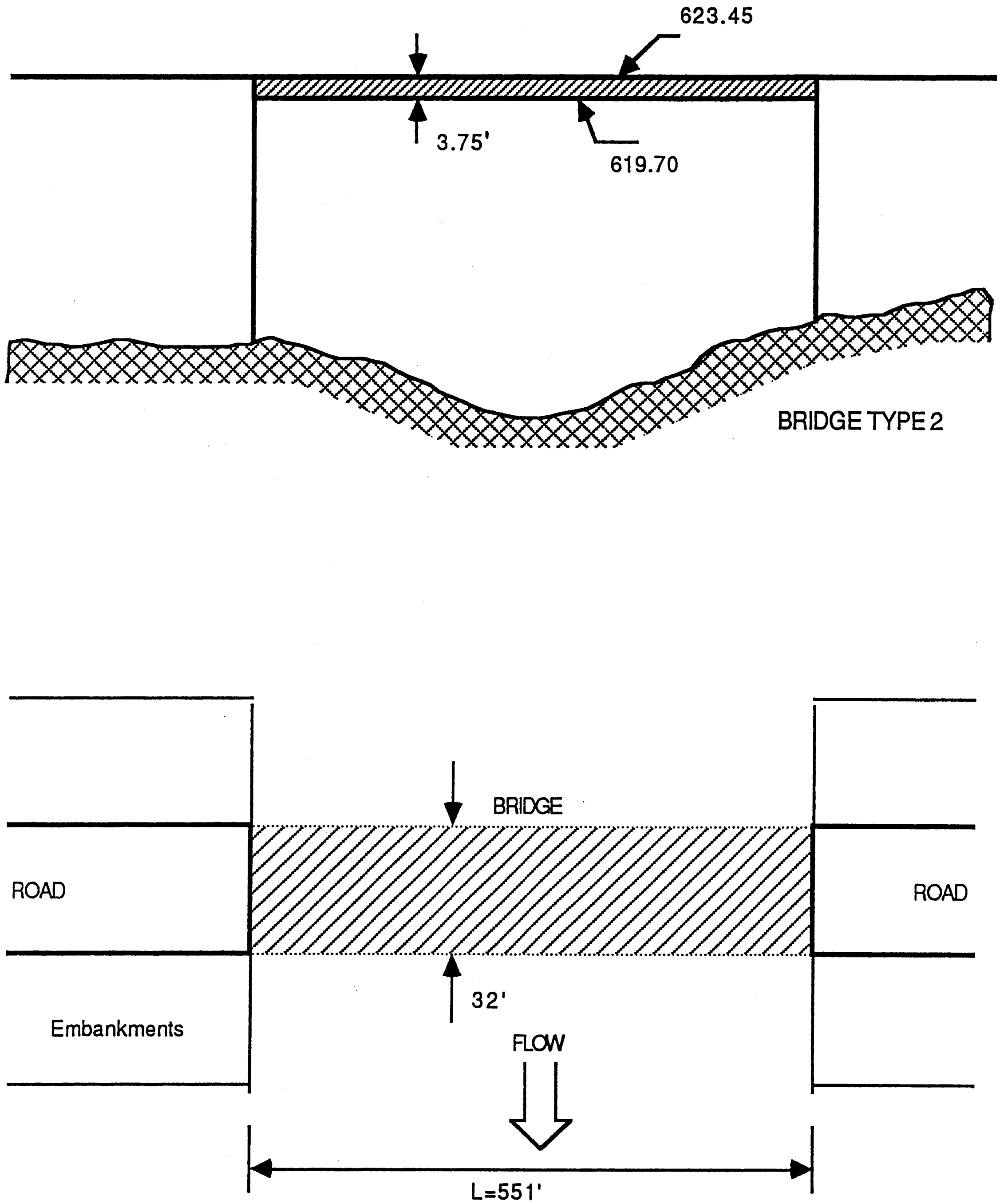


Figure 10. Bridge Modeling - Site 2

presented in Appendices A and B. Results obtained by both models are compared in Table 2. Computed values of the WSE for the approach section are 620.49 ft. from the WSPRO simulation and 620.60 ft from the HEC 2 simulation. The difference of 0.11 ft represents less than 1% of the water depth.

TABLE 2

WATER SURFACE ELEVATIONS FOR SITE 2

SECTION	SRD (ft)	WSE WSPRO (ft)	WSE HEC 2 (ft)
..Q_{100} = 10900 cfs..			
Exit*	-50		616.38
Exit**	0	616.69	
Bridge	100	616.96	617.12
Approach	651	620.49	620.60

* Exit section for HEC 2
** Exit section for WSPRO

Site 3 - Caney River

The US-75 highway crossing of Caney River, south of Bartlesville, was selected to represent a wide floodplain site with a high peak discharge. The constricted section has three waterway openings: Main Bridge, Overflow Structure 1 (OF1), and Overflow Structure 2 (OF2). This site was the locus of a 500-year flood in October, 1986, that caused extensive flooding of Bartlesville.

In this application I was particularly interested in evaluating the amount of backwater caused at the approach section by the constricted valley. The total backwater will be determined by subtracting the value of the WSE for the natural profile from that of the WSE for the bridge option. An extensive study of the 1986 flood in this particular site is presented by Tyagi (1988).

The valley is two miles wide and the main stream is located in the left corner, looking upstream. A small dike was built by the owner of the land to retain the flow in the main channel during small floods. The overbank flow will occur only in the right side of the floodplain. Figures 11 and 12 show cross-section shapes.

According to WSPRO recommendations for the bridge backwater computation, cross sections were located one bridge length downstream, at the bridge site, and one bridge length upstream to model as the Exit, Full Valley, and Approach sections. The slope of the river bed is equal to 0.0004 ft/ft or 2 ft/mi in the vicinity of the bridge. For the HEC 2 program, the locations of the cross-sections were based on the side constriction of the main channel. Figure 13 shows cross-section locations for both models.

Flow discharges to be analyzed represent the 50-, 100- and 500-year frequency in the Caney River. They correspond to 42,800, 51,400 and 108,000 cfs, respectively. The entire floodplain was divided into the main channel, and the left

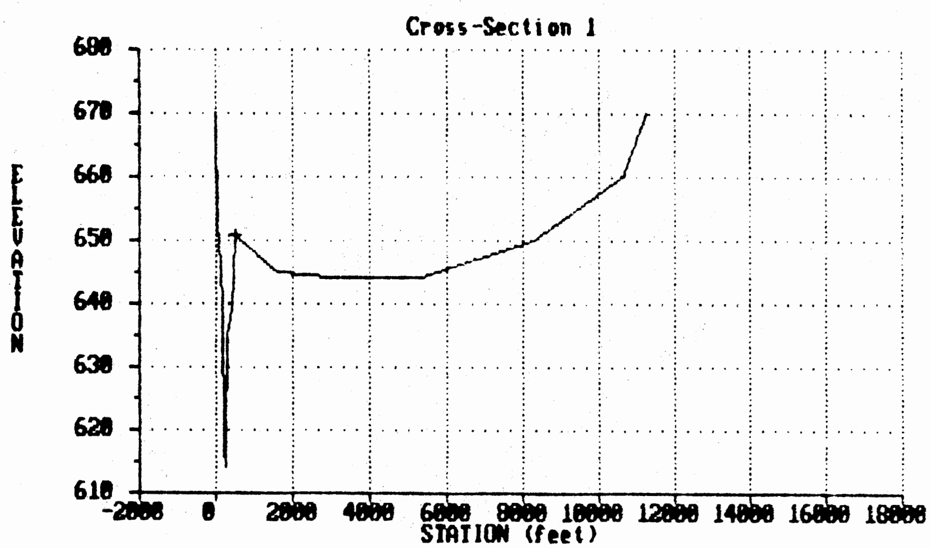


Figure 11. Exit Section - Site 3

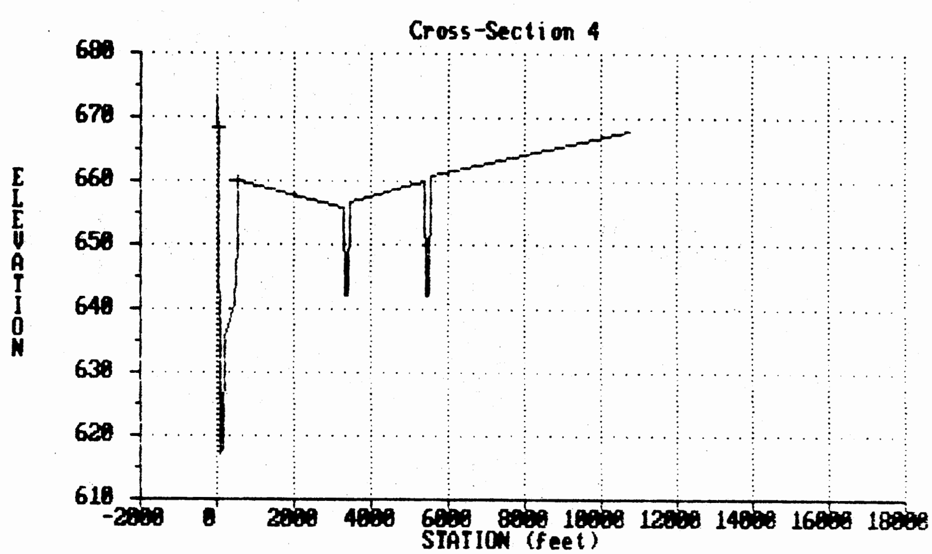
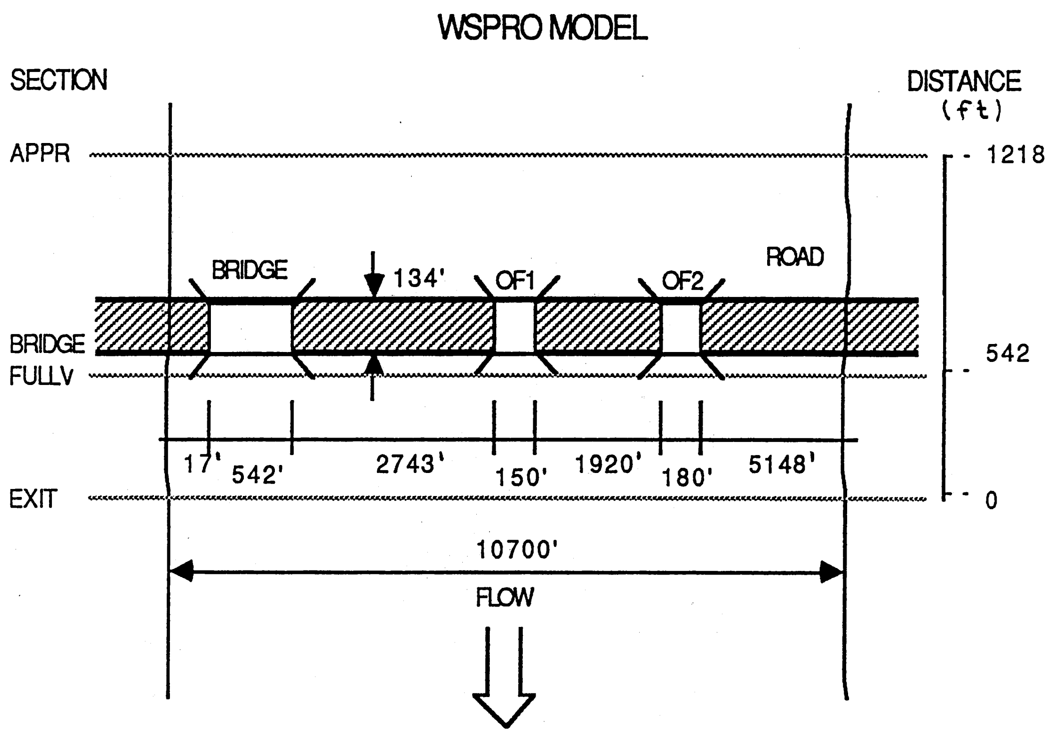


Figure 12. Bridge Section - Site 3



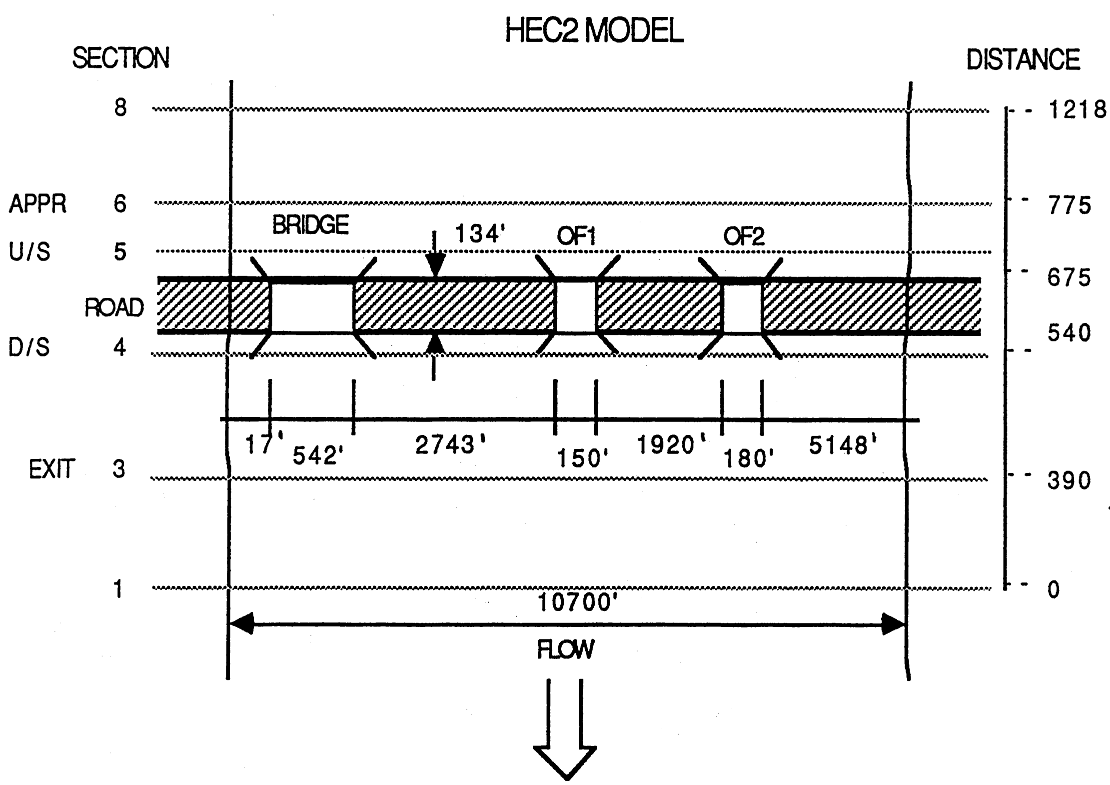


Figure 13. Cross Section Locations - Site 3

and right overbanks. Initial values for the roughness coefficient were estimated on the bases of tables presented by Chow (1988) and illustrations from Barnes (1849). Computations were carried out upstream because of the sub-critical flow pattern of the flood. The initial value of the WSE at the Exit Section was estimated by the models using the slope-conveyance method. The calibration procedure was performed based on the value of water level measured for 500-year flood by the Corps of Engineers (COE, 1987).

The main bridge length is 542 feet. The low chord is at 668.23 ft above mean sea level at the south end of the bridge. The total bridge width including two road lanes is 134 ft. The bridge has slope embankment and slope abutment. The main bridge is located at the left corner of the floodplain beginning at 17 ft from station zero.

Overflow Structure 1 begins at station 3,300 ft. It is 150 ft long, being the same type as the main bridge. The low chord is at level 656.00 ft. Overflow Structure 2 is located at section 5,370 ft. The structure length is 180 ft, and the low chord elevation is at 660 ft above mean sea level. Figure 13 shows the most important parameters of the main structure. No road grade was coded because overtopping did not occur.

Computer runs from each model are presented in Appendices A and B. Results of the simulations showing values of the WSE, can be obtained from Table 3. Water levels at the Approach Section computed by HEC 2 and WSPRO, for Q_{500}, are 653.45 and 655.59 ft respectively. The difference of 2.14 ft represents 7 percent of the normal depth for the given flow. The water-surface profile computed in the absence of the bridge was generally consistent for the two models. The difference in the backwater observed at the approach section could be due to the bridge backwater computation, particularly for the multiple-opening condition. The HEC 2 program does not have procedures for splitting flow into multiple bridge openings and evaluating the backwater in such a situation.

TABLE 3

WATER SURFACE ELEVATIONS FOR SITE 3

SECTION	SRD (ft)	WSE WSPRO (ft)	WSE HEC 2 (ft)
..Q_{50} = 42,800 cfs..			
Exit	0	648.22	649.09
Bridge	542	648.62	649.34
Approach	1218	649.72	650.03
..Q_{100} = 51,400 cfs..			
Exit	0	648.81	649.72
Bridge	542	649.20	649.83
Approach	1218	650.60	650.87
..Q_{500}= 108,000 cfs..			
Exit	0	651.56	651.40
Bridge	542	651.73	650.84
Approach	1218	655.59	653.45

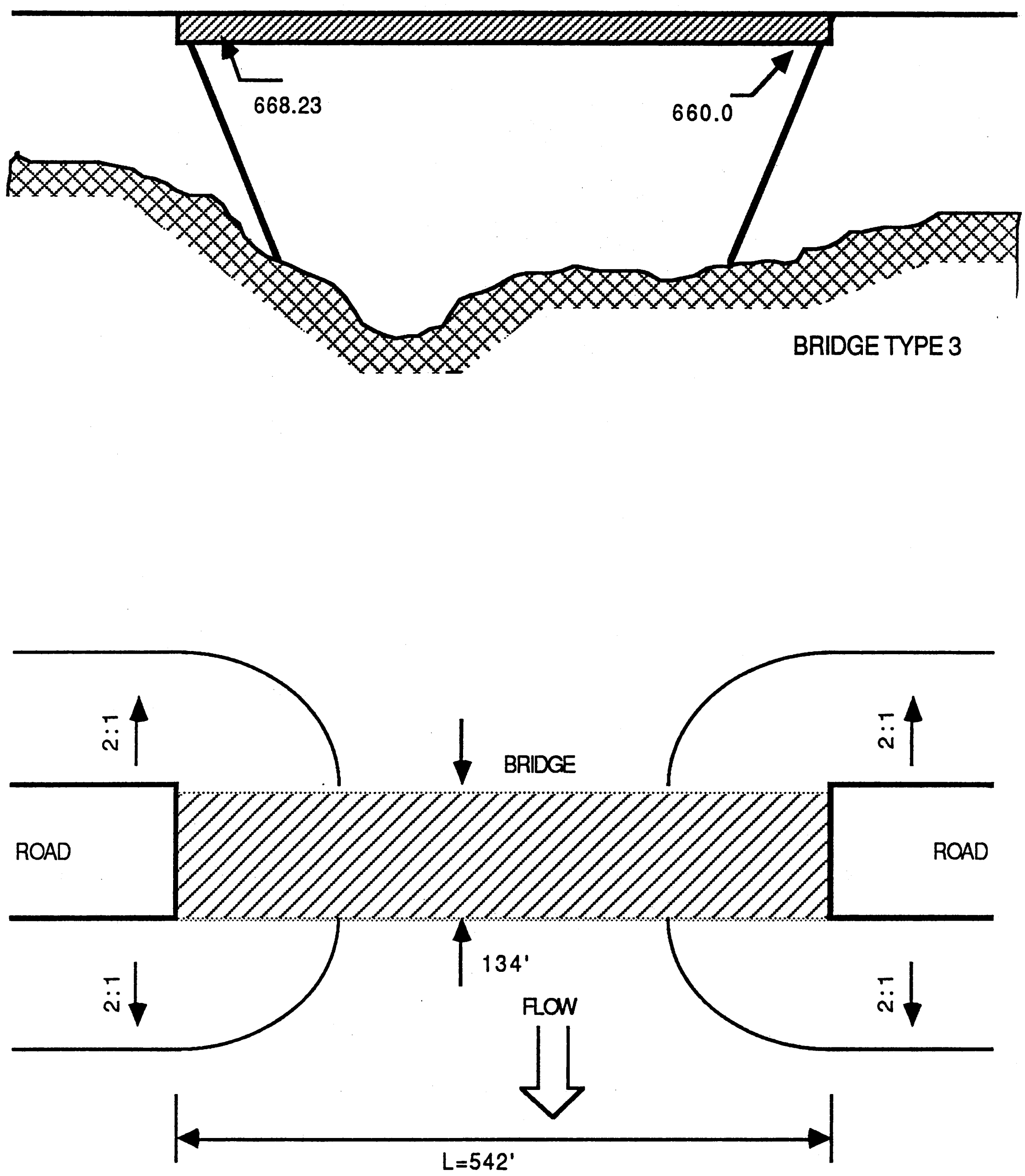


Figure 14. Main Bridge Modeling - Site 3

CHAPTER V

SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate model sensitivity for main input parameters; to compare the results obtained by different models; and to determine model adequacy and suitability to solve engineering problems concerning river hydraulics. The results obtained from the computer simulations are given in this chapter and discussed in Chapter VII.

Three sites were used in the sensitivity analysis. Site descriptions and computer runs using WSPRO and HEC 2 were presented in Chapter IV. A summary of the main characteristics of the sites and values of interest for the sensitivity analysis is presented in Table 4.

Five parameters were considered for the sensitivity analysis: (1) roughness factor; (2) reach length; (3) backwater effect; (4) channel slope; and (5) friction-slope averaging technique. The analysis was made for a single parameter at a time while the others remained unchanged.

The sensitivity analysis for the roughness factor was performed for Sites 1, 2, and 3 using HEC 2 and WSPRO. Reach length and friction-slope technique were studied for Sites 1 and 3 using both models. Simulations to establish

TABLE 4

SUMMARY OF SITE CHARACTERISTICS

Description	Site 1	Site 2	Site 3
1)Location (County)	Alfalfa	Tulsa	Washing.
2)Stream	Twin Sp.	Posey	Caney
3)Flow: Q_{50}	1650	8300	42800
Q_{100}	2100	10600	51400
Q_{500}	-	-	108000
4)Flood plain width (ft)	400	1700	10700
5)Channel slope (ft/mi)	4.6	28.6	2.0
6)n channel	0.055	0.07	0.06
7)n overbank	0.07	0.05	0.048
8)Q used for Sens. Analysis	Q_{100}	Q_{100}	Q_{500}
9)Normal depth (ft)[a]	9.30	17.00	31.55
10)Velocity at Appr.Sec.(fps)[a]	1.39	3.02	0.88
11)Bridge length (ft)	45	551	542
12)Velocity at bridge (fps)[a]	6.54	5.77	10.00
13)OF1 length (ft)[a]	-	-	150
14)Velocity at OF1 (fps)[a]	-	-	11.65
15)OF2 length (ft)[a]	-	-	180
16)Velocity at OF2 (fps)[a]	-	-	11.01
17)Backw. appr. sect.(ft)[a]	1.06	0.81	3.78
18)Backwater effect (mi)[a]	1.02	0.11	7.35

[a] Values obtained from WSPRO's simulation.

the backwater effect were made by WSPRO for all sites. The influence of channel slope was analyzed at Sites 1 and 3 using WSPRO. Site 2 was ignored in the analysis of four variables because of the linear relationship found in the results with Sites 1 and 3.

Roughness Factor

The roughness factor is represented by Manning's coefficient n in the models. Friction losses are then estimated by Manning's equation. The objectives of the sensitivity analysis for Manning's coefficient are to

(a) evaluate the importance of the accuracy in the determination of the coefficient;

(b) compare the impact in the water surface profile caused by changes of +20 percent and -20 percent in the n values for the main channel and for the overbanks; and

(c) compare site sensitivity based on flood plain shapes.

The Approach Section was selected as the observation point because it is of the most interest when studying the maximum backwater caused by the bridge-constricted section.

A total of 18 runs was made to conduct this analysis. The files' characteristics are described in Table 5. The base values for this analysis are described in the chapter, "Application." Values of the water-surface elevation and water depths at the Approach Section for the base run and for the variations in n coefficient are summarized in Table 6. Figures 15, 16, and 17 show the correlation between changes in n values and water depths computed by HEC 2 and WSPRO, in a dimensionless form.

TABLE 5

INPUT FILES USED IN THE SENSITIVITY ANALYSIS FOR ROUGHNESS COEFFICIENT

FILE	DESCRIPTION	
HY7ALMN1	Base run - Site 1	WSPRO
HY7ALMN2	N + 20 % - Site 1	WSPRO
HY7ALM-2	N - 20 % - Site 1	WSPRO
HY7POMN1	Base run - Site 2	WSPRO
HY7POMN2	N + 20 % - Site 2	WSPRO
HY7POM-2	N + 20 % - Site 2	WSPRO
HY7CAMN1	Base run - Site 3	WSPRO
HY7CAMN2	N + 20 % - Site 3	WSPRO
HY7CAM-2	N + 20 % - Site 3	WSPRO
HE2ALMN1	Base run - Site 1	HEC 2
HE2ALMN2	N + 20 % - Site 1	HEC 2
HE2ALM-2	N + 20 % - Site 1	HEC 2
HE2POMN1	Base run - Site 2	HEC 2
HE2POMN2	N + 20 % - Site 2	HEC 2
HE2POM-2	N + 20 % - Site 2	HEC 2
HE2CAMN1	Base run - Site 3	HEC 2
HE2CAMN2	N + 20 % - Site 3	HEC 2
HE2CAM-2	N + 20 % - Site 3	HEC 2

TABLE 6

WATER SURFACE ELEVATION AT APPROACH SECTION
FROM DIFFERENT ROUGHNESS COEFFICIENT

ROUGH. COEFF. (n/no)	WSPRO WSE (ft)	HEC 2 WSE (ft)	WSPRO Depth (ft)	HEC 2 Depth (ft)	WSPRO D/Do (ft/ft)	HEC 2 D/Do (ft/ft)
T W I N S P R I N G C R E E K						
0.80	1255.46	1255.00	9.85	9.45	0.959	0.937
1.00	1255.88	1255.63	10.27	10.08	1.000	1.000
1.20	1256.29	1256.22	10.68	10.67	1.040	1.059
P O S E Y C R E E K						
0.80	620.11	620.21	17.32	17.59	0.979	0.978
1.00	620.49	620.60	17.70	17.98	1.000	1.000
1.20	620.87	620.95	18.08	18.33	1.021	1.019
C A N N E Y R I V E R						
0.80	654.81	652.88	37.81	35.51	0.980	0.984
1.00	655.59	653.45	38.59	36.08	1.000	1.000
1.20	656.38	654.02	39.38	36.65	1.020	1.016

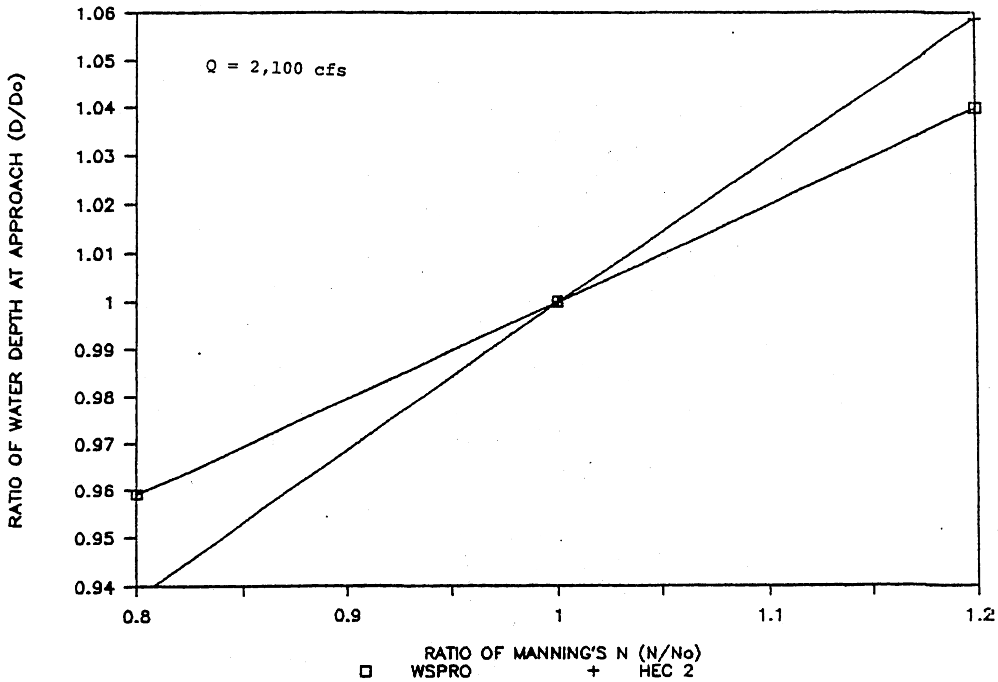


Figure 15. Roughness Factor Analysis, Site 1

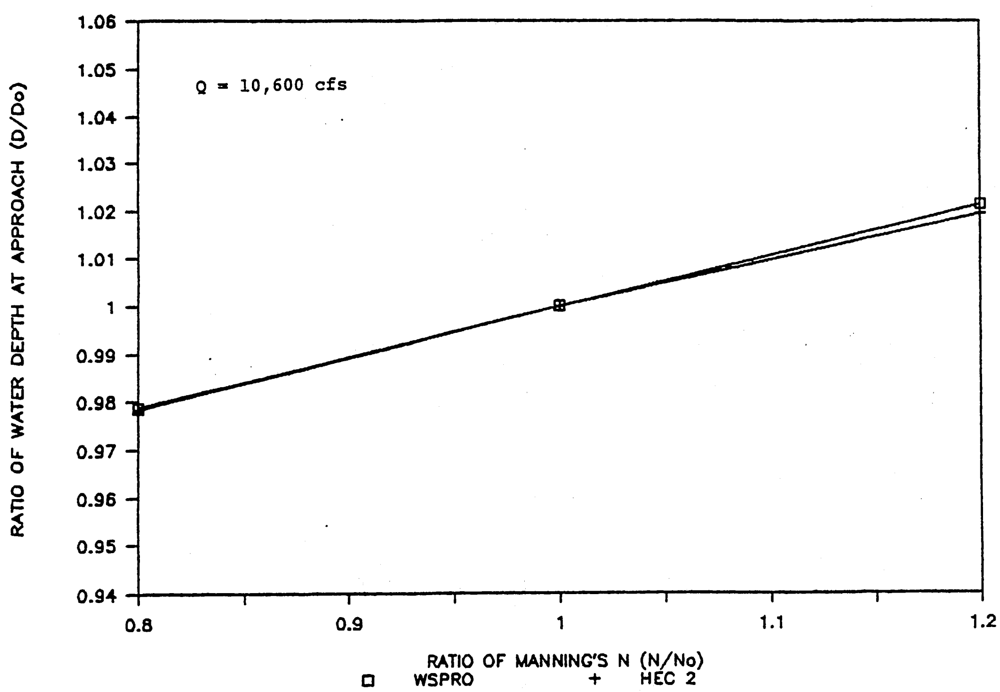


Figure 16. Roughness Factor Analysis, Site 2

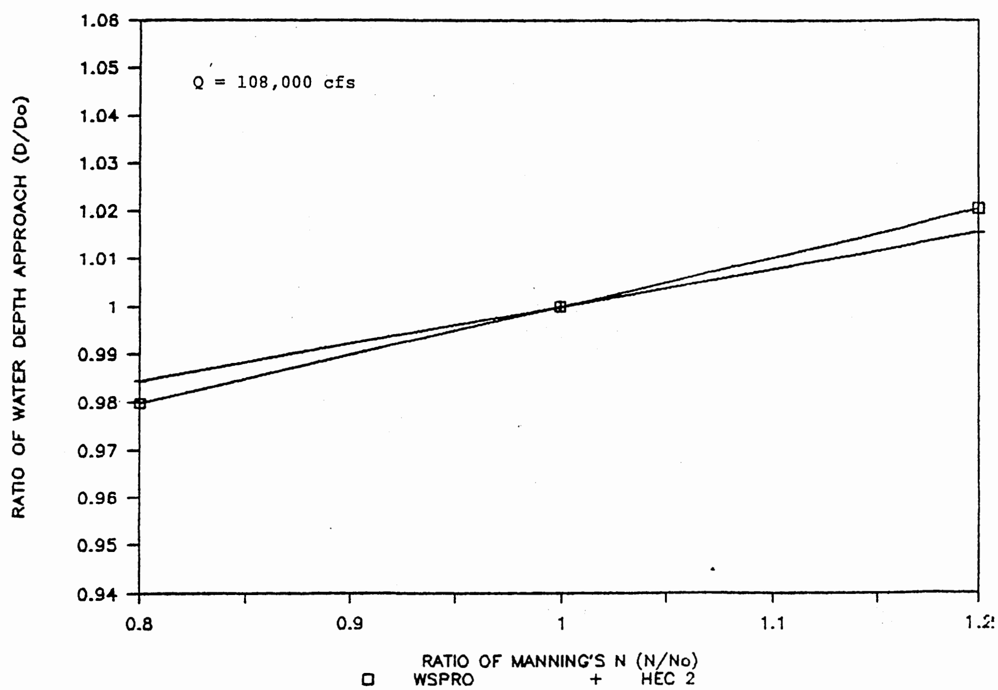


Figure 17. Roughness Factor Analysis, Site 3

Reach Length

A sensitivity analysis for reach length was developed to determine the maximum reach-length that will not affect the accuracy of the water surface profile computation, and to determine an ideal reach for use in computing the backwater effect.

The location of cross-sections in the vicinity of the bridge is determined according to model requirements and reach-lengths cannot be arbitrarily selected. So, it was convenient to perform the analysis in the upstream side of the bridge only. Reaches equal to 200, 500, 1000, 2000, and 4000 feet were used to arrive 4000 feet upstream of the Approach Section in Twin Spring Creek. In Caney River, Site 3, water surface elevations 10,000 feet upstream of the Approach Section were computed with reaches equal to 200, 500, 1000, 2500, and 5000 feet.

Results of the simulations showing WSE and depth of water are presented in Tables 7 and 8. Figure 18 illustrates the water-surface profile for the last 300 feet for Site 1 as obtained by the WSPRO run. Figures 19 and 20 show the water-surface profiles computed by both models for Caney River.

Backwater Effect

The objective of this section is to compute the backwater effect upstream of the bridge. The backwater

TABLE 7

WATER SURFACE ELEVATION AT 4000 FT UPSTREAM OF THE APPROACH SECTION FOR SEVERAL REACH LENGTHS - SITE 1

	** HEC 2 **		** WSPRO **	
Reach Length	WSE (ft)	DEPTH (ft)	WSE (ft)	DEPTH (ft)
200	1258.28	9.21	1258.38	9.25
500	1258.28	9.21	1258.34	9.21
1000	1258.29	9.22	1258.36	9.23
2000	1258.28	9.21	1258.33	9.20
4000	1258.27	9.20	1258.33	9.20

TABLE 8

WATER SURFACE ELEVATION AT 10000 FT UPSTREAM OF THE APPROACH SECTION FOR SEVERAL REACH LENGTHS - SITE 3

	** HEC 2 **		** WSPRO **	
Reach Length	WSE (ft)	DEPTH (ft)	WSE (ft)	DEPTH (ft)
200	653.40	32.40	653.48	32.48
500	653.40	32.40	653.47	32.47
1000	653.40	32.40	653.46	32.46
2500	653.39	32.39	653.45	32.45
5000	653.38	32.38	653.44	32.44

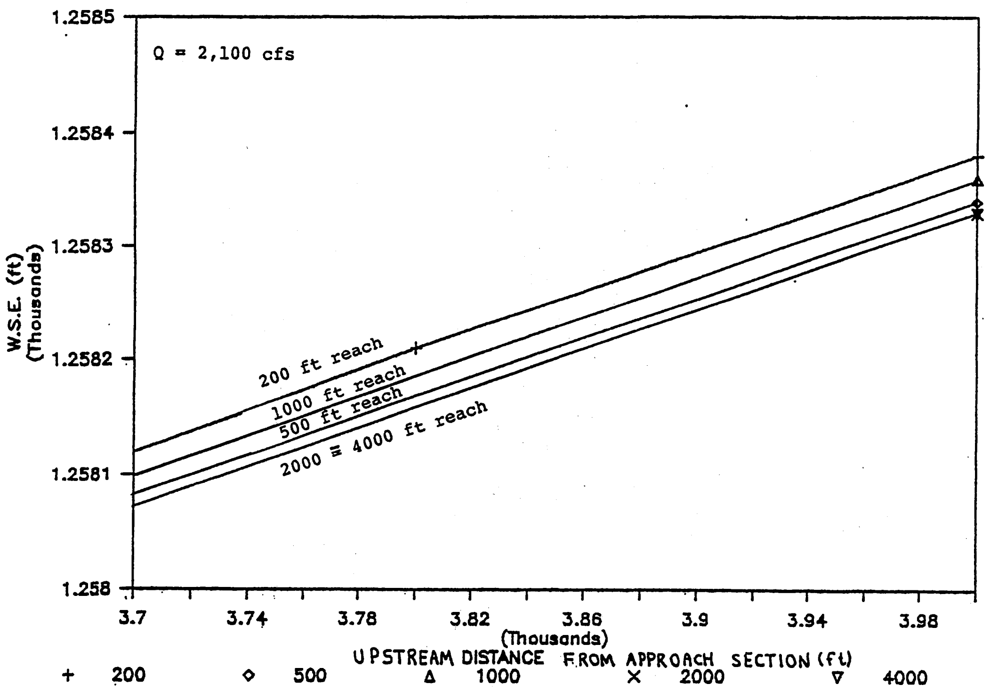


Figure 18. Reach Length Analysis, Site 1-WSPRO

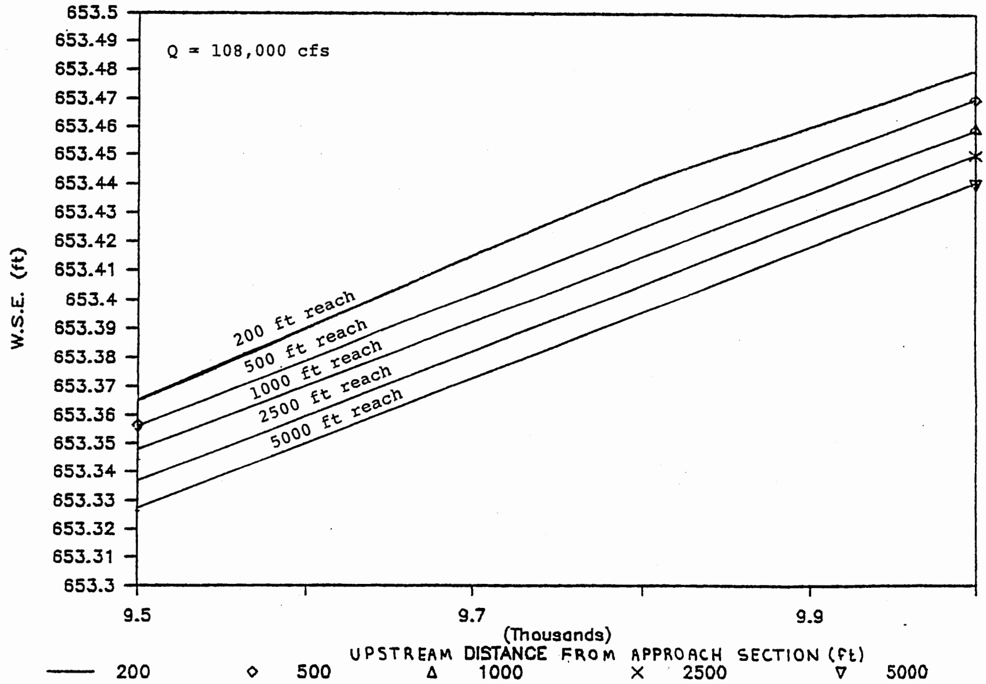


Figure 19. Reach Length Analysis, WSPRO-Site 3

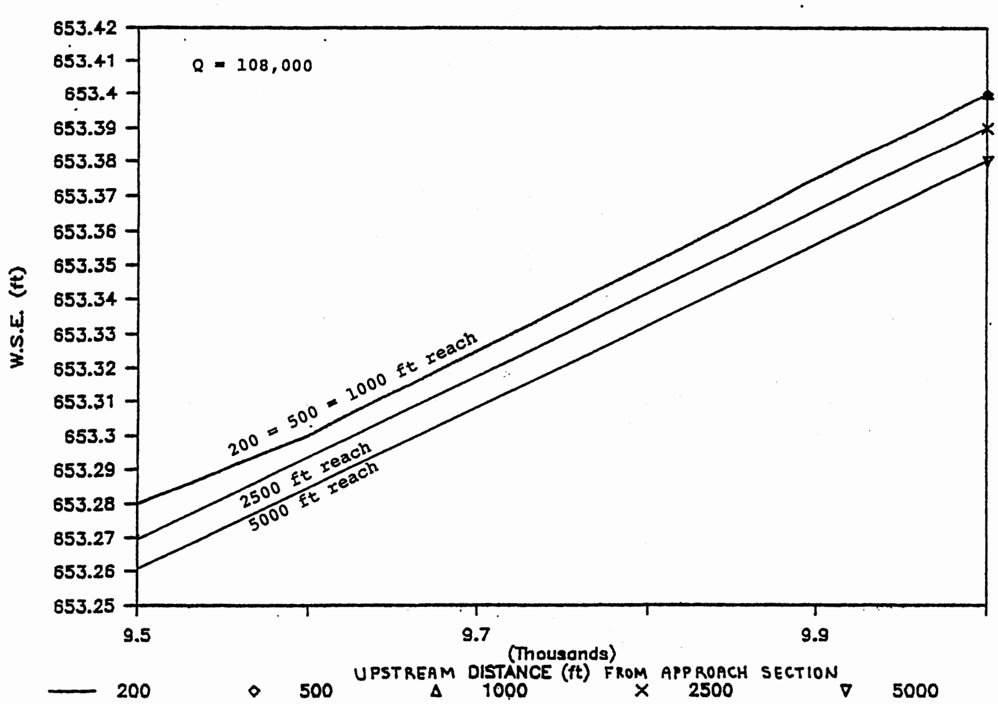


Figure 20. Reach Length Analysis, HEC 2-Site 3

caused by the constricted section may be understood as the difference between the water-surface with the bridge and without any bridge or road embankment. The procedure requires the propagation of computations upstream until the water-surface elevation drops to a normal depth. This condition is achieved when the difference in water-depth between two consecutive sections remains small, say one percent.

Computations began at the Approach Section with values for the starting WSE obtained by the bridge backwater computation. Figure 21 illustrates the extension of the backwater upstream of the Approach Section; it is shown as distance **Lo**. Using the WSPRO program, computer simulations were performed for the three sites under study.

The reach-length used in the computation of Site 1, Twin Spring Creek, was 200 ft. Computations were carried up to 10,000 feet (1.9 mi) upstream. In Site 2, Posey Creek, a 100-foot reach was adopted. For Site 3, Caney River, a 5,000-foot reach-length was used and computations were propagated to 50,000 feet (9.5 mi) upstream.

Results of computations for each site are listed in Tables 9, 10, and 11. Figures 22 and 23 illustrate backwater profiles for Site 1 for the 100-year flood and the natural profile that would exist if there was no road obstructing the flood plain. M_1 curves for Site 2 are presented in Figures 24 and 25. Figures 26 and 27 show the M_1 curve generated for Site 3, considering the 500-year flood of 1986.

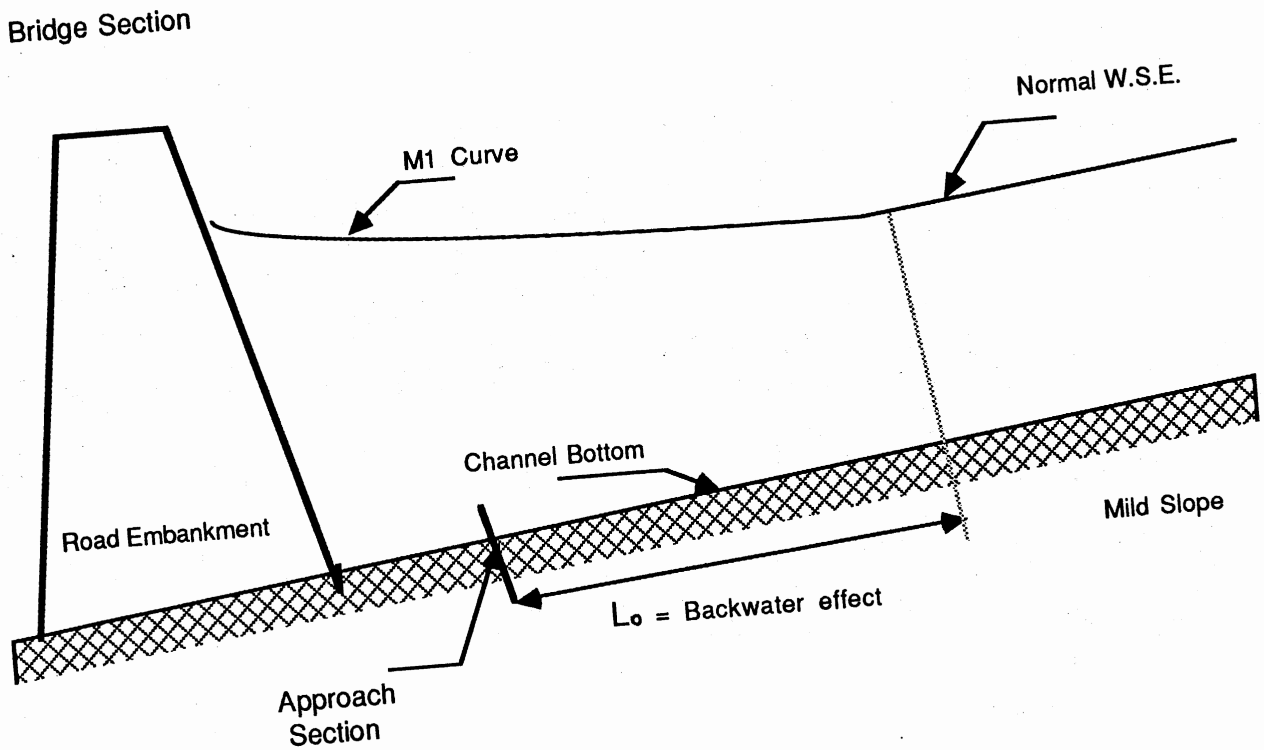


Figure 21. Backwater Effect Due to Road Embankment

TABLE 9

WATER LEVELS DUE TO BACKWATER EFFECT - SITE 1

SRD (ft)	Distance[a] (mi)	WSE (ft)	Depth (ft)	Delta D (Dn/Dn-1)
127	0.00	1255.88	10.27	
327	0.04	1255.97	10.18	0.84
527	0.08	1256.06	10.10	0.85
727	0.11	1256.16	10.02	0.76
927	0.15	1256.27	9.96	0.66
1127	0.19	1256.38	9.89	0.67
1327	0.23	1256.49	9.82	0.67
1527	0.27	1256.61	9.77	0.57
1727	0.30	1256.74	9.72	0.47
1927	0.34	1256.86	9.67	0.58
2127	0.38	1257.00	9.63	0.37
2327	0.42	1257.13	9.58	0.48
2527	0.45	1257.27	9.55	0.38
2727	0.49	1257.42	9.52	0.27
2927	0.53	1257.56	9.49	0.38
3127	0.57	1257.71	9.46	0.27
3327	0.61	1257.87	9.44	0.17
3527	0.64	1258.02	9.42	0.28
3727	0.68	1258.18	9.40	0.17
3927	0.72	1258.34	9.39	0.17
4127	0.76	1258.50	9.37	0.17
4327	0.80	1258.66	9.35	0.17
4527	0.83	1258.83	9.35	0.06
4727	0.87	1258.99	9.33	0.17
4927	0.91	1259.16	9.33	0.06
5127	0.95	1259.33	9.32	0.06
5327	0.98	1259.49	9.30	0.17
5527	1.02	1259.66	9.30	0.06

[a] from the approach section

TABLE 10

WATER LEVELS DUE TO BACKWATER EFFECT - SITE 2

SRD (ft)	Distance[a] (mi)	WSE (ft)	Depth (ft)	Delta D (Dn/Dn-1)
651	0.00	620.49	17.70	
751	0.02	620.76	17.43	1.565
851	0.04	621.12	17.24	1.059
951	0.06	621.54	17.12	0.717
1051	0.08	622.02	17.06	0.368
1151	0.09	622.52	17.02	0.251
1251	0.11	623.05	17.00	0.075
1351	0.13	623.59	17.00	0.016
1451	0.15	624.13	17.00	0.016
1551	0.17	624.67	17.00	0.016
1651	0.19	625.21	16.99	0.016
1751	0.21	625.76	17.00	0.043
1851	0.23	626.30	17.00	0.016
1951	0.25	626.84	16.99	0.016
2051	0.27	627.39	17.00	0.043
2151	0.28	627.93	17.00	0.016
2251	0.30	628.47	17.00	0.016
2351	0.32	629.01	16.99	0.016
2451	0.34	629.56	17.00	0.043

[a] from the approach section

TABLE 11

WATER LEVELS DUE TO BACKWATER EFFECT - SITE 3

SRD (ft)	Distance[a] (mi)	WSE (ft)	Depth (ft)	Delta D (Dn/Dn-1)
1218	0.10	655.59	38.59	
5000	0.82	655.73	37.22	3.68
10000	1.77	656.01	35.50	4.85
15000	2.71	656.51	34.00	4.41
20000	3.66	657.33	32.82	3.60
25000	4.61	658.60	32.09	2.27
30000	5.55	660.25	31.74	1.10
35000	6.50	662.12	31.61	0.41
40000	7.45	664.07	31.56	0.16
45000	8.39	666.06	31.55	0.03
50000	9.34	668.06	31.55	0.00
55000	10.29	670.06	31.55	0.00

[a] from the approach section

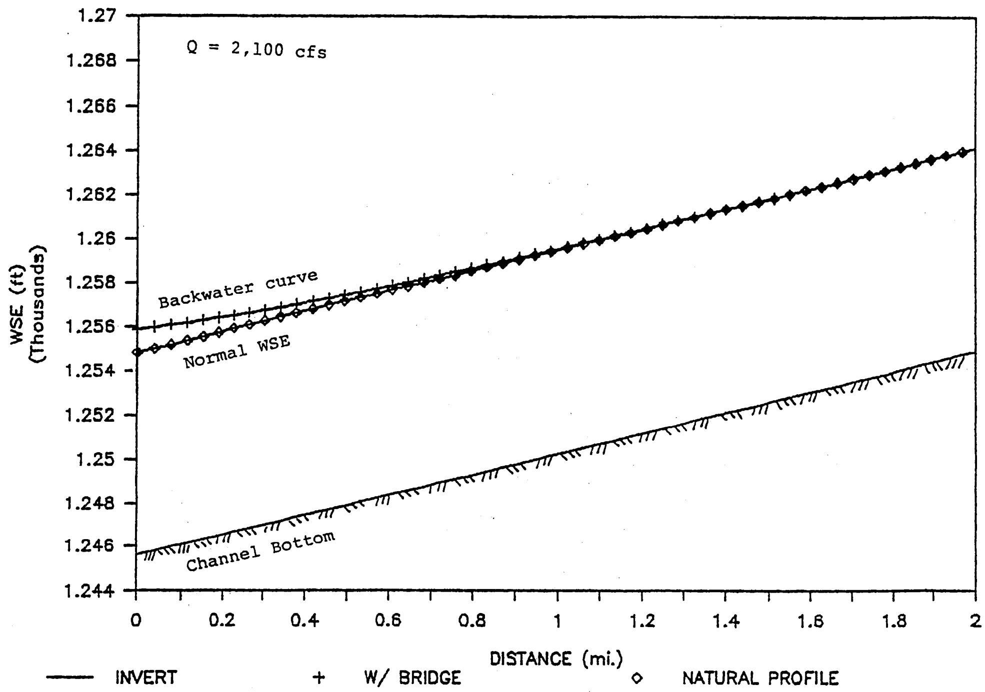


Figure 22. M1 Curve Entire Reach, Site 1

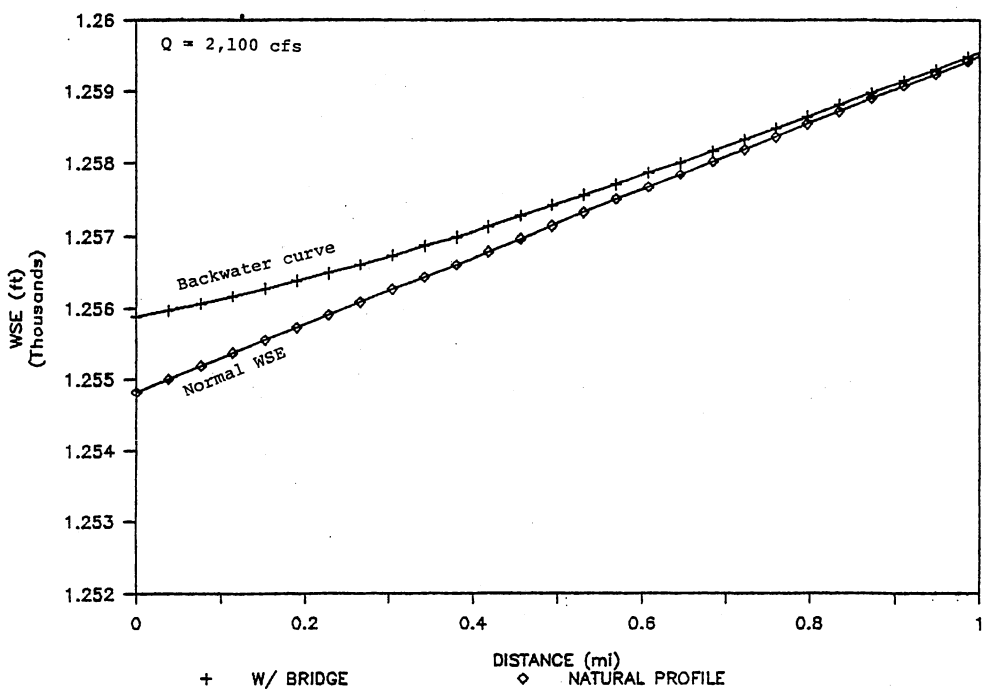


Figure 23. M1 Curve Detail, Site 1

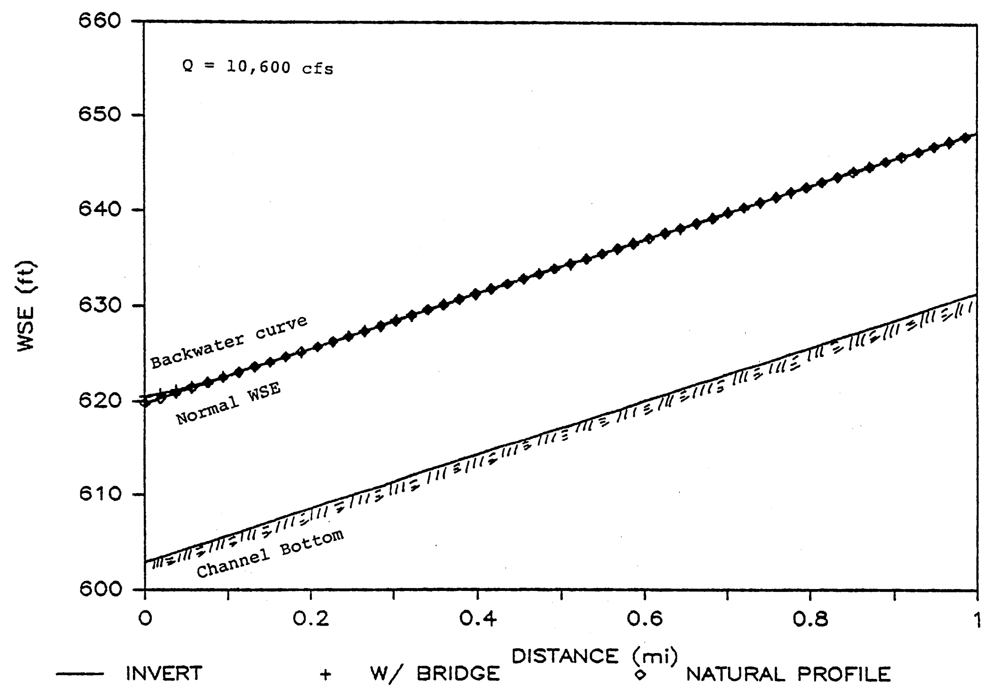


Figure 24. M1 Curve Entire Reach, Site 2

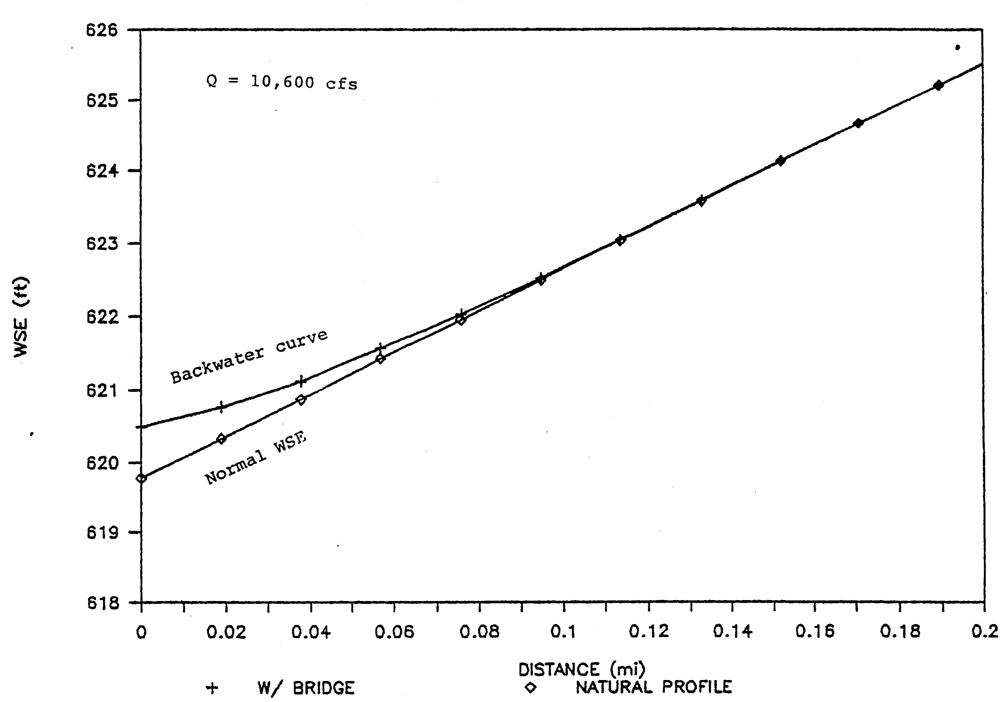


Figure 25. M1 Curve Detail, Site 2

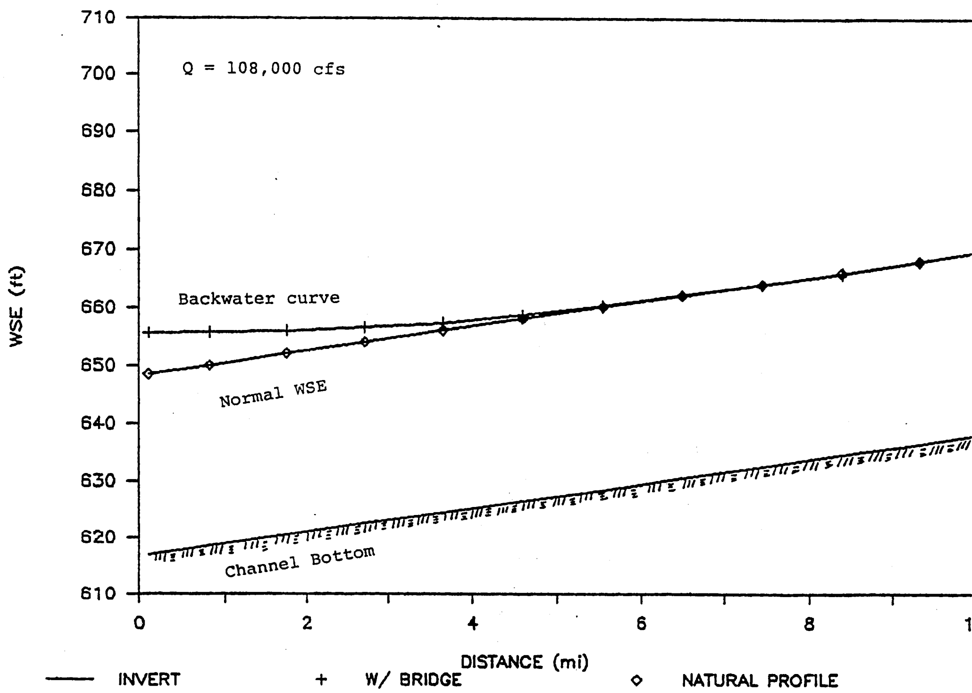


Figure 26. M1 Curve Entire Reach, Site 3

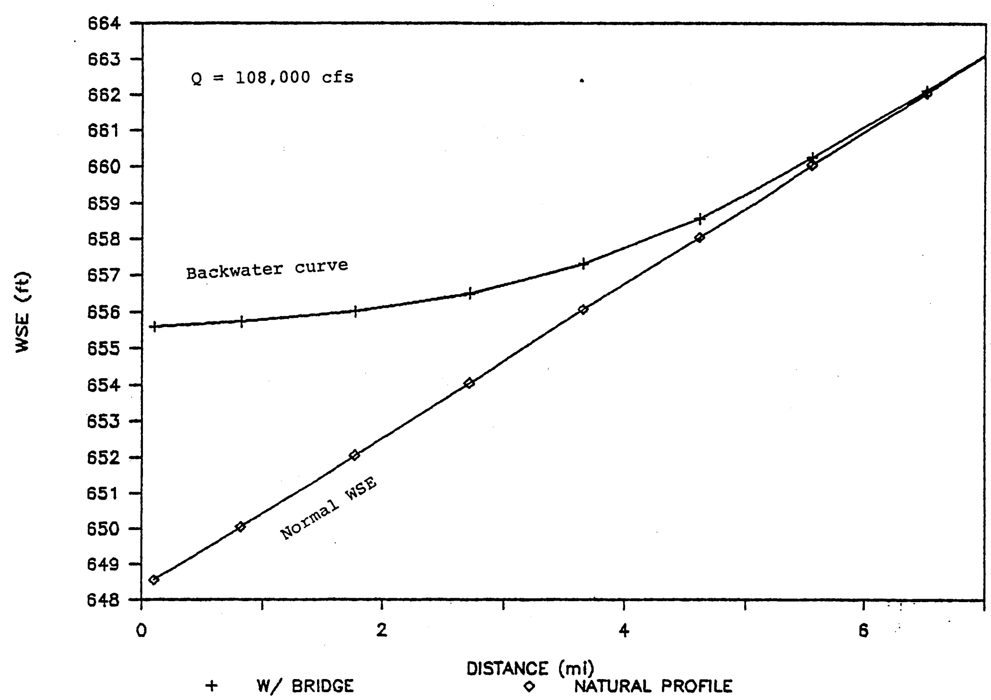


Figure 27. M1 Curve Detail, Site 3

Channel Slope

The purpose of this analysis is to correlate the total backwater at the Approach Section with the channel bed-slope. The natural bed-slope was pivoted at the bridge section to generate new slopes equal to two and half of the original slope.

The present analysis was performed for Sites 1 and 3 using the WSPRO model. Figures 28 and 29 illustrate variations imposed in the natural profile of each site. For Site 1, the decreased slope caused the development of pressure flow, with the water elevation hitting the bridge span. Road-grade data were removed and Q_{50} was used to avoid the pressure flow and to prevent weir flow over the banks, conditions that are not desirable for the purposes of this analysis.

Table 12 presents the correlation between channel slope and water-depth in a dimensionless form for Site 1. Figure 30 depicts the results of the correlation shown in Table 12. Table 13 and Figure 31 show results for Site 3.

Friction-Slope-Averaging Technique

A sensitivity analysis for the friction-slope-averaging technique was developed to determine the influence of different friction-loss equations on the water-surface elevation. Four equations are available in

TABLE 12

WATER SURFACE ELEVATION AT APPROACH SECTION FOR DIFFERENT CHANNEL SLOPES - SITE 1

Channel Slope	S/So	WSE (ft)	Depth (ft)	D/Do
0.00044	0.50	1255.75	10.17	1.104
0.00088[a]	1.00	1254.82	9.21	1.000
0.00200	2.27	1254.16	8.46	0.919

[a] actual slope

TABLE 13

WATER SURFACE ELEVATION AT APPROACH SECTION FOR DIFFERENT CHANNEL SLOPES - SITE 3

Channel Slope	S/So	WSE (ft)	Depth (ft)	D/Do
0.0002	0.5	656.15	39.01	1.018
0.0004[a]	1.0	655.59	38.32	1.000
0.001	2.5	655.26	37.58	0.981

[a] actual slope

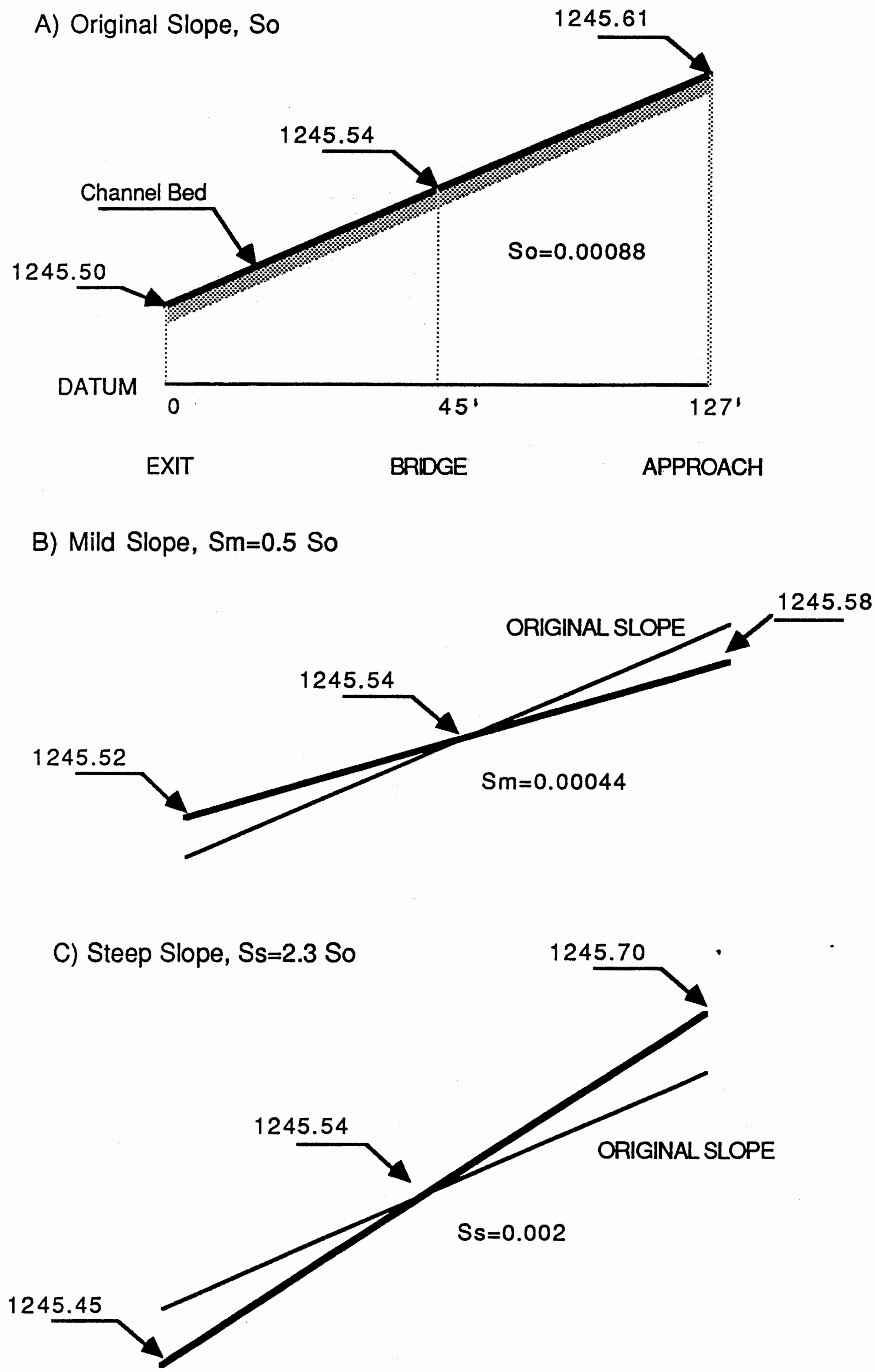


Figure 28. Channel Slope Variations, Site 1

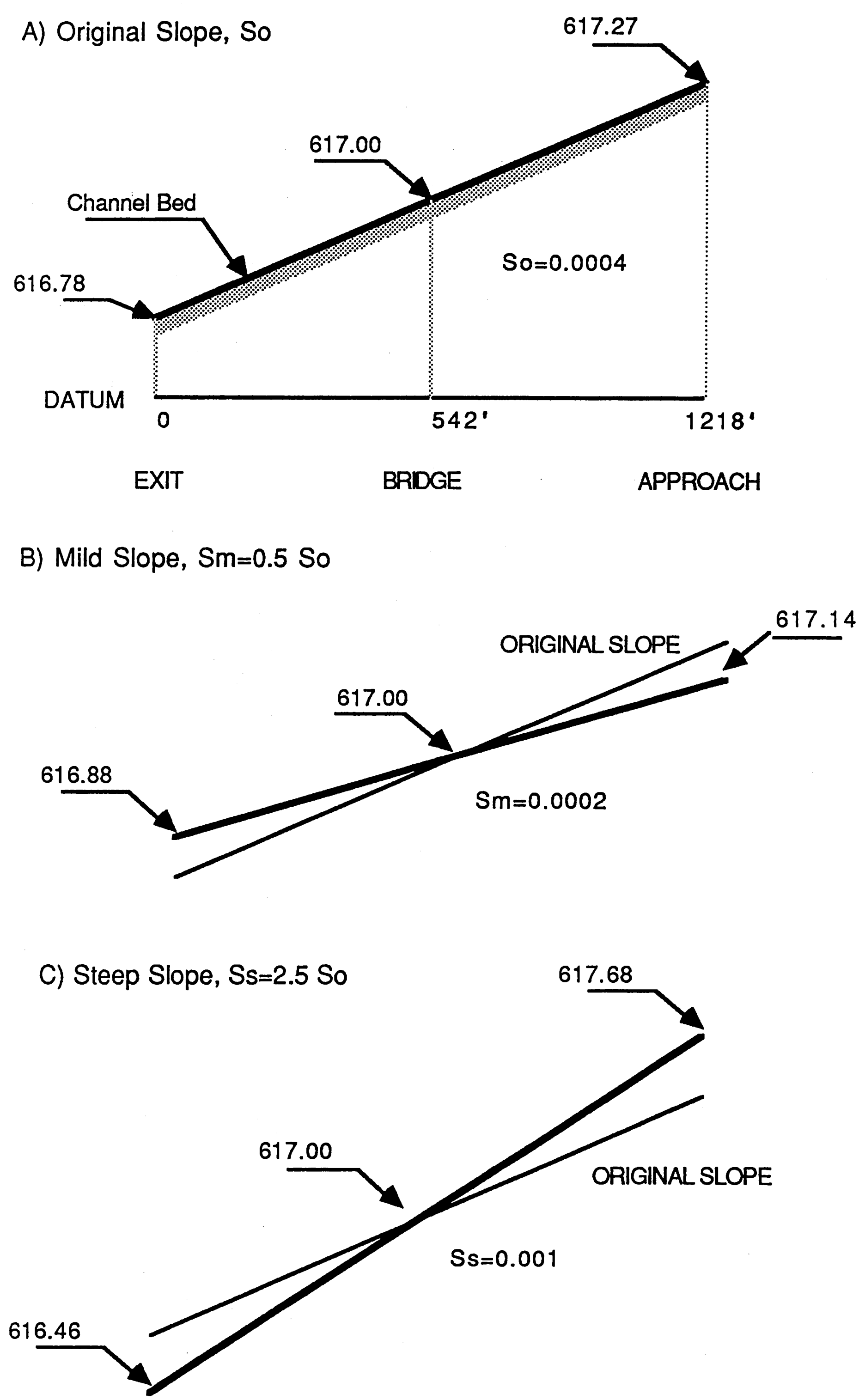


Figure 29. Channel Slope Variations, Site 3

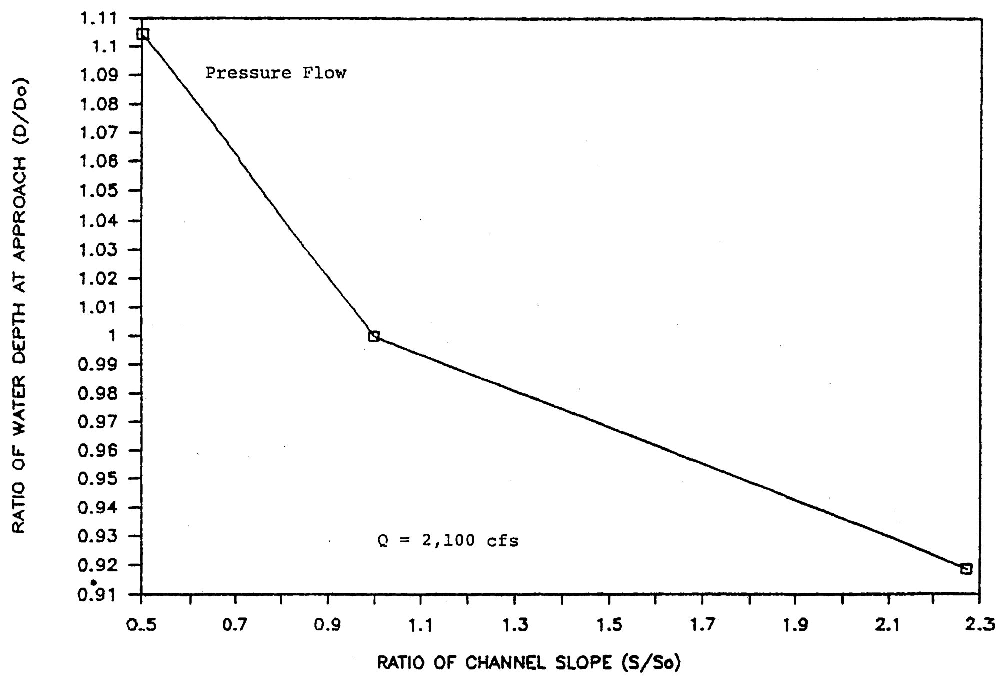


Figure 30. Channel Slope Analysis, Site 1

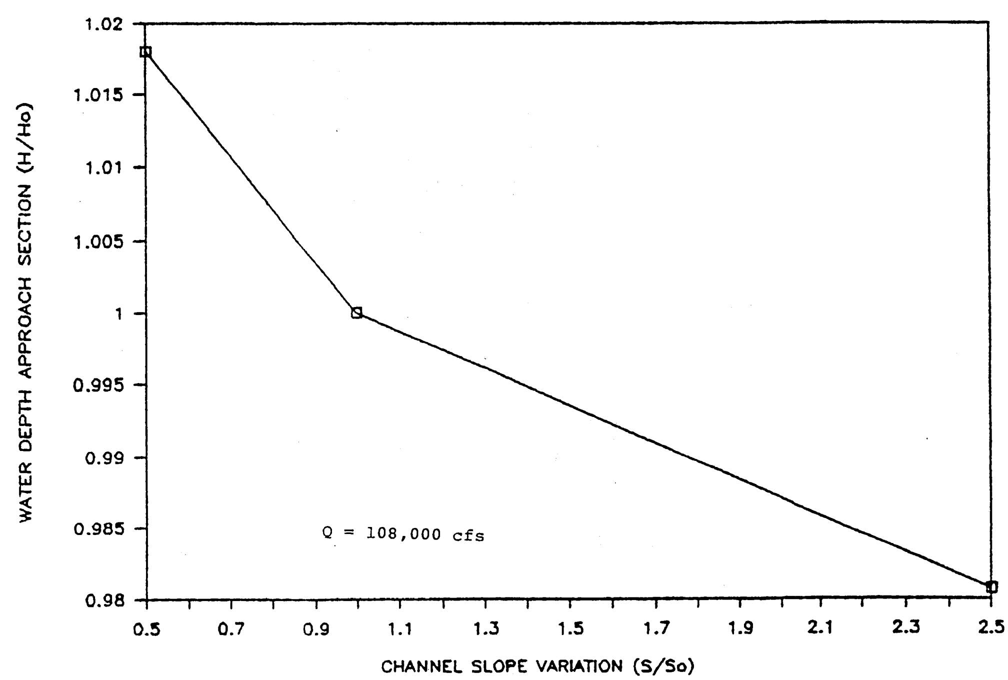


Figure 31. Channel Slope Analysis, Site 3

HEC 2 and WSPRO for computing the friction losses between cross-sections. They are described in detail in Chapter II, page 15. The user may select a specific equation to be used in the simulation or he may use the default equation set by each model. This analysis was made in Sites 1 and 3 using all four equations available in both models.

Tables 14 and 15 show the variations in water levels at the Approach Section that result from the use of different friction-loss equations.

TABLE 14

WATER SURFACE ELEVATION AT APPROACH SECTION USING DIFFERENT FRICTION LOSS EQUATIONS - SITE 1

METHOD	HEC 2 (ft)	Diff.[a] (%)	WSPRO (ft)	Diff. (%)
Average Conveyance[b]	1255.63	0	1255.88	0
Aver. Frict. Slope	1256.19	5.6	1255.88	0
Geometric mean F.S.[c]	1255.77	1.4	1255.88	0
Harmonic mean F.S.	1255.56	-0.7	1255.88	0
Model select	1255.68	0.5	NA[d]	

[a] water depth relative to default equation
[b] default equation for HEC 2
[c] default equation for WSPRO
[d] option is not available in the model

TABLE 15

WATER SURFACE ELEVATION AT APPROACH SECTION USING DIFFERENT FRICTION LOSS EQUATIONS - SITE 3

METHOD	HEC 2 (ft)	Diff.[a] (%)	WSPRO (ft)	Diff. (%)
Average Conveyance[b]	653.36	0	655.58	0.0
Aver. Frict. Slope	653.82	1.3	655.59	0.0
Geometric mean F.S.[c]	653.45	0.2	655.59	0.0
Harmonic mean F.S.	653.34	-0.1	655.58	0.0
Model select	653.40	0.1	NA[d]	

[a] water depth relative to default equation
[b] default equation for HEC 2
[c] default equation for WSPRO
[d] option is not available in this model.

CHAPTER VI

BENCHMARK TESTS

Benchmark tests were performed to compare the efficiency of HEC 2 and WSPRO to run the same application; and to evaluate the hardware performances in processing the same simulation. The files used in the benchmark test with a description of the number of profiles, number of cross-sections, and type of analysis performed are described in Table 16. The micro-computers' hardware configurations are listed in Table 17.

Variables of interest for model comparison are input and output file sizes and computer run-time. Two problems were simulated for each site. The modeling technique was adapted according to particular features of each model. For example, problem CABM1 was partially modeled in a HEC 2 run because this model is limited to the analyzing of a single bridge opening.

Two types of computers were used to run the test for model comparison: an IBM PC and a PC-AT. They are listed as machines B and C in Table 17. Results of this analysis are presented in Tables 18 and 19. It is noted that input files for WSPRO are smaller than those for HEC 2. This reflects the effort spent in the preparation of input parameters required by each model.

Output files generated by WSPRO are slightly smaller than those from HEC 2 except when processing multiple-bridge-openings. In that case many iterations are performed by WSPRO to balance the WSE at the Approach section and the model outputs those intermediate computations. Another point to be considered is the fact that HEC 2 plots the water-surface profile for the entire reach under standard conditions.

A knowledge of the size of output files from selected applications may help in the estimation of the total storage capacity required to develop the project. For example, to run a problem similar to CABM2 (See description in Table 18), one double-density soft-sectored floppy disk is needed to store a maximum of three output simulations. Along with storage requirements it is helpful to compare the run-time of the models.

The run-time of HEC 2 is generally shorter than WSPRO's, as can be seen in Tables 18 and 19. This difference reduces when using AT machines with hard-disk drives. Besides the advantage of a faster micro-processor chip, less time is spent in retrieving information from auxiliary storage devices such as the hard drive. HEC 2 and WSPRO run-times ranged from two to five times as fast in the XT machines and between one-and-a-half and three-and-a-half times as fast in the AT micro-computers.

The second analysis performed was intended to evaluate the performance of several hardware configurations in solving selected WSPRO applications. Four additional IBM files from Tyagi et al. (1988) were used in this test. Two PCs, one with a mathematical co-processor and another without, and Two PC-ATs, a PS-2 Model 50 and an Executive-At-Turbo were used for this test. Simulations for hardware performance were conducted with WSPRO files only. Results obtained are presented in Table 20. A discussion of this analysis is included in Chapter VII.

TABLE 16

INPUT FILES FOR BENCHMARK TEST

File	Site/ Procedure	# of Profiles	# of Cross Sections	Analysis Performed
REDFOX	WORKSHOP 1	5	4	P
EX 2	WORKSHOP 3	5	4	B
EX 4	WORKSHOP 4	5	5	B,R
STEEP	WORKSHOP 5	4	7	P
ALBM1	SITE 1	4	4	B, R
POBM1	SITE 2	2	4	B, R
CABM1	SITE 3	3	4	M
ALBM2	SITE 1	1	40	P
POBM2	SITE 2	1	26	P
CABM2	SITE 3	1	50	P

Legend:
P - Propagation of the WSE upstream or downstream
B - Bridge backwater computation
R - Road grade included for weir computation
M - Multiple opening situation with main bridge and overflow structures 1 and 2.

TABLE 17

HARDWARE CONFIGURATION OF MICRO-COMPUTERS

Reference	A	B	C	D
Model	IBM-PC	IBM-PC	Executive	IBM PS/2-50
Microprocessor	I-8086	I-8086	I-80286	I-80286
Math/co-proc.	-	I-8087	I-80287	I-80287
Speed (Mhz)	4.78	4.78	10	10
RAM memory(Kb)	640	640	1 Mb	1 Mb
Hard disk (Mb)	-	-	20	20
Performance[a]	1.0	1.0	9.0	10.3

[a]based on the SI Test from Norton Utilities

TABLE 18

BENCHMARK TEST FOR MODEL COMPARISON - COMPUTER B

File	** Input (Kb)	HEC2 Output (Kb)	** Time (min)	** Input (Kb)	WSPRO Output (Kb)	** Time (min)
ALBM1	3627	29204	4.5	842	20918	6.0
POBM1	4177	31290	4.0	1959	22258	10.0
CABM1	2892	38551	4.6	1807	61234	16.0
ALBM2	4105	86693	11.0	1434	82615	6.0
POBM2	5746	69384	9.0	1460	60716	4.2
CABM2	4830	107487	9.0	1857	105721	6.7

TABLE 19

BENCHMARK TEST FOR MODEL COMPARISON - COMPUTER C

File	** Input (Kb)	HEC2 Output (Kb)	** Time (min)	** Input (Kb)	WSPRO Output (Kb)	** Time (min)
ALBM1	3627	29204	0.7	842	20918	1.5
POBM1	4177	31290	0.6	1959	22258	3.0
CABM1	2892	38551	0.8	1807	61234	3.5
ALBM2	4105	86693	0.8	1434	82615	1.1
POBM2	5746	69384	0.8	1460	60716	0.8
CABM2	4830	107487	1.0	1857	105721	1.3

TABLE 20

BENCHMARK TEST FOR HARDWARE PERFORMANCE

File	Input (Kb)	Output (Kb)	Run Time (min) Comp.A	Comp.B	Comp.C	Comp.D
REDFOX	1664	16035	9.0	3.0	0.8	0.7
EX 2	1214	23270	35.0	9.0	0.5	0.5
EX 4	1303	26457	42.0	10.0	0.6	0.9
STEEP	2125	26600	19.0	5.0	1.1	1.1
ALBM1	842	20918	22.0	6.0	1.5	1.3
POBM1	1959	22258	32.0	10.0	3.0	2.0
CABM1	1807	61234	39.0	16.0	3.5	2.5
ALBM2	1434	82615	14.1	6.0	1.1	1.3
POBM2	1460	60716	8.0	4.2	0.8	1.0
CABM2	1857	105721	11.0	6.7	1.3	1.5

CHAPTER VII

DISCUSSION

In this chapter the results presented in Chapters V and VI are discussed. A summary of the parameters studied as well as the model used to run the simulations is shown in Table 21.

TABLE 21

PARAMETERS STUDIED IN THE SENSITIVITY ANALYSIS

Parameter	**		Model Used			**
	WSPRO			HEC 2		
Sites --->	1	2	3	1	2	3
Roughness Factor n	X	X	X	X	X	X
Reach Length	X		X	X		X
Backwater Effect	X	X	X			
Channel Slope	X		X			
Friction Slope Av. Tech.	X		X	X		X
Benchmark Tests	X	X	X	X	X	X

Roughness Factor

A comparison of the results obtained by HEC 2 and

WSPRO for each site is considered based on the values of the water-surface elevation at the Approach Section presented in Table 6 and illustrated in Figures 15, 16, and 17. Water depths (D) were measured from the bottom of the main channel .

WSPRO results from Twin Spring Creek, Site 1 showed a 4.1 percent decrease in the WSE when the roughness reduced by 20 percent and a 4 percent increase in the WSE for a 20 percent increase in the n value. HEC 2 results for the same site showed 6.3 percent decrease and 5.9 percent increase in the water-surface elevations for the same variations imposed to n values.

For Site 2, Posey Creek, results from both models were close, differing by only 0.2 percent. For this site, the water-surface elevation at the Approach Section varied an average of 2 percent for the variation of 20 percent imposed to the roughness coefficient.

WSPRO's result for Caney River, Site 3, presented a 2 percent variation in the WSE for the correspondent variations in n values. HEC 2 results showed differences in the WSE to the order of 1.6 percent. The above results are grouped together in Figures 32 and 33, showing the impact of the coefficient considering small, medium, and large discharge values. It is observed that the low discharge is more sensitive to coefficient n. The flow area in these sites is considerably smaller than in those of Sites 2 and 3. Larger floodplains have higher carry

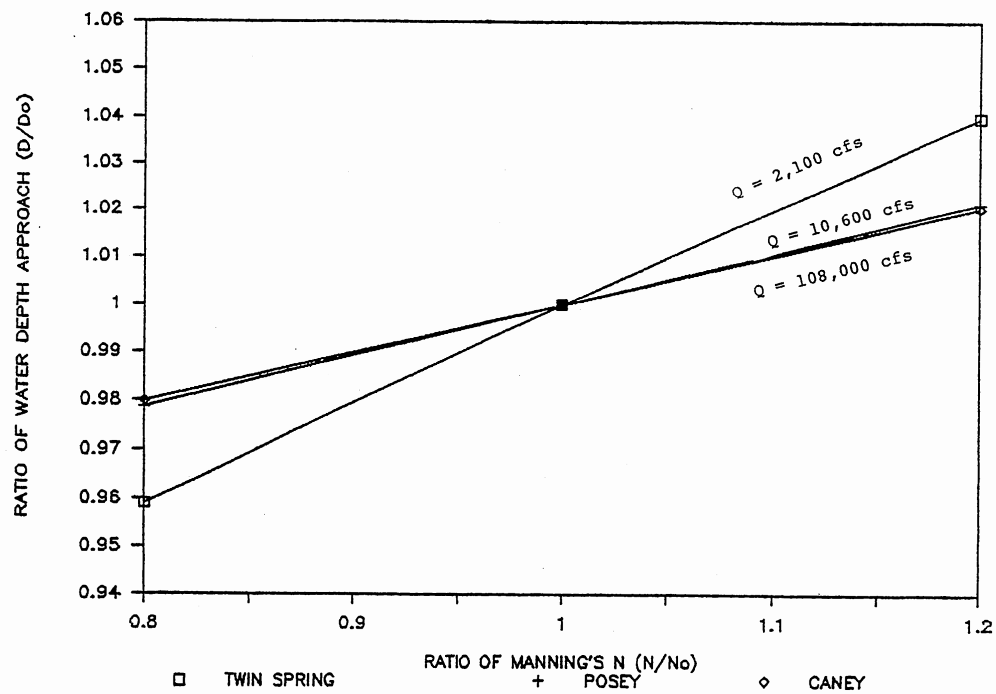


Figure 32. Impact of Roughness Factor by WSPRO

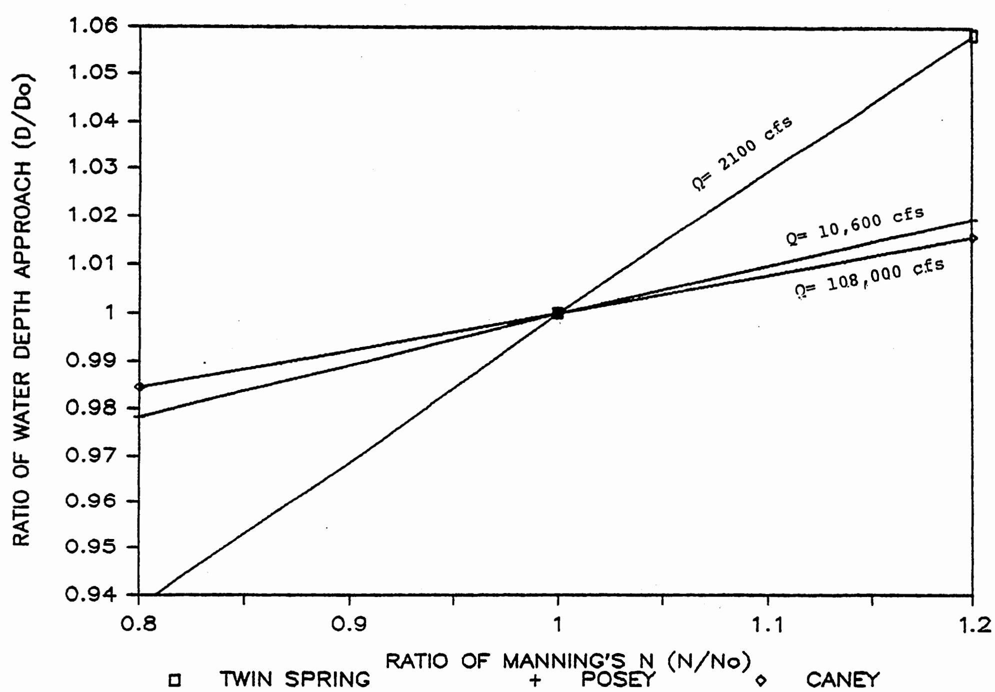


Figure 33. Impact of Roughness Factor by HEC 2

capacity, making them less sensitive to the roughness factor.

HEC 2 results presented in Figure 33 are more dispersed than WSPRO's showed in Figure 32, leading to the conclusion that the HEC 2 model is more sensitive for the roughness factor. In summary the following was observed.

(1) A small site with low Q is more sensitive to the roughness coefficient and a more accurate evaluation of this parameter is required. Therefore, more data are needed to calibrate the application;

(2) Underestimation of n value is worse than overestimation;

(3) The HEC 2 model is slightly more sensitive to the roughness factor than WSPRO.

Reach-Length

The main points observed in the sensitivity analysis for reach-length, extracted from Tables 7 and 8, and illustrated in Figures 18 to 20, are listed below:

(1) The reach length variation has only a minor influence on the water-surface elevation of cross-sections when the hydraulic characteristics of the floodplain do not change much and the slope is small.

(2) Water-depths computed with 200-, 500-, 1000-, 2000- and 4000-foot reach-lengths for Site 1, Twin Spring Creek, vary little; they present a maximum difference equal to 0.05 foot from WSPRO runs and equal to 0.02 foot from HEC 2 runs.

(3) In Caney River, Site 3, the water-surface elevation computations using several reach-lengths differed by a maximum of 0.04 foot from WSPRO runs and by 0.02 foot from HEC 2 runs.

(4) The difference in the WSE computed using several reach-lengths is dependent on the starting WSE adopted at the downstream section (for sub-critical flow computation). This fact is illustrated in Figures 34 and 35.

(5) The WSPRO model is more sensitive than HEC 2 to the reach-length parameter.

(6) Results for Site 3 presented in Figure 20 suggest that a 1,000-foot reach was the best value to use because it produced the same water elevations compared to computations using 500- and 200-foot reach-lengths.

Backwater Effect

Results of the backwater analysis show M_1 shaped curves generated by the WSPRO model for each site. Figures 22, 24, and 26 show the river bed, natural profile and backwater profile for each site. Figures 23, 25 and 27 present a detailed view of the M_1 curve and its limits of influence. Tables 9, 10, and 11 give the values of water depths used to generate the above figures.

Site 1, Twin Spring Creek, provided the best defined M_1 curve with more than 20 points plotted before convergence. The backwater effect extended to one mile upstream of the Approach Section. A backwater equal to one

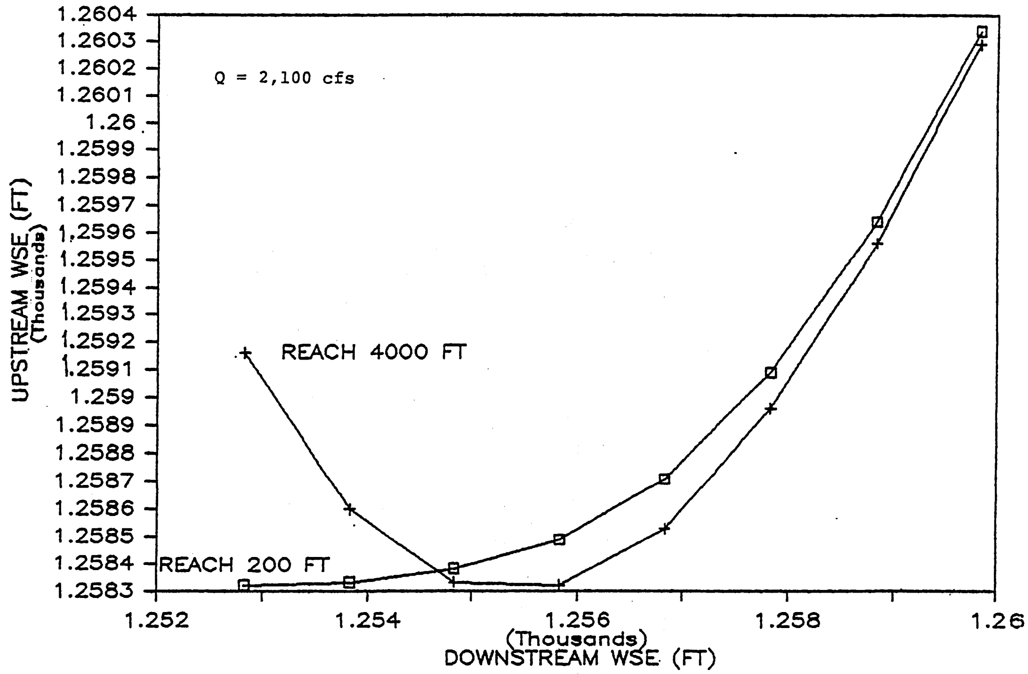


Figure 34. Upstream Versus Downstream WSE, Site 1

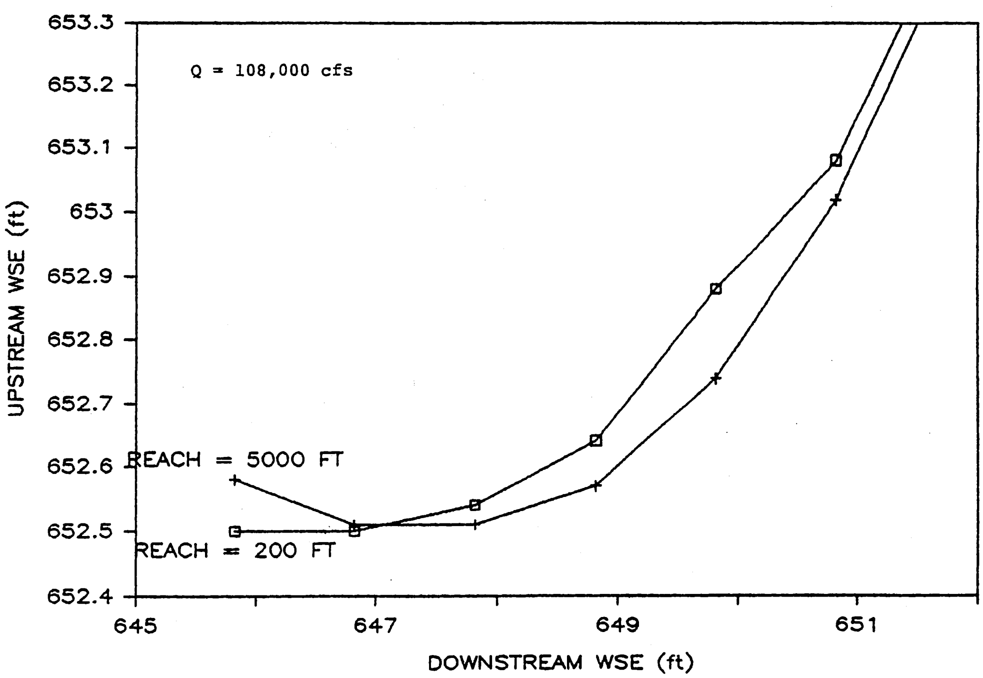


Figure 35. Upstream Versus Downstream WSE, Site 3

foot was computed representing 11 percent of the normal depth, which was found to be 9.30 feet for the Q_{100} flow.

The study of Site 2, Posey Creek, presented a less defined M_1 curve than that generated for Sites 1 and 3. Computations covered a 100-foot reach-length in order to generate a satisfactory number of points. Convergence to normal depth was readily obtained at a distance of 0.11 miles (580 feet) upstream of the Approach Section. The water depth at this section for the Q_{100} flow was computed as 17.70 feet and compared to a normal the depth of 17.00 feet; it represents a backwater equal to four percent of the normal depth.

For the Caney River, Site 3, convergence to the normal depth was obtained at 7.35 miles upstream of the Approach Section. The M_1 generated curve showed eight points before convergence. The normal water depth was determined as 31.55 feet. The depth of water due to the bridge backwater effect was 35.59 feet. The backwater of 3.78 feet represents 12 percent of the normal depth.

Figure 36 shows a dimensionless analysis of the backwater effect for Sites 1, 2, and 3. It correlates the ratio of the backwater extension (L/Lo) to the ratio of the water depth times the ratio between bridge length and the floodplain width. The dimensionless parameter introduced for the Y axis is directly related to the amount of flow under consideration. This was useful in analyzing the backwater caused by different flow discharges.

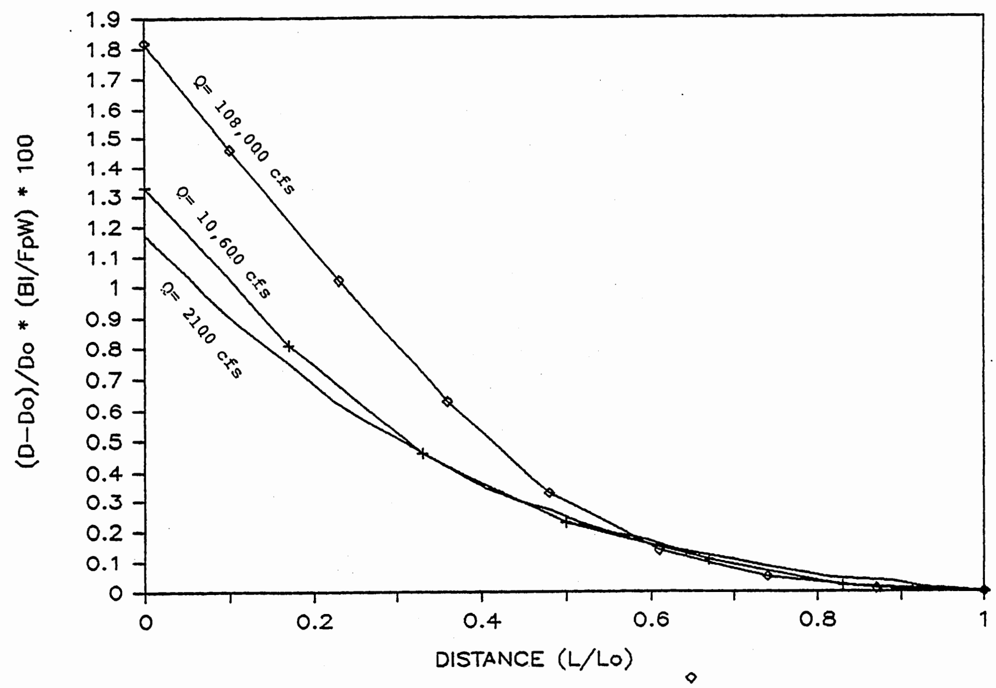


Figure 36. Backwater Analysis, Sites 1, 2, and 3

Channel Slope

A correlation between channel bed slope and water depth at the Approach Section was established in Tables 12 and 13 and is illustrated in Figures 30 and 31. For Site 1, a slope 50 percent smaller caused a 10 percent increase in the water depth at the Approach Section. A slope 127 percent greater produced an 8 percent drop in the water elevation.

Results from the Caney River, Site 3, showed that when the natural slope is changed to 50 percent less, the water depth increases by 1.8 percent. When it is increased by 150 percent, the water depth decreases 1.9 percent.

Summarizing, it was noted that the impact of the channel slope is greater when it decreases than when it increases. This can be attributed primarily to the pressure-flow situation occurring as a consequence of the rise in the water levels. For Site 1, the road grade was removed and a Q_{50} was used in a tentative effort to eliminate this problem. Flow type 3, representing pressure and weir conditions, was still obtained, however. This fact was not observed in the base run for the normal slope. In the Caney River site, flow type 1 was checked for all slopes.

A comparison of the results from both sites is shown in Figure 37. It is observed that a larger discharge, and consequently a wider floodplain, is less sensitive for bed

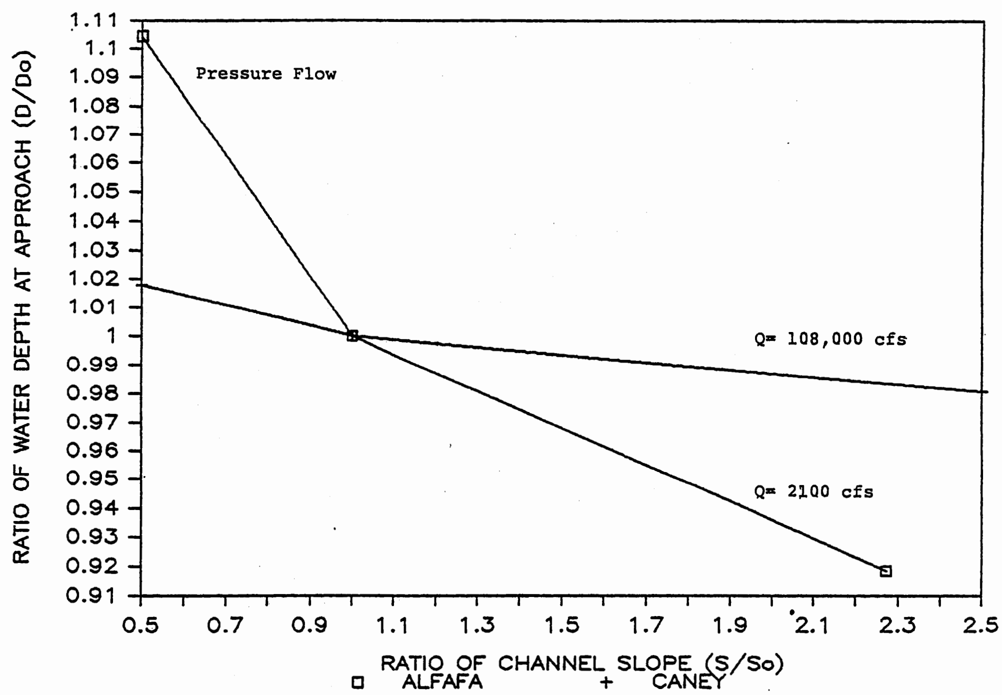


Figure 37. Impact of Channel Slope, Sites 1 and 3

slope parameter. This phenomenon may occur because a large floodplain has more buffer capacity to retain the excess flow caused by water-depth fluctuations.

Friction-Slope-Averaging Technique

From the results obtained in this analysis, presented in Tables 14 and 15, it is noted that the selection of the friction-loss equation has a minor influence on the computed values of the water-surface elevation.

Results for Twin Spring Creek, Site 1, from the HEC 2 run, produced a maximum difference of 0.56 feet corresponding to 6.1 percent of the water depth, measured from the bottom of the main channel. WSPRO simulations generated the same WSE regardless of the equations used. This can be attributed to a particular WSPRO feature, the use of the geometric mean of conveyances for the bridge backwater computation no matter which equation is selected. Also, this site has a relatively short reach with a total length of 127 feet from the Exit to the Approach Sections.

Results for the Caney River, Site 3, showed a maximum difference of 0.39 feet in the WSE computed by different equations using the HEC 2 model and corresponding to 1.2 percent of the normal depth. Almost no difference was obtained by WSPRO's computation for the same reasons given above for Site 1.

Results obtained from HEC 2 runs agreed with Laureson (1986), who ranked the four equations by their relative magnitudes in computing the average friction slope. He concluded analytically and proved experimentally, using simulations with the HEC 2 program, the following relation:

A(S1,S2) > G(S1,S2) > Sk > H(S1,S2) where:

A(S1,S2) = Arithmetic means of reach-end fric. slopes
G(S1,S2) = Geometric " " " " "
H(S1,S2) = Harmonic " " " " "
Sk = Arithmetic " " " " conveyance.

This study also suggests that in a small degree of magnitude

(1) the Hec 2 program appeared to be more sensitive than WSPRO to the friction loss equation; and
(2) the small floodplain site is more sensitive to the selection of the friction-loss equation.

Benchmark Tests

Results of the benchmark tests for hardware performance developed in Chapter VI, and presented in Table 20, are illustrated in Figures 38 and 39. The performance of the PS-2 and the Executive are equivalent. They are, on the average, five times faster than the IBM PC-XT with the mathematical co-processor, which is in turn four times faster than the same machine without the co-processor. For example, to run a small application like the Redfox file it takes 0.7 minute in the PS 2 computer, Machine D, and 9 minutes in the IBM-PC, Machine A. To run a more complex

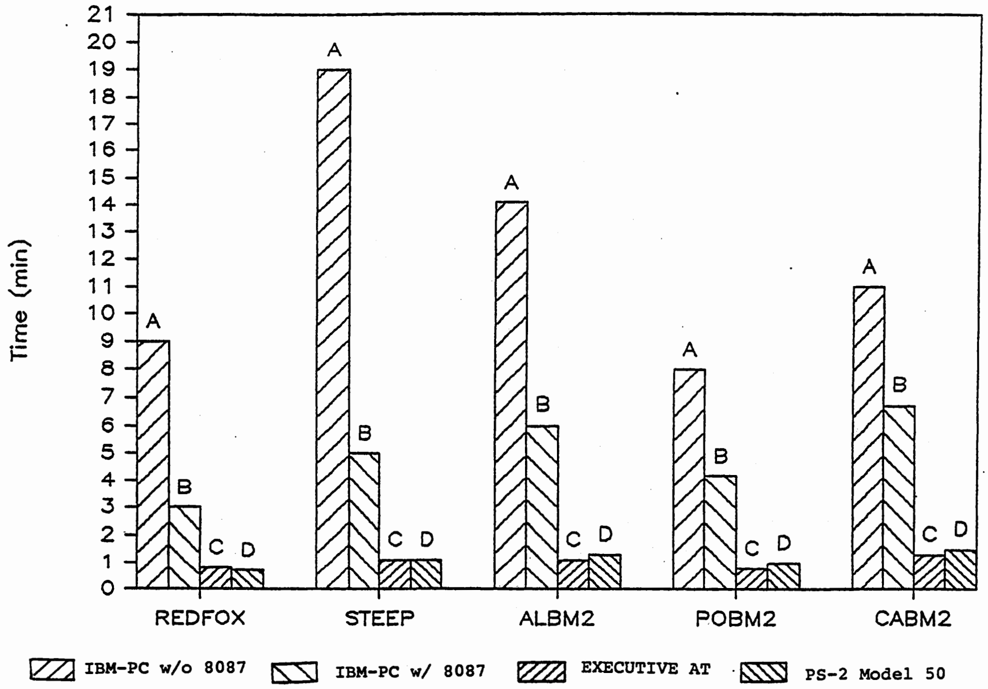


Figure 38. Benchmark Tests WSE Propagation

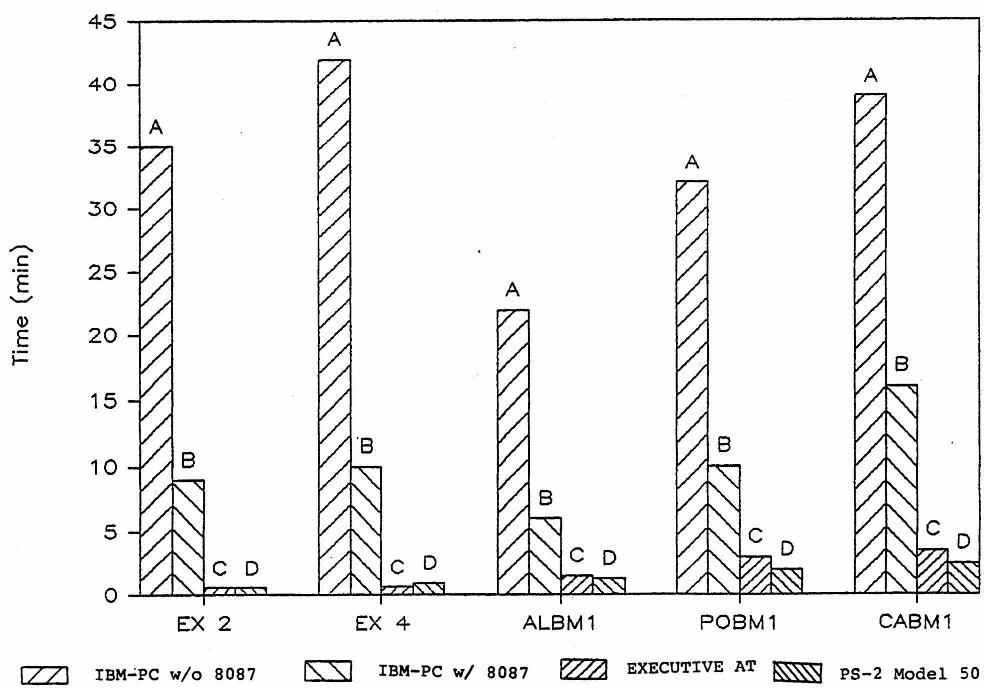


Figure 39. Benchmark Tests with Backwater

application with a bridge backwater computation, as in EX4, takes approximately one minute using Machine D compared to 42 minutes using Machine A.

CHAPTER VIII

CONCLUSION AND RECOMMENDATIONS

A comparative floodway analysis was developed using WSPRO and HEC 2 computer programs. HEC 2 was developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. WSPRO, also known as HY 7, was developed by the USGS for the Federal Highway Administration as a model for bridge design. Recent models always tend to improve an already existing models by incorporating new and desirable features and trying to make their use more attractive. A summary of the main features of each model is presented in Chapter III.

The findings of this study are as follow:

(1) Sites with small floodplains and low discharges are more sensitive to the roughness coefficient and a more accurate evaluation of this parameter is required.

(2) Underestimation of n values is worse than overestimation at low discharges.

(3) The HEC 2 model is more sensitive to the roughness factor than WSPRO. A difference equal to 2 percent was observed.

(4) The reach length has a minor influence on the water-surface elevations of cross-sections when the

hydraulic characteristics of the floodplain do not change much and slope is small.

(5) The WSPRO model is 4 percent more sensitive than HEC 2 to the reach-length parameter.

(6) Channel slope has a higher impact on water levels when it decreases than when it increases.

(7) A small floodplain is more sensitive to channel slope.

(8) Results obtained from the use of different friction-loss equations agree with those found by Laureson (1986). The four equations are based on the magnitude of the water levels generated. They are ranked below.

A(S1,S2) > G(S1,S2) > Sk > H(S1,S2)

where:

A(S1,S2)	= Arith. means of	reach-end	friction	slope		
G(S1,S2)	= Geometric	"	"	"	"	"
H(S1,S2)	= Harmonic	"	"	"	"	"
Sk	= Arithmetic	"	"	"	"	conveyance.

(9) The HEC 2 program appeared to be more sensitive than WSPRO to the friction loss equation .

(10) The site with a small floodplain is more sensitive to the selection of the friction loss-equation.

(11) WSPRO files are generally smaller than HEC 2 files.

(12) HEC 2 run-time is an average of two-and-a-half times smaller than WSPRO's.

(13) The AT type machine can run a simulation problem five times faster than the IBM-PC with mathematical

co-processor which in turn ran the same problem four times faster without the co-processor.

The input data for both models were prepared in a batch mode using the same concept of punch cards as done earlier for mainframe computers. It would be of considerable value for further improvements to develop an expert and user-friendly front program that would guide the input prepara-tion, prompting for the minimum required parameters for generic cases and checking its consistencies before submitting to the main program.

Another suggestion for further upgrading would be the development of a graphics-oriented program to plot the water-surface profile for the WSPRO model, that would show the backwater effects for the entire reach.

SELECTED BIBLIOGRAPHY

Barnes, H. H., Jr, "Roughness Characteristics of Natural Channels," USGS, Water Supply Paper 1849, 1967, 213 pp.

Benson, Manuel A., "Evaluation of Methods for Evaluating the Occurrence of Floods," USGS, WSP 1580-A, 1962, pp A1-A26.

Bhowmik, N. G. and Demissie, M., "Carrying Capacity of Flood Plains," Journal of Hydraulic Division American Society of Civil Engineering, Vol. 108, No. HY3, March, 1982, pp. 443-452.

Bradley, Joseph N., Hydraulics of Bridge Waterways, Hydraulic Design Series No. 1, USDT, FHA, 2nd. ed., Washington, D.C., 1978, 111 pp.

Bridge Waterways Analysis Model Research Report, USDT, Federal Highway Administration, 1986.

Bridge Waterways Analysis Model (WSPRO) User's Manual, USDT, Federal Highway Administration, 1986.

Chadderton, R. A., and Miller, A. C., "Friction Slope Models for M2 Profiles," Water Resources Bulletin, Vol. 16, No. 2, 1980, pp. 235-242.

Chow, V. T., Maidment, D. R. and Mays, L. W., Applied Hydrology, McGraw-Hill Book Co., 1988.

Chow, V. T., Open Channel Hydraulics, McGraw-Hill, Reprint, 1988, 680 pp.

Chow, V. T., Applied Hydrology,, McGraw-Hill, 1st ed., New York: 1964.

Colson, B. E., and Schneider, V. R., "Backwater and Discharge at Highway Crossings with Multiple Bridges," USGS, W.R.I 83-4065, 1983, 39 pp.

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

Corps of Engineers, "Personal Comunication," Water Levels for Flood 1986, Caney River at US-75, 1987.

Davidian, Jacob, "Computation of Water-Surface Profiles in Open-Channels," USGS, Techniques of Water Surface Investigations, Book 3, Chap. A15, 1984, 48 pp.

Davidian, Jacob, Carrigan, P. H., and Shen, J., "Flow Through Openings in Width Constrictions," USGS, Water Supply Paper 1369-D, 1962, pp. 108-112.

Eichert, B.S., "Survey of Programs for Water-Surface Profiles," ASCE, JHD, Vol. 96, No. HY2, February, 1970, pp. 547-563.

Eichert, B. S., "HEC Software Development and Support," Proceedings of the Emerging Computer Techniques in Stormwater and Flood Management, Ontario, Canada, October, 1983.

Feldman, Arlen D., "HEC Models for Water Resources System Simulation: Theory and Experience," Advances in Hydroscience, Vol. 12, Academic Press, 1981, pp. 297-243.

French, R. H., Open Channel Hydraulics, McGraw-Hill, New York, 1985, 705 pp.

Heggen, R. J., "Flood Routing on a Small Computer," Journal of Civil Engineering, ASCE, Vol. 53, No. 3, March, 1983, pp. 63-66.

Henderson, F. M., Open Channel Flow, Macmillan Publisher, New York, 1966, 522 pp.

Kindsvater, C. E. and Carter, R. W., "Tranquil Flow Through Opening-Channel Constrictions," ASCE Transactions, Paper No. 2770, V. 120, 1955, 955 pp.

Knight, D. W. and Demetriou, J. D., "Flood Plain and Main Channel Flow Interaction," JHD, ASCE, Vol. 109, No.8, August, 1983, pp. 1073-1092.

Laureson, Eric M., "Friction Slope Averaging in Backwater Calculations," JHD, ASCE, Vol. 112, No.12, December, 1986, pp. 1151-1163.

Laursen, Emmett M., "Bridge Backwater in Wide Valleys," JHD, ASCE, Vol. 96 No. HY4, April, 1970, 1019 pp.

Lee, F.N., "Field Verification of Method for Distributing Flow Through Multiple-Bridge Openings," Journal of Research of the USGS, Vol. 4, No. 5, Sep-Oct, 1976, pp. 539-543.

Lee, Jonathan K., "Potential Flow Through Channel Constriction," JHD, ASCE, Vol. 110, No.4, April, 1984, pp. 515-520.

Lester, S. Dixon, "Selecting Terminal W.S.E.," JHD, ASCE, Vol. 112, No. 5, May, 1988, pp. 428-431.

Liu, H. K., Bradley, J. N., and Plate, E. J., "Backwater Effects of Piers and Abutments," Proj. Rept., in cooperation with W.S. Dept. of Commerce, Bur. of Public Roads , Colorado State University, October, 1957, 364 pp.

Matthai, H. F., "Measurement of Peak Discharge at Width Contractions by Indirect Methods," USGS, Tech. of W.R.I., Book 3, Chap. A4, 44 pp.

Mitchell, William D., "Effect of Reservoir on Peak Flow," USGS, WSP 1580-C, 1962, pp. C1-C24.

Nwaogazie, F. and Tyagi, A. K., "Unified Stream Flow Routing by Finite Elements," JHD, ASCE, Vol. 110, No. 11, November, 1984, pp. 1595-1611.

Rao, N. S. L. and Sridharan, K, "Effect of Channel Shape on Gradually Varied Flow Profiles," JHD, ASCE, Vol. 97, HYI, January, 1971, pp. 55-64.

Rao, N. S. L., and Sridharan K., "Characteristics of M1 Backwater Curves," JHD, ASCE, Vol. 92, HY6, November 1966, pp. 131-139.

Reed, J. R., "Accurate Energy Gradients for Varied Flow," Abstract of the 22nd Annual Meeting of the Society of Engineering Science, Inc., University Park, Pa, 1985, pp. 222.

Reed, J. R. and Wolfkill, A. J., "Evaluation of Friction Slopes Models," River 76, Symposium on Inland Waterways for Navigation Flood Control and Water Diversions, Colorado State University, 1976.

Saburo, Komura, "Method for Computing Bed Profiles During Floods," JHD, ASCE, Vol. 112, No. 9, September, 1986.

Schneider, V. R., Board, J. W., Colson, B. E., Lee, F. N., and Druffel, L. A., "Computation of Backwater and Discharge at Width Constrictions of Heavily Vegetated Flood Plains," USGS, Water Resources Investigation 76-129, February, 1977, 64 pp.

Street, R. L. and Vennard J. K., Elementary Fluid Mechanics, 5th. ed., John Wiley & Sons, 1975.

Tavener, G. F., "Stability and Reach Length in Water Surface Profile Determination," Water Resources Bulletin, American Water Resources Association, Vol. 9, No 5, October, 1973, pp. 950-962.

Thomas, W. A. "Water Surface Profiles, Hydrologic Engineering Methods for Water Resources Development," Vol. 6, IHD(1965-1974), The Hydrologic Engineering Center, U.S. Army, Davis, CA, July, 1975, pp. 514-517.

Tracy, H. J., and Carter, R. W., "Backwater Effects of Open-Channel Constrictions," ASCE Transactions, Paper 2771, Vol. 120, 1955, 993 pp.

Tyagi, A. K., Shearmann, J., and Arneson, L., "WSPRO Workshop," Engineering Extension, Oklahoma State University, Oklahoma City, Oklahoma, September 20-22, 1988.

Tyagi, A. K., and Nwaogazie, F., "Finite Element Kinematic Model for Flood Routing," Report No. R(S)22 Water Resources Center, School of Civil Engineering, Oklahoma State University, May, 1982, 75 pp.

Tyagi, A. K., "Analysis of October 1986 Flood in Caney River at U.S. 75," Report 88-2 WRC, School of Civil Engineering, Oklahoma State University, Stillwater, Oklahoma, 1988, 36 pp.

Vallentine, H.R."Generalized Profiles of Gradually Varied Flow," JHD, ASCE, Vol. 93, HY2, March, 1967 pp 17-24.

Vallentine, H.R., "Characteristics of the Backwater Curve," JHD, ASCE, Vol. 90, No. HY4, July, 1964, pp. 39-49.

Vallentine, H. R., "Generalized Profile for Gradually Varied Flow," JHD, ASCE, Vol. 93, No. HY2, March, 1976, pp. 17-24.

Viessman, W. Jr, Knapp, J. W., Lewis, G.R. and Harbaugh, T. E., Introduction to Hydrology, Second Edition, Harper & Row Publishers, 1977, 704 pp.

Wormleaton, P. R., Allen, J., and Hadjipanos, P., "Discharge Assessment in Compound Channel Flow," JHD, ASCE, Vol. 108, No. 9, September, 1982, pp. 975-994.

Yeou-Koung Tung, "River Flood Routing by Nonlinear Muskingum Method," ASCE, JHD, Vol. 111, No. 12, December, 1985, pp. 1447-1460.

APPENDIXES

APPENDIX A

PROGRAM RUNS WSPRO MODEL

SITE 1 - TWIN SPRING CREEK

ALFALFA COUNTY

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         *** RUN DATE & TIME: 04-13-89  14:04

  T1       TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
  T2       10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
  T3       45 EFFECTIVE BRIDGE LENGTH  JV6A SETUP  ***
  *
  Q        850 1300 1650 2100
*** Q-DATA FOR SEC-ID, ISEQ =           1
  SK       0.00088 0.00088 0.00088 0.00088
  *
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
       10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
       45 EFFECTIVE BRIDGE LENGTH  JV6A SETUP  ***
         *** RUN DATE & TIME: 04-13-89  14:04

*** START PROCESSING CROSS SECTION - "EXIT "
  XS   EXIT 0
  GR       0,1260 400,1250.5 475,1249 487,1246 495,1245.5
  GR       500,1246 510,1249.5 600,1260
  N        0.06,0.07,0.06,0.05,0.045,0.06,0.1
  SA       400,475,487,495,500,510
  *

*** FINISH PROCESSING CROSS SECTION - "EXIT "
*** CROSS SECTION "EXIT " ADDED TO DAF, RECORD NO. =    1, IXTYPE =    1

--- DATA SUMMARY FOR SECID "EXIT " AT SRD =      0.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0000      .50       .00

X-Y COORDINATE PAIRS  (NGP =   8):
       X       Y          X       Y          X       Y          X       Y
      .0 1260.00      400.0 1250.50      475.0 1249.00      487.0 1246.00
   495.0 1245.50      500.0 1246.00      510.0 1249.50      600.0 1260.00

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
       .0 1260.00      495.0 1245.50      600.0 1260.00         .0 1260.00

 SUBAREA BREAKPOINTS (NSA =  7):
        400.    475.    487.    495.    500.    510.

 ROUGHNESS COEFFICIENTS (NSA =  7):
         .060    .070    .060    .050    .045    .060    .100
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
        10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
        45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
           *** RUN DATE & TIME: 04-13-89  14:04

*** START PROCESSING CROSS SECTION - "FULLV"
  XS   FULLV 45 * * * 0.00088
  *

*** FINISH PROCESSING CROSS SECTION - "FULLV"
*** CROSS SECTION "FULLV" ADDED TO DAF, RECORD NO. =    2, IXTYPE =    1

--- DATA SUMMARY FOR SECID "FULLV" AT SRD =     45.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0009      .50       .00

X-Y COORDINATE PAIRS  (NGP =   8):
       X      Y          X      Y          X      Y          X      Y
       .0 1260.04     400.0 1250.54     475.0 1249.04     487.0 1246.04
    495.0 1245.54     500.0 1246.04     510.0 1249.54     600.0 1260.04

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
       .0 1260.04     495.0 1245.54     600.0 1260.04        .0 1260.04

 SUBAREA BREAKPOINTS (NSA =  7):
        400.    475.    487.    495.    500.    510.

 ROUGHNESS COEFFICIENTS (NSA =  7):
         .060    .070    .060    .050    .045    .060    .100
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
        10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
        45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
           *** RUN DATE & TIME: 04-13-89  14:04

*** START PROCESSING CROSS SECTION - "BRDGE"
  BR   BRDGE 45 1254.5
  BD        3.5 1258  0.00 500
  BL        45 475 510
  CD        3 27 2 1250
  *

*** FINISH PROCESSING CROSS SECTION - "BRDGE"
*** CROSS SECTION "BRDGE" ADDED TO DAF, RECORD NO. =    3, IXTYPE =    2

--- DATA SUMMARY FOR SECID "BRDGE" AT SRD =     45.  ERR-CODE =     0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0009       .50       .00

X-Y COORDINATE PAIRS  (NGP =  10):
       X      Y           X      Y           X      Y           X      Y
    470.0 1254.50     470.0 1249.14     475.0 1249.04     487.0 1246.04
    495.0 1245.54     500.0 1246.04     510.0 1249.54     515.0 1250.12
    515.0 1254.50     470.0 1254.50

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
    470.0 1254.50     495.0 1245.54     515.0 1250.12     470.0 1254.50

SUBAREA BREAKPOINTS (NSA =  7):
        400.    475.    487.    495.    500.    510.

ROUGHNESS COEFFICIENTS (NSA =  7):
         .060    .070    .060    .050    .045    .060    .100

BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  ABSLPL  ABSLPR
    3      27.0  1254.50 *******   2.00  1250.00 ******* *******

DESIGN DATA:    BRLEN  LOCOPT   XABLT   XABRT
                 45.0      0.   475.0   510.0

               GIRDEP  BDELEV   BDSLP   BDSTA      PARPHT   PARPX
                 3.50 1258.00   .0000   500.0     ******* *******
PIER DATA:  NPW =  0   PCODE = **
```

```
WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
        10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY    SITE 1
        45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
           *** RUN DATE & TIME: 04-13-89  14:04

*** START PROCESSING CROSS SECTION - "ROAD "
  XR   ROAD 45, 26, 2
  GR        0,1257.5 100,1256 200,1255.4 310,1256.5 400,1258
  GR        580,1258  600,1260

*** FINISH PROCESSING CROSS SECTION - "ROAD "
*** CROSS SECTION "ROAD " ADDED TO DAF, RECORD NO. =    4, IXTYPE =    4

--- DATA SUMMARY FOR SECID "ROAD " AT SRD =     45.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0009      .50       .00

X-Y COORDINATE PAIRS  (NGP =   7):
       X      Y           X      Y           X      Y           X      Y
      .0 1257.50      100.0 1256.00      200.0 1255.40      310.0 1256.50
   400.0 1258.00      580.0 1258.00      600.0 1260.00

 X-Y MAX-MIN POINTS:
     XMIN       Y           X    YMIN      XMAX       Y           X    YMAX
      .0 1257.50      200.0 1255.40      600.0 1260.00      600.0 1260.00

 SUBAREA BREAKPOINTS (NSA =  7):
        400.    475.    487.    495.    500.    510.

 ROUGHNESS COEFFICIENTS (NSA =  7):
         .060    .070    .060    .050    .045    .060    .100

 ROAD GRADE DATA:  IPAVE  RDWID  USERCF
                      2.   26.0 *******

 BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                          ******* ******* ******* *******
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
       10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
       45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
          *** RUN DATE & TIME: 04-13-89  14:04

*** START PROCESSING CROSS SECTION - "APRCH"
  AS   APRCH127  * * * 0.00088
  *
  EX

*** FINISH PROCESSING CROSS SECTION - "APRCH"
*** CROSS SECTION "APRCH" ADDED TO DAF, RECORD NO. =    5, IXTYPE =    5

--- DATA SUMMARY FOR SECID "APRCH" AT SRD =    127.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0009       .50       .00

X-Y COORDINATE PAIRS  (NGP =   8):
       X       Y          X       Y          X       Y          X       Y
      .0 1260.11      400.0 1250.61      475.0 1249.11      487.0 1246.11
   495.0 1245.61      500.0 1246.11      510.0 1249.61      600.0 1260.11

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
      .0 1260.11      495.0 1245.61      600.0 1260.11         .0 1260.11

SUBAREA BREAKPOINTS (NSA =  7):
        400.    475.    487.    495.    500.    510.

ROUGHNESS COEFFICIENTS (NSA =  7):
         .060    .070    .060    .050    .045    .060    .100

BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                         ******* ******* ******* *******

 NPROF, NQV  =      4     7


 +++ BEGINNING PROFILE CALCULATIONS --      4
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
       10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY    SITE 1
       45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
          *** RUN DATE & TIME: 04-13-89  14:04

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

EXIT :XS   ******   316.     524.   .08 ***** 1252.58 1250.11    850. 1252.50
        0. ******   536.   28652.  2.02 ***** *******     .26    1.62

FULLV:FV      45.   316.     525.   .08    .04 1252.63 *******    850. 1252.54
       45.    45.   536.   28705.  2.02    .00     .00     .26    1.62
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS      82.   315.     526.   .08    .07 1252.70 *******    850. 1252.62
      127.    82.   536.   28770.  2.02    .00     .00     .26    1.62
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

BRDGE:BR      45.   470.     222.   .31    .06 1252.76 1249.96    850. 1252.44
       45.    45.   515.   17579.  1.37    .11     .00     .36    3.83

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN   XLAB   XRAB
       3. ****   1.    .853 ****** 1254.50     45.   470.   515.

    XSID:CODE     SRD   FLEN     HF    VHD      EGL      ERR       Q    WSEL
   ROAD :RG       45.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

APRCH:AS      55.   307.     574.   .07    .08 1252.90 1250.22    850. 1252.83
      127.    61.   538.   31753.  2.00    .06     .00     .23    1.48

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .796   .367   20077.   463.   508.  1252.79

                 <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

      TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16         HY7AL.DAT
      10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
      45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
        *** RUN DATE & TIME: 04-13-89  14:04

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

EXIT :XS   ******   276.     757.   .09 ***** 1253.54 1250.94   1300. 1253.45
       0. ******   544.   43782.  1.94 ***** *******     .25    1.72

FULLV:FV      45.   276.     758.   .09   .04 1253.58 *******   1300. 1253.50
      45.     45.   544.   43860.  1.94   .00     .00     .25    1.72
      <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS      82.   275.     759.   .09   .07 1253.66 *******   1300. 1253.57
     127.     82.   544.   43950.  1.94   .00     .00     .25    1.71
      <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

         <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

BRDGE:BR      45.   470.     261.   .59   .08 1253.91 1250.83   1300. 1253.32
      45.     45.   515.   22431.  1.52   .29     .00     .45    4.98

    TYPE PPCD FLOW       C    P/A    LSEL    BLEN   XLAB   XRAB
      3. ****   1.    .810 ****** 1254.50    45.    470.   515.

   XSID:CODE     SRD   FLEN    HF   VHD     EGL      ERR        Q    WSEL
  ROAD :RG       45.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
      SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

APRCH:AS      55.   256.     885.   .06   .09 1254.09 1251.05   1300. 1254.02
     127.     63.   548.   52683.  1.89   .09     .00     .20    1.47

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .832   .500   26295.   457.   502.  1253.99

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
        10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
        45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
           *** RUN DATE & TIME: 04-13-89  14:04

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL     CRWS       Q     WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR      FR#     VEL

EXIT :XS   ******   251.     925.    .09 ***** 1254.14 1251.34   1650. 1254.05
        0. ******   549.   55584.   1.88 ***** *******     .24    1.78

FULLV:FV      45.   250.     927.    .09   .04 1254.18 *******   1650. 1254.09
       45.    45.   549.   55678.   1.88   .00     .00     .24    1.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS      82.   250.     928.    .09   .07 1254.26 *******   1650. 1254.17
      127.    82.   549.   55783.   1.88   .00     .00     .24    1.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =  1253.86    1254.72    1254.82    1254.50

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.08     1255.04     1255.16

 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL     CRWS       Q     WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR      FR#     VEL

BRDGE:BR      45.   470.     285.    .81   .09 1254.67 1251.40   1650. 1253.86
       45.    45.   515.   25647.   1.56   .44     .00     .51    5.78

     TYPE PPCD FLOW      C    P/A     LSEL   BLEN   XLAB   XRAB
       3. ****   1.   .800 ****** 1254.50    45.   470.   515.

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   ROAD :RG      45.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL     CRWS       Q     WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR      FR#     VEL
```

```
APRCH:AS      55.    223.     1132.    .06    .10 1254.88 1251.45    1650. 1254.82
     127.     64.    555.    70888.   1.82    .11     .00     .19     1.46

      M(G)    M(K)       KQ   XLKQ    XRKQ    OTEL
      .849    .604   28068.   452.    497.  1254.79

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        TWIN SPRING CREEK AT ALFALFA COUNTY -ODOT SITE 16        HY7AL.DAT
        10,25,50 AND 100 YR FLOOD      CASE STUDY TULSA COUNTY     SITE 1
        45 EFFECTIVE BRIDGE LENGTH  JVGA SETUP  ***
           *** RUN DATE & TIME: 04-13-89  14:04

 XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS       Q    WSEL
       SRD   FLEN     REW        K   ALPH     HO      ERR      FR#     VEL

EXIT :XS   ******    223.     1131.    .10 ***** 1254.80 1251.76    2100. 1254.70
        0. ******    555.    70747.   1.83 ***** *******     .24     1.86

FULLV:FV      45.    223.     1132.    .10    .04 1254.84 *******    2100. 1254.74
      45.     45.    555.    70860.   1.82    .00     .00     .24     1.86
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS      82.    223.     1134.    .10    .07 1254.92 *******    2100. 1254.82
     127.     82.    555.    70983.   1.82    .00     .00     .24     1.85
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                         WS3N,LSEL =  1254.74    1254.50

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS       Q    WSEL
       SRD   FLEN     REW        K   ALPH     HO      ERR      FR#     VEL
```

```
BRDGE:BR      45.   470.     314.   .87 ***** 1255.37 1251.99   2056. 1254.50
        45. ******   515.   19071.  1.31 ***** *******     .50    6.54

      TYPE PPCD FLOW       C    P/A    LSEL    BLEN   XLAB   XRAB
        3. ****   6.    .800 ****** 1254.50    45.   470.   515.

     XSID:CODE     SRD    FLEN    HF    VHD     EGL     ERR       Q    WSEL
     ROAD :RG      45.     56.   .02    .05 1255.90     .00     46. 1255.82

                 Q   WLEN    LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
     LT:       46.   112.   130.   242.    .4    .2   2.1   2.0    .3   2.6
     RT:        0. ****** ****** ****** ***** ***** ***** ***** ***** *****

   XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
         SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APRCH:AS      55.   178.    1512.   .05   .15 1255.93 1251.87   2100. 1255.88
       127.    65.   564. 100986.  1.74   .11     .00     .16    1.39

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      ****** ****** ******** ****** ****** ********

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

SITE 2 - POSEY CREEK

TULSA COUNTY

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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         *** RUN DATE & TIME: 04-13-89  13:59

  T1        INDUSTRIAL BYPASS                             HY7PO.DAT
  T2        POSEY CREEK IN TULSA COUNTY  CASE STUDY         SITE 2
  T3        100 YEAR FLOOD
  *
  *                                              (ORIGINAL FILE)
  Q         10900
*** Q-DATA FOR SEC-ID, ISEQ =           1
  SK        0.005427
  *
```

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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       INDUSTRIAL BYPASS                                    HY7PO.DAT
       POSEY CREEK IN TULSA COUNTY  CASE STUDY               SITE 2
       100 YEAR FLOOD
          *** RUN DATE & TIME: 04-13-89  13:59
 *** START PROCESSING CROSS SECTION - "EXIT "
  XS    EXIT  0 * * *
  GR        1000.0 646.2  1052.9 644.5  1066.2 645.6  1082.9 643.5
  GR        1146.2 641.8  1180.9 639.1  1326.8 634.7  1451.2 632.0
  GR        1491.8 631.9  1527.3 629.9  1656.2 627.6  1779.9 625.8
  GR        1913.5 623.8  2057.1 620.7  2168.3 617.2  2308.9 615.4
  GR        2389.3 615.4  2447.4 616.5  2468.8 600.8  2483.1 599.7
  GR        2492.9 600.8  2514.4 610.9  2552.1 613.9  2616.9 615.4
  GR        2758.3 614.8  2870.0 614.2  3014.5 613.9  3047.0 614.5
  GR        3096.3 614.7  3250.7 615.1  3415.8 616.9  3601.5 619.0
  GR        3674.8 620.5  3707.2 622.0  3859.1 625.9  4022.2 632.2
  GR        4129.1 637.6
  N         .05 .07 .05
  SA         2447.4  2616.9
  *
*** FINISH PROCESSING CROSS SECTION - "EXIT "
*** CROSS SECTION "EXIT " ADDED TO DAF, RECORD NO. =     1, IXTYPE =    1
--- DATA SUMMARY FOR SECID "EXIT " AT SRD =      0.  ERR-CODE =      0
     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0000      .50       .00

X-Y COORDINATE PAIRS  (NGP =  37):
       X       Y          X       Y          X       Y          X       Y
   1000.0  646.20    1052.9  644.50    1066.2  645.60    1082.9  643.50
   1146.2  641.80    1180.9  639.10    1326.8  634.70    1451.2  632.00
   1491.8  631.90    1527.3  629.90    1656.2  627.60    1779.9  625.80
   1913.5  623.80    2057.1  620.70    2168.3  617.20    2308.9  615.40
   2389.3  615.40    2447.4  616.50    2468.8  600.80    2483.1  599.70
   2492.9  600.80    2514.4  610.90    2552.1  613.90    2616.9  615.40
   2758.3  614.80    2870.0  614.20    3014.5  613.90    3047.0  614.50
   3096.3  614.70    3250.7  615.10    3415.8  616.90    3601.5  619.00
   3674.8  620.50    3707.2  622.00    3859.1  625.90    4022.2  632.20
   4129.1  637.60
 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
   1000.0  646.20    2483.1  599.70    4129.1  637.60    1000.0  646.20

SUBAREA BREAKPOINTS (NSA =  3):
       2447.   2617.

ROUGHNESS COEFFICIENTS (NSA =  3):
         .050    .070    .050
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

      INDUSTRIAL BYPASS                                  HY7PO.DAT
      POSEY CREEK IN TULSA COUNTY  CASE STUDY             SITE 2
      100 YEAR FLOOD
         *** RUN DATE & TIME: 04-13-89  13:59
 *** START PROCESSING CROSS SECTION - "FULLV"
  XS   FULLV     100 * * * 0.005427
  GR       1000.0 646.3  1052.9 644.6  1066.2 645.6  1082.9 643.5
  GR       1146.2 641.9  1180.9 639.2  1326.8 634.8  1451.2 632.1
  GR       1491.8 632.0  1527.3 630.0  1656.2 627.7  1779.9 625.9
  GR       1913.5 623.9  2057.1 620.8  2168.3 617.3  2308.9 615.5
  GR       2389.3 615.5  2447.4 616.6  2468.8 600.9  2483.1 599.8
  GR       2492.9 600.9  2514.4 611.0  2552.1 614.0  2616.9 615.5
  GR       2758.3 614.9  2870.0 614.3  3014.5 614.0  3047.0 614.6
  GR       3096.3 614.8  3250.7 615.2  3415.8 617.0  3601.5 619.1
  GR       3674.8 620.6  3707.2 622.1  3859.1 626.0  4022.2 632.3
  GR       4129.1 637.7
  N        .05 .07 .05
  SA       2447.40 2616.9
  *
*** FINISH PROCESSING CROSS SECTION - "FULLV"
*** CROSS SECTION "FULLV" ADDED TO DAF, RECORD NO. =    2, IXTYPE =    1

--- DATA SUMMARY FOR SECID "FULLV" AT SRD =    100.  ERR-CODE =      0
     SKEW     IHFNO    VSLOPE        EK        CK
      .0        0.      .0054       .50       .00

X-Y COORDINATE PAIRS  (NGP =  37):
       X      Y          X      Y          X      Y          X      Y
   1000.0  646.30    1052.9  644.60    1066.2  645.60    1082.9  643.50
   1146.2  641.90    1180.9  639.20    1326.8  634.80    1451.2  632.10
   1491.8  632.00    1527.3  630.00    1656.2  627.70    1779.9  625.90
   1913.5  623.90    2057.1  620.80    2168.3  617.30    2308.9  615.50
   2389.3  615.50    2447.4  616.60    2468.8  600.90    2483.1  599.80
   2492.9  600.90    2514.4  611.00    2552.1  614.00    2616.9  615.50
   2758.3  614.90    2870.0  614.30    3014.5  614.00    3047.0  614.60
   3096.3  614.80    3250.7  615.20    3415.8  617.00    3601.5  619.10
   3674.8  620.60    3707.2  622.10    3859.1  626.00    4022.2  632.30
   4129.1  637.70
 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
   1000.0  646.30    2483.1  599.80    4129.1  637.70    1000.0  646.30

SUBAREA BREAKPOINTS (NSA =  3):
      2447.   2617.

ROUGHNESS COEFFICIENTS (NSA =  3):
        .050    .070    .050
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       INDUSTRIAL BYPASS                                  HY7PO.DAT
       POSEY CREEK IN TULSA COUNTY  CASE STUDY             SITE 2
       100 YEAR FLOOD
         *** RUN DATE & TIME: 04-13-89  13:59

*** START PROCESSING CROSS SECTION - "BRDGE"
  BR   BRDGE100  619.7 * 0.5 0.3
  BD        3.75 623.45 0.00 2700
  BL        551 2468.8 2870.0
  CD        2 32 0 618
  PW        610 3 611 9 614 18
  *

*** FINISH PROCESSING CROSS SECTION - "BRDGE"
*** CROSS SECTION "BRDGE" ADDED TO DAF, RECORD NO. =    3, IXTYPE =    2

--- DATA SUMMARY FOR SECID "BRDGE" AT SRD =     100.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0       0.     .0054      .50       .30

X-Y COORDINATE PAIRS  (NGP =  14):
        X       Y          X       Y          X       Y          X       Y
   2393.9  619.70     2393.9  615.59     2447.4  616.60     2468.8  600.90
   2483.1  599.80     2492.9  600.90     2514.4  611.00     2552.1  614.00
   2616.9  615.50     2758.3  614.90     2870.0  614.30     2944.9  614.14
   2944.9  619.70     2393.9  619.70

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
   2393.9  619.70     2483.1  599.80    2944.9  614.14     2393.9  619.70

SUBAREA BREAKPOINTS (NSA =  3):
      2447.   2617.

ROUGHNESS COEFFICIENTS (NSA =  3):
         .050    .070    .050

BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  EMBSS    EMBELV    YABLT    YABRT
    2      32.0   619.70 *******    .00    618.00   615.59   614.14

DESIGN DATA:     BRLEN  LOCOPT   XABLT   XABRT
                 551.0      0.  2468.8  2870.0

                GIRDEP  BDELEV   BDSLP   BDSTA     PARPHT   PARPX
                  3.75  623.45   .0000  2700.0     ******* *******
```

```
PIER DATA:  NPW =  3   PCODE = 0.
    PELV  PWDTH      PELV  PWDTH      PELV  PWDTH      PELV  PWDTH
   610.00   3.0     611.00   9.0     614.00  18.0

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       INDUSTRIAL BYPASS                                  HY7PO.DAT
       POSEY CREEK IN TULSA COUNTY  CASE STUDY             SITE 2
       100 YEAR FLOOD
          *** RUN DATE & TIME: 04-13-89  13:59

*** START PROCESSING CROSS SECTION - "ROAD "
  XR   ROAD 100 32 1
  GR        1779.9 625.9  1913.5 623.9  2400 624.5  3000 624.5  3700 625
  *

*** FINISH PROCESSING CROSS SECTION - "ROAD "
*** CROSS SECTION "ROAD " ADDED TO DAF, RECORD NO. =    4, IXTYPE =    4

--- DATA SUMMARY FOR SECID "ROAD " AT SRD =    100.  ERR-CODE =      0

    SKEW     IHFNO    VSLOPE       EK        CK
      .0        0.     .0054      .50       .30

X-Y COORDINATE PAIRS  (NGP =   5):
      X       Y          X       Y          X       Y          X       Y
   1779.9  625.90    1913.5  623.90    2400.0  624.50    3000.0  624.50
   3700.0  625.00

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
   1779.9  625.90    1913.5  623.90    3700.0  625.00    1779.9  625.90

SUBAREA BREAKPOINTS (NSA =  3):
      2447.   2617.

ROUGHNESS COEFFICIENTS (NSA =  3):
        .050    .070    .050

ROAD GRADE DATA:  IPAVE  RDWID  USERCF
                     1.   32.0 *******

BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                        ******* ******* ******* *******
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186         MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       INDUSTRIAL BYPASS                                 HY7PO.DAT
       POSEY CREEK IN TULSA COUNTY  CASE STUDY            SITE 2
       100 YEAR FLOOD
          *** RUN DATE & TIME: 04-13-89  13:59

*** START PROCESSING CROSS SECTION - "APRCH"
  AS   APRCH   651
  *
  EX

*** FINISH PROCESSING CROSS SECTION - "APRCH"
*** CROSS SECTION "APRCH" ADDED TO DAF, RECORD NO. =    5, IXTYPE =    5

--- DATA SUMMARY FOR SECID "APRCH" AT SRD =    651.  ERR-CODE =      0

     SKEW    IHFNO    VSLOPE       EK       CK
       .0       0.     .0054      .50      .30

X-Y COORDINATE PAIRS  (NGP =  37):
       X       Y          X       Y          X       Y          X       Y
   1000.0  649.29    1052.9  647.59    1066.2  648.59    1082.9  646.49
   1146.2  644.89    1180.9  642.19    1326.8  637.79    1451.2  635.09
   1491.8  634.99    1527.3  632.99    1656.2  630.69    1779.9  628.89
   1913.5  626.89    2057.1  623.79    2168.3  620.29    2308.9  618.49
   2389.3  618.49    2447.4  619.59    2468.8  603.89    2483.1  602.79
   2492.9  603.89    2514.4  613.99    2552.1  616.99    2616.9  618.49
   2758.3  617.89    2870.0  617.29    3014.5  616.99    3047.0  617.59
   3096.3  617.79    3250.7  618.19    3415.8  619.99    3601.5  622.09
   3674.8  623.59    3707.2  625.09    3859.1  628.99    4022.2  635.29
   4129.1  640.69

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
   1000.0  649.29    2483.1  602.79    4129.1  640.69    1000.0  649.29

 SUBAREA BREAKPOINTS (NSA =  3):
       2447.   2617.

 ROUGHNESS COEFFICIENTS (NSA =  3):
         .050    .070    .050

 BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                          ******* ******* ******* *******

  NPROF, NQV  =       1     4

 +++ BEGINNING PROFILE CALCULATIONS --      1
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 WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY

P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       INDUSTRIAL BYPASS                              HY7PO.DAT
       POSEY CREEK IN TULSA COUNTY  CASE STUDY         SITE 2
       100 YEAR FLOOD
          *** RUN DATE & TIME: 04-13-89  13:59

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL     CRWS        Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR      FR#      VEL

EXIT :XS   ******  2208.    2733.   .31 *****  616.99  615.79  10900.  616.69
       0. ******  3396.  147928.  1.23 ***** *******     .51     3.99

FULLV:FV     100.  2175.    3260.   .21   .43  617.43 *******  10900.  617.22
     100.    100.  3435.  186355.  1.18   .00     .00     .40     3.34
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS     551.  2216.    2618.   .34  2.51  620.02 *******  10900.  619.68
     651.    551.  3387.  139965.  1.25   .07     .02     .55     4.16
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL     CRWS        Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR      FR#      VEL

BRDGE:BR     100.  2394.    1888.   .89   .67  617.85  616.11  10900.  616.96
     100.    100.  2945.  119092.  1.71   .18    -.01     .72     5.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       2.   0.   1.   .765   .053  619.70   551.  2394.  2945.

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   ROAD :RG     100.         <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL     CRWS        Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR      FR#      VEL

APRCH:AS     519.  2162.    3614.   .16  2.54  620.65  618.89  10900.  620.49
     651.    546.  3460.  214261.  1.16   .27     .00     .34     3.02

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .530   .304  149083.  2402.  2953.  619.14

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
 ER
 NORMAL  END  OF  WSPRO  EXECUTION.
```

SITE 3 - CANEY RIVER

WASHINGTON COUNTY

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         *** RUN DATE & TIME: 04-13-89  14:00

  T1        MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
  T2        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
  T3        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
  *                                   CASE STUDY                     SITE 3
  Q         42800 51400 108000
*** Q-DATA FOR SEC-ID, ISEQ =          1
  SK        .0004 .0004 .0004
  *
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

*** START PROCESSING CROSS SECTION - "EXIT "
  XS   EXIT  0 * * *
  GR       0 670 60 652 100 650 160 640 200 617 230 614
  GR       270 617 290 635 400 639  500  651 1600 645 3047 644
  GR       5353 644 8282 650 10625 660 11250 670
  SA       0 500
  N        .048 .06 .048
  *

*** FINISH PROCESSING CROSS SECTION - "EXIT "
*** CROSS SECTION "EXIT " ADDED TO DAF, RECORD NO. =    1, IXTYPE =    1

--- DATA SUMMARY FOR SECID "EXIT " AT SRD =      0.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0000       .50       .00

X-Y COORDINATE PAIRS  (NGP =  16):
       X       Y            X       Y            X       Y            X       Y
      .0  670.00         60.0  652.00        100.0  650.00        160.0  640.00
   200.0  617.00        230.0  614.00        270.0  617.00        290.0  635.00
   400.0  639.00        500.0  651.00       1600.0  645.00       3047.0  644.00
  5353.0  644.00       8282.0  650.00      10625.0  660.00      11250.0  670.00

 X-Y MAX-MIN POINTS:
    XMIN       Y           X    YMIN      XMAX       Y           X    YMAX
      .0  670.00       230.0  614.00   11250.0  670.00          .0  670.00

 SUBAREA BREAKPOINTS (NSA =  3):
         0.     500.

 ROUGHNESS COEFFICIENTS (NSA =  3):
        .048    .060    .048
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                                HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

*** START PROCESSING CROSS SECTION - "FULLV"
  XS   FULLV       542
  GR       0 672.99 70 665.46 80 618 125 617 170 618 190 625 218.4 627
  GR       245 637.6 395.72 639.24 540.13 650 550.16 649.23 3099 642.6
  GR       3345 639.52 3430 640.22 4857.5 643.64 5457 639.82 9315 648.23
  GR       10765 681.41
  SA       0 540.13
*** FINISH PROCESSING CROSS SECTION - "FULLV"
*** CROSS SECTION "FULLV" ADDED TO DAF, RECORD NO. =    2, IXTYPE =    1
--- DATA SUMMARY FOR SECID "FULLV" AT SRD =    542.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0000       .50       .00

X-Y COORDINATE PAIRS  (NGP =  18):
        X       Y           X       Y           X       Y           X       Y
       .0  672.99        70.0  665.46        80.0  618.00       125.0  617.00
    170.0  618.00       190.0  625.00       218.4  627.00       245.0  637.60
    395.7  639.24       540.1  650.00       550.2  649.23      3099.0  642.60
   3345.0  639.52      3430.0  640.22      4857.5  643.64      5457.0  639.82
   9315.0  648.23     10765.0  681.41
X-Y MAX-MIN POINTS:
     XMIN       Y           X    YMIN        XMAX       Y           X    YMAX
       .0  672.99       125.0  617.00     10765.0  681.41     10765.0  681.41

SUBAREA BREAKPOINTS (NSA =  3):
          0.    540.

ROUGHNESS COEFFICIENTS (NSA =  3):
         .048    .060    .048
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

*** START PROCESSING CROSS SECTION - "BRDGE"
  BR   BRDGE   542
  GR       17.3 668.23 44.17 668.23 81.25 618 156 618 217 635.8 477.8 640.91
  GR       534.8 650 556.7 660 17.3 668.23
  SA       17.3 556.7
  CD       3 134 2 665
  PW       621 4.3 624 4.3 624 8.6 636 8.6 636 12.9 637 12.9 637 17.2
  PW       640 17.2 640 21.5
  KD       44.17 534.8 160 44.17 534.8 160
  *

*** FINISH PROCESSING CROSS SECTION - "BRDGE"
*** CROSS SECTION "BRDGE" ADDED TO DAF, RECORD NO. =    3, IXTYPE =    2

--- DATA SUMMARY FOR SECID "BRDGE" AT SRD =    542.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0000       .50       .00

X-Y COORDINATE PAIRS  (NGP =   9):
       X      Y           X      Y           X      Y .         X      Y
     17.3  668.23       44.2  668.23       81.3  618.00      156.0  618.00
    217.0  635.80      477.8  640.91      534.8  650.00      556.7  660.00
     17.3  668.23

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN      XMAX       Y          X    YMAX
     17.3  668.23       81.3  618.00     556.7  660.00       17.3  668.23

 SUBAREA BREAKPOINTS (NSA =  3):
          17.    557.

 ROUGHNESS COEFFICIENTS (NSA =  3):
          .048    .060    .048

 BRIDGE PARAMETERS:
  BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  ABSLPL  ABSLPR
     3     134.0 ******** *******   2.00   665.00 ******* *******

 PIER DATA:  NPW =  9   PCODE = 0.
      PELV  PWDTH       PELV  PWDTH       PELV  PWDTH       PELV  PWDTH
    621.00    4.3     624.00    4.3     624.00    8.6     636.00    8.6
    636.00   12.9     637.00   12.9     637.00   17.2     640.00   17.2
    640.00   21.5
```

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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                             HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
         *** RUN DATE & TIME: 04-13-89  14:00

*** START PROCESSING CROSS SECTION - "OFBR1"
  BR   OFBR1   542
  GR       3300 656 3333.73 642 3415.21 642 3450.5 656.47 3300 656
  CD       3 134 2 659
  PW       642 2.2
  KD       3300 3450.5 3375.25 3300 3448.63 3374
  *

*** FINISH PROCESSING CROSS SECTION - "OFBR1"
*** CROSS SECTION "OFBR1" ADDED TO DAF, RECORD NO. =    4, IXTYPE =    2

--- DATA SUMMARY FOR SECID "OFBR1" AT SRD =    542.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0000       .50       .00

X-Y COORDINATE PAIRS  (NGP =   5):
       X       Y          X      Y          X      Y          X      Y
   3300.0  656.00     3333.7  642.00     3415.2  642.00     3450.5  656.47
   3300.0  656.00

 X-Y MAX-MIN POINTS:
     XMIN        Y          X    YMIN      XMAX        Y          X    YMAX
   3300.0  656.00     3333.7  642.00     3450.5  656.47     3450.5  656.47

SUBAREA BREAKPOINTS (NSA =  3):
          0.    540.

ROUGHNESS COEFFICIENTS (NSA =  3):
         .048    .060    .048

BRIDGE PARAMETERS:
 BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  ABSLPL  ABSLPR
    3     134.0 ******** *******    2.00   659.00 ******* *******

PIER DATA:  NPW =  1   PCODE = 0.
     PELV  PWDTH      PELV  PWDTH      PELV  PWDTH      PELV  PWDTH
   642.00   2.2
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186         MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                           HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

*** START PROCESSING CROSS SECTION - "OFBR2"
  BR   OFBR2  542
  GR       5370 660 5404.34 642 5513 642 5550.5 661 5370 660
  CD       3 134 2 663
  PW       643 3.3
  KD       5370 5550.5 5460.25 5370 5550.5 5460.25
  *

*** FINISH PROCESSING CROSS SECTION - "OFBR2"
*** CROSS SECTION "OFBR2" ADDED TO DAF, RECORD NO. =    5, IXTYPE =    2

--- DATA SUMMARY FOR SECID "OFBR2" AT SRD =    542.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE        EK        CK
       .0        0.     .0000       .50       .00

X-Y COORDINATE PAIRS  (NGP =    5):
       X        Y          X       Y          X       Y          X       Y
   5370.0  660.00    5404.3  642.00    5513.0  642.00    5550.5  661.00
   5370.0  660.00

 X-Y MAX-MIN POINTS:
     XMIN       Y          X     YMIN      XMAX       Y          X     YMAX
   5370.0  660.00    5404.3  642.00    5550.5  661.00    5550.5  661.00

 SUBAREA BREAKPOINTS (NSA =  3):
          0.     540.

 ROUGHNESS COEFFICIENTS (NSA =  3):
         .048    .060    .048

 BRIDGE PARAMETERS:
  BRTYPE  BRWDTH     LSEL  USERCD  EMBSS   EMBELV  ABSLPL  ABSLPR
     3     134.0 ******** *******    2.00   663.00 ******* *******

 PIER DATA:  NPW =  1   PCODE = 0.
      PELV  PWDTH      PELV  PWDTH      PELV  PWDTH      PELV  PWDTH
    643.00   3.3
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
         *** RUN DATE & TIME: 04-13-89  14:00

*** START PROCESSING CROSS SECTION - "APRCH"
 AS   APRCH   1218
 GR       0 671 16 665.7 70 638 200 638 230 618 275 617 320 618
 GR       350 638 353 636.17 365 638.99 589 639.5 626 643.65 1491.8 647.9
 GR       3381 638.9 4810 642.54 5468 641.67 9308 646 9873 654 11629 662
 GR       15883 738
 SA       16 589
 EX

*** FINISH PROCESSING CROSS SECTION - "APRCH"
*** CROSS SECTION "APRCH" ADDED TO DAF, RECORD NO. =    6, IXTYPE =    5

--- DATA SUMMARY FOR SECID "APRCH" AT SRD =   1218.  ERR-CODE =      0

     SKEW     IHFNO    VSLOPE       EK        CK
       .0        0.     .0000      .50       .00

X-Y COORDINATE PAIRS  (NGP =  20):
       X       Y           X      Y           X       Y          X       Y
      .0  671.00        16.0  665.70        70.0  638.00      200.0  638.00
   230.0  618.00       275.0  617.00       320.0  618.00      350.0  638.00
   353.0  636.17       365.0  638.99       589.0  639.50      626.0  643.65
  1491.8  647.90      3381.0  638.90      4810.0  642.54     5468.0  641.67
  9308.0  646.00      9873.0  654.00     11629.0  662.00    15883.0  738.00

 X-Y MAX-MIN POINTS:
     XMIN       Y          X    YMIN       XMAX       Y          X    YMAX
      .0  671.00       275.0  617.00    15883.0  738.00    15883.0  738.00

 SUBAREA BREAKPOINTS (NSA =  3):
        16.    589.

 ROUGHNESS COEFFICIENTS (NSA =  3):
        .048    .060    .048

 BRIDGE PROJECTION DATA:  XREFLT  XREFRT  FDSTLT  FDSTRT
                          ******* ******* ******* *******

  NPROF, NQV  =      3     6


 +++ BEGINNING PROFILE CALCULATIONS --      3
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
         *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT :XS   ******   111.   25747.   .06 ***** 648.29  637.60  42800.  648.22
        0. ******  7415. 2139525.  1.49 ***** *******     .18    1.66

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  2.00

FULLV:FV     542.    74.   45481.   .02   .11  648.40 ******* 42800.  648.38
      542.   542.  9322. 4284308.  1.15   .00     .00     .08     .94
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS     676.    50.   52876.   .01   .06  648.45 ******* 42800.  648.44
     1218.   676.  9480. 5248580.  1.11   .00     .00     .06     .81
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

A3 ---    6711.    619.    772.

QS ---   35453.   3267.   4079.

BOLEW ---       59.   3318.   5392.

BOREW ---      525.   3431.   5526.

STAGLT --- ********   3083.   4303.

STAGRT ---    3083.   4303.********

AS ---   17147.  10348.  25380.  52876.

KS --- 1816711.1335693.2273578.5425981.

CA3 ---    5342.    542.    667.   6552.      CRF ---     2.317   2.408   2.240

CJ ---      .796    .876    .864               QS ---   34905.   3680.   4215.

CDF ---    2.474    .310    .227               CDF ---     2.436    .349    .235
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR     FR#     VEL

BRDGE:BR     539.    59.    6823.    .68   .54  649.30  634.73  34905.  648.62
      542.   539.   526.  985770.   1.68   .20     .00     .31    5.12

    TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
      3.   0.   1.   .773    .054 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    47.   20816.    .05   .20  649.70  632.93  34905.  649.65
     1215.   919.  3083. 5825242.   1.20   .21     .00     .12    1.68

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .838   .497 2931481.    44.   535.   649.63

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR     FR#     VEL

OFBR1:BR     151.  3318.     612.    .74   .08  649.07  645.89   3680.  648.33
      542.   151.  3431.   58094.   1.32   .60     .00     .52    6.01

    TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
      3.   0.   1.   .871    .023 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH    HO     ERR     FR#     VEL

SLICE:AS     151.  3083.   11979.    .00   .10  649.78  639.10   3680.  649.78
      827.   255.  4303.  595420.   1.00   .61     .00     .02     .31

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .877   .859   84095.  3300.  3449.   649.77
                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

```
===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APRCH"     KRATIO =  2.87

 XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS       Q      WSEL
       SRD   FLEN     REW        K   ALPH     HO      ERR      FR#     VEL

APRCH:XS     392.   3083.   11986.    .00    .01   649.78 *******   3680.   649.78
     1218.   392.   4303. 1706198.   1.00    .00      .00      .02     .31

WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                                  HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS       Q      WSEL
       SRD   FLEN     REW        K   ALPH     HO      ERR      FR#     VEL

OFBR2:BR     181.   5392.     778.    .62    .13   649.04   645.56   4215.   648.43
      542.   181.   5526.    77039.  1.36    .53      .00      .46    5.41

     TYPE PPCD FLOW       C     P/A     LSEL    BLEN    XLAB    XRAB
       3.   0.   1.    .858    .023 ******* ****** ****** ******

 XSID:CODE   SRDL     LEW     AREA    VHD     HF      EGL     CRWS       Q      WSEL
       SRD   FLEN     REW        K   ALPH     HO      ERR      FR#     VEL

SLICE:AS     181.   4303.   32263.    .00    .23   649.76   645.56   4215.   649.76
      857.   439.   9573.   787621.  1.00    .48      .00      .01     .13

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
       .965   .946   42445.  5370.  5551.   649.75

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APRCH"     KRATIO =  4.26
```

```
 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

APRCH:XS     362.   4303.   32276.   .00    .00  649.76 *******   4215.  649.76
     1218.   362.   9574. 3353641.  1.00    .00     .00     .01     .13

APRCH:XS   ******     47.   64856.   .01  *****  649.71 *******  42800.  649.70
     1218. ******   9570. 7240104.  1.06  *****    1.26     .05     .66

STAGLT --- ********   3088.   4294.

STAGRT ---    3088.   4294.********

AS ---   21038.  11762.  32056.  64856.

KS --- 2426143.1666843.3313492.7406478.

CA3 ---     5271.     533.     668.    6473.

CJ ---      .773     .871     .858

CDF ---     2.436     .349     .235

CRF ---     2.307    2.402    2.257

QS ---    34816.    3667.    4316.

CDF ---     2.483     .381     .225

          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

BRDGE:BR     539.     59.    6822.   .68    .53  649.30  634.69  34816.  648.62
      542.   539.    526.  985539.  1.68    .20     .00     .30    5.10

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .772   .054 ******* ****** ****** ******
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                             HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
         *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    47.   20845.   .05   .19  649.69  632.90  34816.  649.64
     1215.   927.  3088. 5944030.  1.20   .21     .00     .12    1.67

      M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
      .839   .497 2986062.    44.    535.  649.62

                <<<<<END OF BRIDGE COMPUTATIONS>>>>>

         <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

OFBR1:BR     151.  3318.     612.   .74   .08  649.06  645.89   3667.  648.33
      542.   151.  3431.   58092.  1.32   .59     .00     .52    5.99

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .871    .023 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     151.  3088.   11828.   .00   .09  649.76  639.10   3667.  649.76
      827.   255.  4294.  640566.  1.00   .61     .00     .02     .31

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .875   .857   91404.  3300.  3449.  649.75

                <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                               "APRCH"    KRATIO =  2.63
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```
XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

APRCH:XS     392.  3088.   11834.   .00   .00  649.77 *******   3667.  649.76
    1218.    392.  4294. 1683896.  1.00   .00     .00     .02     .31

          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

OFBR2:BR     181.  5392.     779.   .65   .14  649.08  645.62   4316.  648.43
     542.    181.  5526.   77148.  1.36   .56     .00     .47    5.54

    TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
      3.   0.   1.   .858   .023 ******* ****** ****** ******

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                               HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

SLICE:AS     181.  4294.   32754.   .00   .26  649.84  645.62   4316.  649.84
     857.    439.  9579.  773321.  1.00   .50     .00     .01     .13

      M(G)   M(K)      KQ   XLKQ   XRKQ    OTEL
      .965   .947  41390.  5370.  5551.  649.83

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APRCH"    KRATIO =  4.44

XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

APRCH:XS     362.  4294.   32767.   .00   .00  649.84 *******   4316.  649.84
    1218.    362.  9579. 3432856.  1.00   .00     .00     .01     .13

APRCH:XS   ******    47.   65015.   .01 *****  649.73 *******  42800.  649.72
    1218. ******  9571. 7268408.  1.06 *****     .02     .05     .66
```

```
STAGLT --- ********   3088.   4294.

STAGRT ---    3088.   4294.********

AS ---   21089.  11779.  32148.  65016.

KS --- 2434757.1671163.3328744.7434664.

CA3 ---    5269.    533.    668.   6471.

CJ ---     .772    .871    .858

CDF ---    2.483    .381    .225

CRF ---    2.307   2.402   2.257

QS ---   34811.   3669.   4320.

CDF ---    2.484    .381    .225

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRDGE:BR     539.    59.    6822.   .68   .53  649.30  634.69  34811.  648.62
      542.   539.   526.  985532.  1.68   .20     .00     .30    5.10

     TYPE PPCD FLOW      C     P/A     LSEL    BLEN    XLAB    XRAB
       3.   0.   1.   .772    .054 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    47.   20843.   .05   .19  649.69  632.90  34811.  649.64
     1215.   927.  3088. 5944072.  1.20   .21     .00     .12    1.67

       M(G)   M(K)        KQ   XLKQ    XRKQ    OTEL
       .839   .497 2986226.    44.    535.   649.62

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                               HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q     WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

OFBR1:BR     151.  3318.     612.    .74    .08  649.06  645.89   3669.  648.33
      542.   151.  3431.   58092.   1.32    .59     .00     .52    5.99

     TYPE PPCD FLOW       C     P/A    LSEL    BLEN    XLAB    XRAB
       3.   0.   1.    .871    .023 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q     WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

SLICE:AS     151.  3088.   11826.    .00    .09  649.76  639.10   3669.  649.76
      827.   255.  4294.  641517.   1.00    .61     .01     .02     .31

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
       .875   .857   91562.  3300.  3449.   649.76

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APRCH"    KRATIO =  2.62

 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q     WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

APRCH:XS     392.  3088.   11832.    .00    .00  649.77 *******   3669.  649.76
     1218.   392.  4294. 1683708.   1.00    .00     .00     .02     .31
```

```
                 <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL     CRWS      Q      WSEL
      SRD   FLEN    REW        K   ALPH     HO     ERR      FR#     VEL

OFBR2:BR    181.  5392.     779.    .65    .14  649.08  645.62   4320.  648.43
     542.   181.  5526.   77148.   1.36    .56     .00     .47    5.55

     TYPE PPCD FLOW      C     P/A     LSEL    BLEN    XLAB    XRAB
       3.   0.   1.   .858    .023 ******* ****** ****** ******

XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL     CRWS      Q      WSEL
      SRD   FLEN    REW        K   ALPH     HO     ERR      FR#     VEL

SLICE:AS    181.  4294.   32769.    .00    .26  649.84  645.62   4320.  649.84
     857.   439.  9579.  773993.   1.00    .50     .00     .01     .13

       M(G)   M(K)       KQ   XLKQ   XRKQ     OTEL
       .965   .947   41415.  5370.  5551.   649.83

                        <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                               "APRCH"     KRATIO =  4.44

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL     CRWS      Q      WSEL
      SRD   FLEN    REW        K   ALPH     HO     ERR      FR#     VEL

APRCH:XS    362.  4294.   32783.    .00    .00  649.84 *******   4320.  649.84
    1218.   362.  9579. 3435364.   1.00    .00     .00     .01     .13

APRCH:XS  ******    47.   65022.    .01  ***** 649.73 *******  42800.  649.72
    1218. ******  9571. 7269541.   1.06  *****    .00     .05     .66
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                            HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT :XS   ******   107.   29836.   .06 *****  648.87  639.74  51400.  648.81
        0. ****** 7701. 2569815.  1.38 ***** *******     .18    1.72

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  1.95

FULLV:FV     542.    73.   50780.   .02   .11  648.99 ******* 51400.  648.97
      542.   542.  9347. 5009138.  1.12   .00     .00     .08    1.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS     676.    48.   58459.   .01   .06  649.04 ******* 51400.  649.03
     1218.   676.  9522. 6144229.  1.08   .00     .00     .06     .88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

A3 ---    6986.    685.    851.

QS ---   42132.   4133.   5134.

BOLEW ---      58.   3317.   5391.

BOREW ---     528.   3432.   5527.

STAGLT --- ********   3068.   4306.

STAGRT ---    3068.   4306.********

AS ---   18810.  11219.  28429.  58459.

KS --- 2072598.1513788.2733002.6319388.

CA3 ---   5479.    599.    733.  6811.  CDF ---    2.499    .336    .231

CJ ---     .784    .874    .861         QS ---   41320.   4699.   5381.

CRF ---    2.311   2.405   2.249        CDF ---    2.451    .382    .242
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                                 HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRDGE:BR     539.    58.    7094.   .90   .63  650.10  638.57  41320.  649.20
      542.   539.   530. 1045706.  1.70   .30     .00     .35    5.82

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.    .766    .053 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    46.   23284.   .06   .22  650.57  634.60  41320.  650.51
     1215.   929.  3068. 6942407.  1.15   .25     .00     .12    1.77

       M(G)    M(K)        KQ   XLKQ   XRKQ    OTEL
       .838    .537 3212053.    44.   535.   650.49

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

OFBR1:BR     151.  3317.     676.  1.00   .09  649.88  646.57   4699.  648.88
      542.   151.  3432.   67306.  1.33   .82     .00     .58    6.95

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.    .867    .022 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
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```
SLICE:AS     151.  3068.   13318.    .00   .11  650.73  639.10   4699.  650.73
     827.    257.  4306.  768830.   1.00   .73     .01     .02     .35

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .878   .862  105679.  3300.  3449.   650.72

                 <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                         "APRCH"     KRATIO =  2.62

 XSID:CODE   SRDL    LEW    AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW       K   ALPH     HO     ERR     FR#     VEL

APRCH:XS     392.  3068.   13325.    .00   .01  650.73 *******   4699.  650.73
    1218.    392.  4306. 2016204.   1.00   .00     .00     .02     .35

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW    AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW       K   ALPH     HO     ERR     FR#     VEL

OFBR2:BR     181.  5391.     855.    .84   .13  649.84  646.19   5381.  649.00
     542.    181.  5527.   89045.   1.37   .74     .00     .52    6.29

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.    0.   1.   .854    .023 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW    AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW       K   ALPH     HO     ERR     FR#     VEL

SLICE:AS     181.  4306.   37045.    .00   .25  650.66  646.19   5381.  650.66
     857.    450.  9637. 1013482.   1.00   .58     .00     .01     .15

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      .965   .948   52248.  5370.  5551.   650.66

                 <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                         "APRCH"     KRATIO =  4.13
```

```
 XSID:CODE   SRDL    LEW      AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K  ALPH     HO     ERR     FR#     VEL

APRCH:XS     362.  4306.    37058.   .00    .00  650.67 *******   5381.  650.67
     1218.   362.  9638. 4189528.  1.00    .00     .00     .01     .15

APRCH:XS   ******    45.    73365.   .01 *****  650.60 *******  51400.  650.59
     1218. ******  9633. 8807030.  1.04 *****    1.56     .05     .70

STAGLT --- ********    3075.    4297.

STAGRT ---    3075.    4297.********

AS ---    23606.  13000.  36759.  73365.

KS --- 2887728.1951836.4131354.8970917.

CA3 ---     5436.     586.     731.    6752.

CJ ---      .766     .867     .854

CDF ---     2.451     .382     .242

CRF ---     2.303    2.397    2.264

QS ---    41308.    4634.    5457.

CDF ---     2.497     .414     .231

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW      AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K  ALPH     HO     ERR     FR#     VEL

BRDGE:BR     539.    58.     7093.   .90    .62  650.09  638.57  41308.  649.20
      542.   539.   530. 1045552.  1.70    .31     .00     .35    5.82

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .766   .053 ******* ****** ****** ******
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WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                             HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    46.   23338.   .06   .21  650.56  634.60  41308.  650.51
     1215.   931.  3075. 7086738.  1.15   .25     .00     .12    1.77

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .838   .538 3270128.    44.   535.   650.49

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

OFBR1:BR     151.  3317.     676.   .97   .09  649.86  646.52   4634.  648.89
      542.   151.  3432.   67332.  1.33   .79     .00     .57    6.86

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .867   .022 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     151.  3075.   13090.   .00   .10  650.67  639.10   4634.  650.67
      827.   256.  4297.  818181.  1.00   .71     .01     .02     .35

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .877   .861  113803.  3300.  3449.   650.66

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APRCH"    KRATIO =  2.42
```

```
 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

APRCH:XS     392.  3075.   13096.   .00    .01  650.68 *******   4634.  650.67
     1218.   392.  4297. 1976047.  1.00    .00     .00     .02     .35

          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

OFBR2:BR     181.  5391.     856.   .87    .14  649.87  646.22   5457.  649.00
      542.   181.  5527.   89164.  1.37    .76     .00     .52    6.38

    TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
      3.   0.   1.   .854    .023 ******* ****** ****** ******

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

SLICE:AS     181.  4297.   37494.   .00    .27  650.73  646.22   5457.  650.73
      857.   451.  9642.  983212.  1.00    .59    -.01     .01     .15

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
       .965   .949    50407.  5370.  5551.  650.73

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APRCH"    KRATIO =  4.34

 XSID:CODE   SRDL    LEW     AREA   VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH     HO     ERR     FR#     VEL

APRCH:XS     362.  4297.   37508.   .00    .00  650.74 *******   5457.  650.73
     1218.   362.  9642. 4267161.  1.00    .00     .00     .01     .15

APRCH:XS   ******    45.   73457.   .01  *****  650.61 *******  51400.  650.60
     1218. ******  9633. 8824604.  1.04  *****     .01     .05     .70
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXIT :XS   ******     69.   51865.   .07 ***** 651.64  646.86 108000.  651.56
        0. ******  8648. 5397919.  1.10 ***** *******     .16    2.08

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                               "FULLV"     KRATIO =  1.77

FULLV:FV     542.     73.   76523.   .03    .12  651.76 ******* 108000.  651.73
      542.   542.  9468. 9545916.  1.03    .00     .00     .09    1.41
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRCH:AS     676.     43.   85056.   .03    .07  651.83 ******* 108000.  651.81
     1218.   676.  9718. ********  1.03    .00     .00     .08    1.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

A3 ---    8304.   1022.   1241.

QS ---   84873.  10446.  12681.

BOLEW ---      56.   3310.   5386.

BOREW ---     539.   3439.   5532.

STAGLT --- ********    3007.    4318.

STAGRT ---     3007.    4318.********

AS ---   26515.  15480.  43061.  85056.

KS --- 3495248.2490742.5335229.********

CA3 ---     6310.    880.   1053.   8244.  CRF ---     2.298    2.390    2.270

CJ ---      .760   .861   .849           QS ---   82452.  11956.  13592.

CDF ---     2.545  .440   .249           CDF ---     2.473     .503     .267
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF    EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO    ERR     FR#     VEL

BRDGE:BR     539.    56.    8308.  2.75  1.13 654.49  643.92  82452.  651.74
      542.   539.   539. 1338240.  1.79  1.35   -.01     .56    9.92

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .747   .052 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF    EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO    ERR     FR#     VEL

SLICE:AS     539.    36.   36930.   .08   .33 655.40  643.22  82452.  655.32
     1215.   962.  3007. ********  1.03   .58   -.02     .11    2.23

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .834   .663 4930408.    44.   535.   655.30

                 <<<<<END OF BRIDGE COMPUTATIONS>>>>>

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF    EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO    ERR     FR#     VEL

OFBR1:BR     151.  3311.     978.  3.32   .15 654.71  650.17  11956.  651.39
      542.   151.  3438.  116199.  1.43  2.81    .00     .93   12.22

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .836   .021 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF    EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO    ERR     FR#     VEL
```

```
SLICE:AS     151.  3007.   21408.   .00   .15  656.33  639.10  11956.  656.33
      827.   260.  4318. 2151347.  1.00  1.48     .01     .02     .56

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .885   .875  268041.  3300.  3449.   656.32

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APRCH"     KRATIO =  1.99

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR    FR#     VEL

APRCH:XS     392.  3007.   21416.   .00   .01  656.34 *******  11956.  656.33
     1218.   392.  4318. 4278254.  1.00   .00     .00     .02     .56

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                              HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR    FR#     VEL

OFBR2:BR     181.  5386.    1225.  2.77   .13  654.39  649.63  13592.  651.62
      542.   181.  5532.  153716.  1.45  2.51    -.02     .81   11.10

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.    0.   1.   .831   .023 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR    FR#     VEL

SLICE:AS     181.  4318.   65448.   .00   .27  655.81  649.63  13592.  655.81
      857.   487. 10269. 2683195.  1.00  1.15    -.01     .01     .21

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       .967   .954  122966.  5370.  5551.   655.80

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APRCH"     KRATIO =  3.75
```

```
 XSID:CODE   SRDL    LEW      AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K  ALPH    HO     ERR     FR#     VEL

APRCH:XS     362.  4318.    65463.   .00   .00  655.81 ******* 13592.  655.81
     1218.   362. 10270. ******** 1.00   .00     .00     .01     .21

APRCH:XS   ******    36.  122846.   .01 *****  655.65 ******* 108000.  655.64
     1218. ****** 10233. ******** 1.01 *****    3.83     .04     .88

STAGLT --- ********   3019.   4303.

STAGRT ---   3019.   4303.********

AS ---   38067.  20098.  64680. 122846.

KS --- 6184045.3903777.9875140.********

CA3 ---    6203.    818.   1018.   8039.

CJ ---     .747    .836    .831

CDF ---    2.473    .503    .267

CRF ---    2.302   2.385   2.274

QS ---   83161.  11357.  13481.

CDF ---    2.486    .538    .252

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW      AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW         K  ALPH    HO     ERR     FR#     VEL

BRDGE:BR     539.     56.     8307.  2.80  1.15  654.53  643.98  83161.  651.73
      542.   539.    539. 1337850.  1.80  1.38    -.01     .57   10.01

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .746   .052 ******* ****** ****** ******
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                               HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    36.   37289.   .08   .33  655.46  643.22  83161.  655.38
     1215.   965.  3019. ********  1.03   .59   -.02     .11    2.23

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
       .835   .666 4978703.    44.   535.   655.36

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

             <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

OFBR1:BR     151.  3311.     982.  2.96   .14  654.37  649.91  11357.  651.42
      542.   151.  3438.  116869.  1.42  2.49     .00     .87   11.56

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.    .839    .021 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     151.  3019.   20338.   .00   .13  655.83  639.10  11357.  655.83
      827.   259.  4303. 2141231.  1.00  1.33     .00     .02     .56

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
       .883   .873  272781.  3300.  3449.   655.82

                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                               "APRCH"     KRATIO =  1.86
```

```
 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

APRCH:XS     392.   3019.   20346.    .00    .01  655.84 *******  11357.  655.83
     1218.   392.   4303. 3984302.   1.00    .00     .00     .02     .56

          <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

OFBR2:BR     181.   5386.    1226.   2.72    .14  654.35  649.59  13481.  651.63
      542.   181.   5532.  154006.   1.45   2.47    -.02     .80   10.99

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.   .831    .023 ******* ****** ****** ******

WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                             HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75     ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

SLICE:AS     181.   4303.   65458.    .00    .30  655.77  649.59  13481.  655.77
      857.   488.  10261. 2533872.   1.00   1.13    -.02     .01     .21

       M(G)   M(K)      KQ   XLKQ   XRKQ    OTEL
       .967   .954  115807.  5370.  5551.  655.76

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APRCH"    KRATIO =  3.96
 XSID:CODE   SRDL    LEW     AREA    VHD     HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K   ALPH     HO     ERR     FR#     VEL

APRCH:XS     362.   4303.   65473.    .00    .00  655.77 *******  13481.  655.77
     1218.   362.  10262. ********   1.00    .00     .00     .01     .21
```

```
APRCH:XS   ******    36.  122222.    .01 *****  655.59 ******* 108000.  655.58
     1218. ****** 10219. ********  1.01 *****    -.06     .05     .88

STAGLT --- ********   3018.   4304.

STAGRT ---    3018.   4304.********

AS ---   37868.  20056.  64299. 122222.

KS --- 6133142.3885054.9794497.********

CA3 ---    6198.    824.   1020.   8042.

CJ ---     .746    .839    .831

CDF ---    2.486    .538    .252

CRF ---    2.302   2.385   2.274

QS ---   83069.  11435.  13496.

CDF ---    2.485    .540    .253

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

BRDGE:BR     539.    56.    8307.  2.79  1.15  654.53  643.98  83069.  651.73
      542.   539.   539. 1337887.  1.80  1.38    -.01     .57   10.00

     TYPE PPCD FLOW       C     P/A     LSEL    BLEN    XLAB    XRAB
       3.    0.    1.   .746   .052 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     539.    36.   37249.   .08   .33  655.45  643.22  83069.  655.37
     1215.   965.  3018. ********  1.03   .59    -.02     .11    2.23

       M(G)    M(K)        KQ   XLKQ    XRKQ    OTEL
       .835    .666 4973694.    44.    535.   655.35

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>
```

```
WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186         MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

       MULTIPLE BRIDGE OPENING RUN                               HY7CA.DAT
       CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
       FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
          *** RUN DATE & TIME: 04-13-89  14:00

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

OFBR1:BR     151.  3311.     982.  3.00   .14  654.41  649.94  11435.  651.41
      542.   151.  3438.  116778.  1.42  2.53     .00     .88   11.65

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.    0.   1.   .838   .021 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

SLICE:AS     151.  3018.   20454.   .00   .13  655.89  639.10  11435.  655.89
      827.   259.  4304. 2167666.  1.00  1.34     .00     .02     .56

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
       .883   .873  275569.  3300.  3449.   655.88

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ***135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                "APRCH"    KRATIO =  1.85

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APRCH:XS     392.  3018.   20462.   .00   .01  655.90 *******  11435.  655.89
     1218.   392.  4304. 4017053.  1.00   .00     .00     .02     .56

           <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
```

```
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

OFBR2:BR      181.  5386.    1226.  2.73   .14  654.35  649.59  13496.  651.63
      542.    181.  5532.  153989.  1.45  2.47    -.02     .81   11.01

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       3.    0.   1.    .831    .023 ******* ****** ****** ******

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

SLICE:AS      181.  4304.   65484.   .00   .30  655.78  649.59  13496.  655.78
      857.    488. 10263. 2539880.  1.00  1.13    -.02     .01     .21

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
       .967   .954  116109.  5370.  5551.   655.77

                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                                "APRCH"    KRATIO =  3.96

WSPRO        FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
P123186          MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        MULTIPLE BRIDGE OPENING RUN                                HY7CA.DAT
        CANEY RIVER BRIDGE AT US-75      ** NEW BRIDGE ** CASE 1
        FLOOD FLOW OF 1986 , 50 YRS, & 100 YRS RECURRENCE INTERVAL
           *** RUN DATE & TIME: 04-13-89  14:00

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS        Q     WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#      VEL

APRCH:XS      362.  4304.   65499.   .00   .00  655.78 *******  13496.  655.78
     1218.    362. 10264. ********  1.00   .00     .00     .01     .21

APRCH:XS    ******    36.  122301.   .01 *****  655.60 ******* 108000.  655.59
     1218.  ****** 10221. ********  1.01 *****     .01     .05     .88
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX B

PROGRAM RUNS HEC 2 MODEL

SITE 1 - TWIN SPRING CREEK

ALFALFA COUNTY

```
*****************************************************          ****************************************
*  WATER SURFACE PROFILES                           *          *  U.S. ARMY CORPS OF ENGINEERS        *
*  VERSION OF NOVEMBER 1976                         *          *  THE HYDROLOGIC ENGINEERING CENTER   *
*  UPDATED MAY 1984                                 *          *  609 SECOND STREET, SUITE D          *
*  IBM-PC-XT VERSION                                *          *  DAVIS, CALIFORNIA 95616             *
*  RUN DATE  04/13/89  TIME  14:19:38               *          *  (916) 440-2105 (FTS) 448-2105       *
*****************************************************          ****************************************
```

```
X     X XXXXXXX  XXXXX           XXXXX
X     X X       X     X         X     X
X     X X       X                     X
XXXXXXX XXXX    X         XXXXX  XXXXX
X     X X       X               X
X     X X       X     X         X
X     X XXXXXXX  XXXXX          XXXXXXX
```

THIS RUN EXECUTED 04/13/89 14:19:40

****
HEC2 RELEASE DATED NOV 76 UPDATED MAY 1984
ERROR CORR - 01,02,03,04,05,06
MODIFICATION - 50,51,52,53,54,55,56
IBM-PC-XT VERSION APRIL 1985
****

C
T1 CASE STUDY 1 - ALFALFA COUNTY FILE: he2al.DAT
T2 10, 25, 50 AND 100 YEARS FLOOD -SPECIAL BRIDGE ** Site 1 **
T3 TWIN SPRING CREEK EFFECTIVE BRIDGE LENGTH (original file)

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	2.	0.	0.	.000880	.00	.0	0.	.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	-1.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

J3 VARIABLE CODES FOR SUMMARY PRINTOUT

38.000	1.000	2.000	3.000	8.000	5.000	14.000	15.000	25.000	26.000
33.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

NC	.060	.100	.055	.000	.500	.000	.000	.000	.000	.000
QT	4.000	850.000	1300.000	1650.000	2100.000	.000	.000	.000	.000	.000
NH	7.000	.060	400.000	.070	475.000	.060	487.000	.050	495.000	.045
NH	500.000	.060	510.000	.100	600.000	.000	.000	.000	.000	.000

	EXIT -135									
X1	1.000	8.000	475.000	510.000	.000	.000	.000	.000	-.119	.000
GR	1260.000	.000	1250.500	400.000	1249.000	475.000	1246.000	487.000	1245.500	495.000
GR	1246.000	500.000	1249.500	510.000	1260.000	600.000	.000	.000	.000	.000
	DOWNSTREAM BRIDG		+45							
X1	2.000	14.000	470.000	515.000	179.000	179.000	179.000	.000	.040	.000
X3	10.000	.000	.000	.000	.000	.000	.000	1258.000	1258.000	.000
GR	1260.000	.000	1256.000	100.000	1255.400	200.000	1256.500	310.000	1258.000	400.000
GR	1258.000	470.000	1249.000	475.000	1246.000	487.000	1245.500	495.000	1246.000	500.000
GR	1249.500	510.000	1258.000	515.000	1258.000	580.000	1260.000	600.000	.000	.000
SB	1.050	1.500	2.600	.000	35.000	.000	326.000	2.000	1246.000	1245.500
	UPSTREAM BRIDGE		+72							
X1	3.000	14.000	470.000	515.000	27.000	27.000	27.000	.000	.063	.000
X2	.000	.000	1.000	1254.500	1258.000	.000	.000	.000	.000	.000
X3	10.000	.000	.000	.000	.000	.000	.000	1258.000	1258.000	.000
BT	12.000	.000	1260.000	1260.000	100.000	1256.000	1256.000	200.000	1255.400	1255.400
BT	310.000	1256.500	1256.500	400.000	1258.000	1258.000	470.000	1258.000	1258.000	475.000
BT	1258.000	1254.500	487.000	1258.000	1254.500	510.000	1258.000	1254.500	515.000	1258.000
BT	1258.000	580.000	1258.000	1258.000	600.000	1260.000	1260.000	.000	.000	.000
GR	1260.000	.000	1256.000	100.000	1255.400	200.000	1256.500	310.000	1258.000	400.000
GR	1258.000	470.000	1249.000	475.000	1246.000	487.000	1245.500	495.000	1246.000	500.000
GR	1249.500	510.000	1258.000	515.000	1258.000	580.000	1260.000	600.000	.000	.000
	APPROACH	+ 127								
X1	4.000	8.000	475.000	510.000	55.000	55.000	55.000	.000	.112	.000
GR	1260.000	.000	1250.500	400.000	1249.000	475.000	1246.000	487.000	1245.500	495.000
GR	1246.000	500.000	1249.500	510.000	1260.000	600.000	.000	.000	.000	.000
EJ	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

```
   SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS   BANK ELEV
   Q        QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA   LEFT/RIGHT
   TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN      SSTA
   SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID     ENDST


*PROF 1

CCHV=    .000 CEHV=    .500
1490 NH CARD USED
*SECNO 1.000
2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED
        EXIT -135
     1.00     7.01  1252.39      .00      .00  1252.46      .07      .00      .00  1248.88
     850.     318.     510.      22.     291.     195.      39.       0.       0.   1249.38
      .00     1.09     2.61      .58     .068     .052     .100     .000  1245.38   315.57
   .000880      0.       0.       0.        0        0        5      .00   220.19   535.76
0
*SECNO 2.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=     1258.00 ELREA=     1258.00

        DOWNSTREAM BRIDG     +45
     2.00     6.99  1252.53      .00      .00  1252.81      .28      .25      .10  1258.04
     850.       0.     850.       0.       0.     201.       0.       1.       1.   1258.04
      .01      .00     4.22      .00     .068     .048     .100     .000  1245.54   473.06
   .002442     179.     179.     179.       1        0        0      .00    38.71   511.76
0

SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
     1.05      1.50      2.60       .00     35.00       .00    326.00      2.00   1246.00   1245.50
```

*SECNO 3.000

6070,LOW FLOW BY NORMAL BRIDGE

EGPRS= .000 EGLWC= 1253.226 ELLC= 1254.500 PCWSE= 1252.529 ELTRD= 1258.000

3370 NORMAL BRIDGE,NRD= 12 MIN ELTRD= 1258.00 MAX ELLC= 1254.50

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 1258.00 ELREA= 1258.00

UPSTREAM BRIDGE +72

3.00	7.04	1252.60	.00	.00	1252.87	.27	.07	.00	1258.06
850.	0.	850.	0.	0.	203.	0.	2.	1.	1258.06
.01	.00	4.19	.00	.068	.048	.100	.000	1245.56	473.04
.002387	27.	27.	27.	2	0	0	.00	38.75	511.79

0

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 4.000

APPROACH + 127

4.00	7.27	1252.88	.00	.00	1252.94	.06	.06	.00	1249.11
850.	340.	485.	25.	335.	205.	46.	2.	1.	1249.61
.02	1.02	2.37	.54	.068	.052	.100	.000	1245.61	304.52
.000689	55.	55.	55.	2	0	0	.00	233.48	538.01

0

THIS RUN EXECUTED 04/13/89 14:19:52

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MAY  1984
  ERROR CORR -  01,02,03,04,05,06
  MODIFICATION -  50,51,52,53,54,55,56
  IBM-PC-XT VERSION APRIL 1985
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

TWIN SPRING CREEK

SUMMARY PRINTOUT

SECNO	CWSEL	CRIWS	EG	DEPTH	10K*S	QCH	QROB	AREA	VCH	K*CHSL
1.000	1252.39	.00	1252.46	7.01	8.80	509.62	22.29	525.44	2.61	.00
2.000	1252.53	.00	1252.81	6.99	24.42	850.00	.00	201.19	4.22	.88
3.000	1252.60	.00	1252.87	7.04	23.87	850.00	.00	202.73	4.19	.88
4.000	1252.88	.00	1252.94	7.27	6.89	485.46	24.65	584.94	2.37	.88

THIS RUN EXECUTED 04/13/89   14:19:53

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**************************************************
 HEC2 RELEASE DATED NOV 76 UPDATED MAY  1984
 ERROR CORR -  01,02,03,04,05,06
 MODIFICATION -  50,51,52,53,54,55,56
 IBM-PC-XT VERSION APRIL 1985
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T1      CASE STUDY 1 ALFALFA COUNTY                  FILE: he2al.DAT
T2      10, 25, 50 AND 100 YEARS FLOOD    -SPECIAL BRIDGE       ** Site 1 **
T3      TWIN SPRING CREEK    45' EFFECTIVE BRIDGE LENGTH   (original file)
```

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	3.	0.	0.	.000880	.00	.0	0.	.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	2.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

```
   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA   LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST


*PROF 2

CCHV=    .000 CEHV=    .500
1490 NH CARD USED
*SECNO 1.000
2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED
     1.00      7.94  1253.32       .00       .00  1253.40       .08       .00       .00  1248.88
    1300.      594.     659.       46.      459.     228.       67.        0.        0.   1249.38
      .00      1.29     2.89       .70      .067      .053      .100      .000  1245.38   276.16
  .000895        0.       0.        0.         0         0         4       .00   267.63   543.78
0
*SECNO 2.000

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=     1258.00 ELREA=     1258.00

     2.00      7.87  1253.41       .00       .00  1253.88       .47       .28       .20  1258.04
    1300.        0.    1300.        0.        0.     235.        0.        2.        1.   1258.04
      .01       .00     5.52       .00      .067      .048      .100      .000  1245.54   472.57
  .003565      179.     179.      179.         2         0         0       .00    39.70   512.28
0

SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
     1.05      1.50      2.60       .00     35.00       .00    326.00      2.00   1246.00   1245.50
```

*SECNO 3.000

6070,LOW FLOW BY NORMAL BRIDGE

EGPRS= .000 EGLWC= 1254.280 ELLC= 1254.500 PCWSE= 1253.409 ELTRD= 1258.000

3370 NORMAL BRIDGE,NRD= 12 MIN ELTRD= 1258.00 MAX ELLC= 1254.50

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 1258.00 ELREA= 1258.00

3.00	7.95	1253.52	.00	.00	1253.98	.46	.09	.00	1258.06
1300.	0.	1300.	0.	0.	239.	0.	2.	1.	1258.06
.01	.00	5.44	.00	.067	.048	.100	.000	1245.56	472.52
.003413	27.	27.	27.	2	0	0	.00	39.80	512.33

0

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 4.000

4.00	8.38	1253.99	.00	.00	1254.04	.06	.07	.00	1249.11
1300.	635.	614.	51.	549.	243.	82.	3.	1.	1249.61
.02	1.16	2.52	.63	.067	.053	.100	.000	1245.61	257.85
.000629	55.	55.	55.	2	0	0	.00	289.66	547.51

0

THIS RUN EXECUTED 04/13/89 14:19:58

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**************************************************
 HEC2 RELEASE DATED NOV 76 UPDATED MAY  1984
 ERROR CORR -  01,02,03,04,05,06
 MODIFICATION -  50,51,52,53,54,55,56
 IBM-PC-XT VERSION APRIL 1985
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T1 CASE STUDY 1 ALFALFA COUNTY FILE: he2al.DAT
T2 10, 25, 50 AND 100 YEARS FLOOD -SPECIAL BRIDGE ** Site 1 **
T3 TWIN SPRING CREEK 45' EFFECTIVE BRIDGE LENGTH (original file)

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	4.	0.	0.	.000880	.00	.0	0.	.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	3.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 3

CCHV= .000 CEHV= .500
1490 NH CARD USED
*SECNO 1.000
2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED

1.00	8.55	1253.93	.00	.00	1254.01	.08	.00	.00	1248.88
1650.	824.	758.	67.	587.	249.	89.	0.	0.	1249.38
.00	1.40	3.04	.76	.067	.053	.100	.000	1245.38	250.69
.000887	0.	0.	0.	0	0	4	.00	298.27	548.97

0
*SECNO 2.000

3301 HV CHANGED MORE THAN HVINS

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 1258.00 ELREA= 1258.00

2.00	8.41	1253.95	.00	.00	1254.59	.64	.30	.28	1258.04
1650.	0.	1650.	0.	0.	257.	0.	2.	1.	1258.04
.01	.00	6.42	.00	.067	.048	.100	.000	1245.54	472.27
.004411	179.	179.	179.	2	0	0	.00	40.32	512.60

0

SPECIAL BRIDGE

SB	XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
	1.05	1.50	2.60	.00	35.00	.00	326.00	2.00	1246.00	1245.50

*SECNO 3.000

6070,LOW FLOW BY NORMAL BRIDGE

EGPRS= 1254.548 EGLWC= 1254.971 ELLC= 1254.500 PCWSE= 1253.951 ELTRD= 1258.000

3370 NORMAL BRIDGE,NRD= 12 MIN ELTRD= 1258.00 MAX ELLC= 1254.50

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 1258.00 ELREA= 1258.00

3.00	8.53	1254.09	.00	.00	1254.71	.62	.12	.00	1258.06
1650.	0.	1650.	0.	0.	262.	0.	3.	1.	1258.06
.01	.00	6.30	.00	.067	.048	.100	.000	1245.56	472.21
.004178	27.	27.	27.	2	0	0	.00	40.46	512.66

0

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 4.000

3301 HV CHANGED MORE THAN HVINS

4.00	9.11	1254.72	.00	.00	1254.77	.06	.07	.00	1249.11
1650.	879.	696.	75.	719.	269.	112.	3.	1.	1249.61
.02	1.22	2.59	.67	.066	.053	.100	.000	1245.61	227.08
.000584	55.	55.	55.	2	0	0	.00	326.69	553.77

0

THIS RUN EXECUTED 04/13/89   14:20:03

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 HEC2 RELEASE DATED NOV 76 UPDATED MAY  1984
 ERROR CORR -  01,02,03,04,05,06
 MODIFICATION -  50,51,52,53,54,55,56
 IBM-PC-XT VERSION APRIL 1985
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T1      CASE STUDY 1  ALFALFA COUNTY                FILE: he2al.DAT
T2      10, 25, 50 AND 100 YEARS FLOOD    -SPECIAL BRIDGE       ** Site 1 **
T3      TWIN SPRING CREEK    45' EFFECTIVE BRIDGE LENGTH   (original file)
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J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	5.	0.	0.	.000880	.00	.0	0.	.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	15.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 4

CCHV= .000 CEHV= .500
1490 NH CARD USED
*SECNO 1.000
2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED

1.00	9.20	1254.58	.00	.00	1254.67	.09	.00	.00	1248.88
2100.	1130.	874.	96.	742.	272.	116.	0.	0.	1249.38
.00	1.52	3.21	.83	.066	.053	.100	.000	1245.38	223.27
.000887	0.	0.	0.	0	0	3	.00	331.28	554.55

0
*SECNO 2.000

3301 HV CHANGED MORE THAN HVINS

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 1258.00 ELREA= 1258.00

2.00	8.97	1254.51	.00	.00	1255.38	.87	.32	.39	1258.04
2100.	0.	2100.	0.	0.	280.	0.	3.	1.	1258.04
.01	.00	7.51	.00	.066	.048	.100	.000	1245.54	471.96
.005555	179.	179.	179.	2	0	0	.00	40.96	512.92

0

SPECIAL BRIDGE

SB	XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
	1.05	1.50	2.60	.00	35.00	.00	326.00	2.00	1246.00	1245.50

*SECNO 3.000

6070,LOW FLOW BY NORMAL BRIDGE

EGPRS= 1255.475 EGLWC= 1255.742 ELLC= 1254.500 PCWSE= 1254.509 ELTRD= 1258.000

3370 NORMAL BRIDGE,NRD= 12 MIN ELTRD= 1258.00 MAX ELLC= 1254.50

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 1258.00 ELREA= 1258.00

3.00	9.17	1254.73	.00	.00	1255.61	.88	.22	.00	1258.06
2100.	0.	2100.	0.	0.	280.	0.	3.	1.	1258.06
.01	.00	7.51	.00	.066	.052	.100	.000	1245.56	471.85
.013860	27.	27.	27.	2	0	0	-8.25	41.19	513.04

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*SECNO 4.000

3301 HV CHANGED MORE THAN HVINS

4.00	10.02	1255.63	.00	.00	1255.69	.05	.08	.00	1249.11
2100.	1213.	779.	108.	964.	301.	155.	4.	1.	1249.61
.02	1.26	2.59	.69	.065	.053	.100	.000	1245.61	188.54
.000507	55.	55.	55.	2	0	0	.00	373.07	561.62

0

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

TWIN SPRING CREEK

SUMMARY PRINTOUT

SECNO	CWSEL	CRIWS	EG	DEPTH	10K*S	QCH	QROB	AREA	VCH	K*CHSL
1.000	1252.39	.00	1252.46	7.01	8.80	509.62	22.29	525.44	2.61	.00
1.000	1253.32	.00	1253.40	7.94	8.95	659.46	46.30	753.74	2.89	.00
1.000	1253.93	.00	1254.01	8.55	8.87	758.21	67.46	924.85	3.04	.00
1.000	1254.58	.00	1254.67	9.20	8.87	874.06	96.42	1129.89	3.21	.00
2.000	1252.53	.00	1252.81	6.99	24.42	850.00	.00	201.19	4.22	.88
2.000	1253.41	.00	1253.88	7.87	35.65	1300.00	.00	235.39	5.52	.88
2.000	1253.95	.00	1254.59	8.41	44.11	1650.00	.00	257.09	6.42	.88
2.000	1254.51	.00	1255.38	8.97	55.55	2100.00	.00	279.77	7.51	.88
3.000	1252.60	.00	1252.87	7.04	23.87	850.00	.00	202.73	4.19	.88
3.000	1253.52	.00	1253.98	7.95	34.13	1300.00	.00	238.82	5.44	.88
3.000	1254.09	.00	1254.71	8.53	41.78	1650.00	.00	261.81	6.30	.88
3.000	1254.73	.00	1255.61	9.17	138.60	2100.00	.00	279.75	7.51	.88
4.000	1252.88	.00	1252.94	7.27	6.89	485.46	24.65	584.94	2.37	.88
4.000	1253.99	.00	1254.04	8.38	6.29	613.77	51.31	874.90	2.52	.88
4.000	1254.72	.00	1254.77	9.11	5.84	695.97	74.67	1100.09	2.59	.88
4.000	1255.63	.00	1255.69	10.02	5.07	779.01	107.98	1420.33	2.59	.88

SITE 2 - POSEY CREEK

TULSA COUNTY

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*****************************************************          **************************************
* WATER SURFACE PROFILES                            *          * U.S. ARMY CORPS OF ENGINEERS       *
* VERSION OF NOVEMBER 1976                          *          * THE HYDROLOGIC ENGINEERING CENTER  *
* UPDATED MAY 1984                                  *          * 609 SECOND STREET, SUITE D         *
* IBM-PC-XT VERSION AUGUST 1985                     *          * DAVIS, CALIFORNIA 95616            *
* RUN DATE  04-13-89   TIME  13:54:31               *          * (916) 440-2105 (FTS) 448-2105      *
*****************************************************          **************************************
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```
X     X  XXXXXXX   XXXXX            XXXXX
X     X  X        X     X          X     X
X     X  X        X                      X
XXXXXXX  XXXX     X          XXXXX   XXXXX
X     X  X        X                X
X     X  X        X     X          X
X     X  XXXXXXX   XXXXX           XXXXXXX
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C
T1      CASE STUDY 2 TULSA COUNTY, OKLAHOMA       FILE: HE2PO.DAT
T2             100 YEARS FLOOD    -SPECIAL BRIDGE         SITE 2
T3      POSEY CREEK     INDUSTRIAL BYPASS
```

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	3.	0.	0.	.005427	.00	.0	0.	.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	-1.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

J3 VARIABLE CODES FOR SUMMARY PRINTOUT

38.000	1.000	2.000	3.000	8.000	5.000	14.000	15.000	25.000	26.000
33.000	57.000	43.000	.000	.000	.000	.000	.000	.000	.000

NC	.050	.050	.070	.300	.500	.000	.000	.000	.000	.000
QT	2.000	8300.000	10900.000	.000	.000	.000	.000	.000	.000	.000
	EXIT	-50								
X1	1.000	37.000	2447.400	2616.900	.000	.000	.000	.000	-.271	.000
GR	646.200	1000.000	644.500	1052.900	645.600	1066.200	643.500	1082.900	641.800	1146.200
GR	639.100	1180.900	634.700	1326.800	632.000	1451.200	631.900	1491.800	629.900	1527.300
GR	627.600	1656.200	625.800	1779.900	623.800	1913.500	620.700	2057.100	617.700	2168.300
GR	615.400	2308.900	615.400	2389.300	616.500	2447.400	600.800	2468.800	599.700	2483.100
GR	600.800	2492.900	610.900	2514.400	613.900	2552.100	615.400	2616.900	614.800	2758.300
GR	614.200	2870.000	613.900	3014.500	614.500	3047.000	614.700	3096.300	615.100	3250.700
GR	616.900	3415.800	619.000	3601.500	620.500	3674.800	622.000	3707.200	625.900	3859.100
GR	632.200	4022.200	637.600	4129.100	.000	.000	.000	.000	.000	.000

	DOWNSTREAM BRIDG		100							
X1	2.000	29.000	2447.400	2616.900	150.000	150.000	150.000	.000	.000	.000
X3	10.000	.000	.000	.000	.000	.000	.000	623.450	623.450	.000
GR	646.300	1000.000	644.600	1052.900	645.600	1066.000	643.500	1082.000	641.900	1146.200
GR	639.200	1180.900	634.800	1326.800	632.100	1451.200	632.000	1491.800	630.000	1527.300
GR	627.700	1656.200	625.900	1779.900	623.900	1913.500	624.500	2393.500	616.600	2447.400
GR	600.900	2468.800	599.800	2483.000	600.900	2492.900	611.000	2514.400	614.000	2552.100
GR	615.500	2616.900	614.900	2758.300	614.300	2870.000	624.500	2944.500	624.500	3000.000
GR	625.000	3700.000	624.000	3859.100	632.300	4022.200	637.700	4129.100	.000	.000

SB	1.050	1.500	2.600	.000	60.000	18.000	2000.000	2.000	601.000	600.000
	UPSTREAM BRIDGE		132							
X1	3.000	29.000	2447.400	2616.900	32.000	32.000	32.000	.000	.174	.000
X2	.000	.000	1.000	619.700	623.450	.000	.000	.000	.000	.000
X3	10.000	.000	.000	.000	.000	.000	.000	623.450	623.450	.000
BT	9.000	1779.900	625.900	625.900	1913.500	623.900	623.900	2393.500	624.500	624.500
BT	2468.000	623.450	619.700	2870.000	623.450	619.700	2944.500	624.500	624.500	3000.000
BT	624.500	624.500	3700.000	625.000	625.000	3859.100	626.000	626.000	.000	.000
GR	646.300	1000.000	644.600	1052.900	645.600	1066.000	643.500	1082.000	641.900	1146.200
GR	639.200	1180.900	634.800	1326.800	632.100	1451.200	632.000	1491.800	630.000	1527.300
GR	627.700	1656.200	625.900	1779.900	623.900	1913.500	624.500	2393.500	616.600	2447.400
GR	600.900	2468.800	599.800	2483.000	600.900	2492.900	611.000	2514.400	614.000	2552.100
GR	615.500	2616.900	614.900	2758.300	614.300	2870.000	624.500	2944.500	624.500	3000.000
GR	625.000	3700.000	624.000	3859.100	632.300	4022.200	637.700	4129.100	.000	.000
	APPROACH		505							
X1	4.000	37.000	2447.400	2616.900	373.000	373.000	373.000	.000	2.198	.000
GR	646.300	1000.000	644.600	1052.900	645.600	1066.000	643.500	1082.900	641.900	1146.200
GR	639.200	1180.000	634.800	1326.800	632.100	1451.200	632.000	1491.800	630.000	1527.300
GR	627.700	1656.200	625.900	1779.900	623.900	1913.500	620.800	2057.100	617.300	2168.300
GR	615.500	2308.900	615.500	2389.300	616.600	2447.400	600.900	2468.800	599.800	2483.100
GR	600.900	2492.900	611.000	2514.400	614.000	2552.100	615.500	2616.900	614.900	2758.300
GR	614.300	2870.000	614.000	3014.500	614.600	3047.000	614.800	3096.300	615.200	3250.700
GR	617.000	3415.800	619.100	3601.500	620.600	3674.800	622.100	3707.200	626.000	3859.100
GR	632.300	4022.200	637.700	4129.100	.000	.000	.000	.000	.000	.000
X1	5.000	.000	.000	.000	146.000	146.000	146.000	.000	.792	.000
EJ	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

```
 SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS   BANK ELEV
 Q        QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA    LEFT/RIGHT
 TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN      SSTA
 SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID     ENDST


*PROF 1

CCHV=    .300 CEHV=    .500
*SECNO 1.000
2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED
            EXIT     -50
     1.00    16.95   616.38      .00      .00   616.68      .31      .00      .00   616.23
   10900.     401.    5699.    4800.     189.    1088.    1396.       0.       0.   615.13
      .00     2.12     5.24     3.44     .050     .070     .050     .000   599.43  2232.49
  .005404       0.       0.       0.        0        0        2      .00  1160.38  3392.87
0
*SECNO 2.000

3301 HV CHANGED MORE THAN HVINS


3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      623.45 ELREA=      623.45

        DOWNSTREAM BRIDG     100
     2.00    17.34   617.14      .00      .00   618.53     1.38     1.30      .54   616.60
   10900.       0.   10900.       0.       0.    1155.       0.       7.       2.   615.50
      .00      .00     9.44      .00     .050     .070     .050     .000   599.80  2447.40
  .016214     150.     150.     150.        2        0        0      .00   169.50  2616.90
0

SPECIAL BRIDGE

SB  XK         XKOR       COFQ       RDLEN      BWC        BWP        BAREA      SS         ELCHU      ELCHD
     1.05       1.50       2.60        .00      60.00      18.00    2000.00       2.00     601.00     600.00
```

*SECNO 3.000
CLASS A LOW FLOW

3420 BRIDGE W.S.= 617.12 BRIDGE VELOCITY=, 8.71 CALCULATED CHANNEL AREA=, 1197.

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD
.00	619.08	.77	0.	10900.	2000.	1485.	619.70	623.45

3495 OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 623.45 ELREA= 623.45

UPSTREAM BRIDGE 132

3.00	17.94	617.91	.00	.00	619.08	1.17	.56	.00	616.77
10900.	0.	10900.	0.	0.	1256.	0.	7.	2.	615.67
.01	.00	8.68	.00	.000	.070	.000	.000	599.97	2447.40
.012263	32.	32.	32.	0	0	0	.00	169.50	2616.90

0
*SECNO 4.000

3301 HV CHANGED MORE THAN HVINS

APPROACH 505

4.00	18.39	620.39	.00	.00	620.48	.10	1.08	.32	618.80
10900.	1057.	3853.	5990.	605.	1332.	2606.	32.	9.	617.70
.05	1.75	2.89	2.30	.050	.070	.050	.000	602.00	2140.04
.001259	373.	373.	373.	4	0	0	.00	1380.94	3520.98

0
*SECNO 5.000

5.00	17.81	620.60	.00	.00	620.74	.15	.24	.02	619.59
10900.	816.	4450.	5634.	429.	1232.	2088.	46.	14.	618.49
.06	1.90	3.61	2.70	.050	.070	.050	.000	602.79	2158.78
.002178	146.	146.	146.	2	0	0	.00	1310.04	3468.82

PLOTTED POINTS (BY PRIORITY)-E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

```
ELEVATION   595.      600.      605.      610.      615.      620.      625.      630.      635.      640.
    SECNO   CUMDIS

     1.00     0.  C        I.         .         .         R LE      .         .         .         .    M    .         .
             20.  C        I.         .         .         R  WE     .         .         .         .    M    .         .
             40.  C        I.         .         .         R  WE     .         .         .         .    M    .         .
             60.  C        I.         .         .         .R W E    .         .         .         .    M    .         .
             80.  C        I.         .         .         .R LWE    .         .         .         .    M    .         .
            100.  C        I.         .         .         .R LW E   .         .         .         .    M    .         .
            120.  C        I.         .         .         .R LW E   .         .         .         .    M    .         .
            140.  C         I         .         .         .R LW  E  .         .         .         .    M    .         .
     2.00   160.  C         I         .         .         .R LW  E  .         .         .         .    M    .         .
            180.  C         I         .         .         .R L W  E .         .         .         .     M   .         .
     3.00   200.  C         I         .         .         .R  L W E .         .         .         .     M   .         .
            220.  C         I         .         .         . R L W E .         .         .         .     M   .         .
            240.  C         I         .         .         . R L W E .         .         .         .     M   .         .
            260.  C         .I        .         .         . R L  W E.         .         .         .     M   .         .
            280.  C         .I        .         .         . R L  W E.         .         .         .      M  .         .
            300.  C         .I        .         .         . R  L W E.         .         .         .      M  .         .
            320.  C         .I        .         .         .  R L W E.         .         .         .      M  .         .
            340.  C         .I        .         .         .  R L  WE.         .         .         .      M  .         .
            360.  C         . I       .         .         .  R L  WE.         .         .         .      M  .         .
            380.  C         . I       .         .         .  R L  W E         .         .         .       M .         .
            400.  C         . I       .         .         .   R L W E         .         .         .       M .         .
            420.  C         . I       .         .         .   R L  WE         .         .         .       M .         .
            440.  C         .  I      .         .         .   R L  WE         .         .         .       M .         .
            460.  C         .  I      .         .         .   R L  WE         .         .         .        M.         .
            480.  C         .  I      .         .         .   R  L  E         .         .         .        M.         .
            500.  C         .  I      .         .         .    R L  E         .         .         .        M.         .
            520.  C         .  I      .         .         .    R L  WE        .         .         .        M.         .
            540.  C         .   I     .         .         .    R L  WE        .         .         .        M.         .
     4.00   560.  C         .   I     .         .         .    R  L .E        .         .         .         M         .
            580.  C         .   I     .         .         .     R L .E        .         .         .         M         .
            600.  C         .   I     .         .         .     R L .E        .         .         .         M         .
            620.  C         .    I    .         .         .     R L .E        .         .         .         M         .
            640.  C         .    I    .         .         .     R L .E        .         .         .         .M        .
            660.  C         .    I    .         .         .     R  L.E        .         .         .         .M        .
            680.  C         .    I    .         .         .      R L.E        .         .         .         .M        .
            700.  C         .     I   .         .         .      R L.E        .         .         .         .M        .
     5.00   720.  C         .     I   .         .         .      R L.E        .         .         .         .M        .
```

THIS RUN EXECUTED 04-13-89

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**************************************************
  HEC2 RELEASE DATED NOV 76 UPDATED MAY  1984
  ERROR CORR -  01,02,03,04,05,06
  MODIFICATION -  50,51,52,53,54,55,56
  IBM-PC-XT VERSION AUGUST 1985
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

POSEY CREEK   INDUSTRI

SUMMARY PRINTOUT

SECNO	CWSEL	CRIWS	EG	DEPTH	10K*S	QCH	QROB	AREA	VCH	K*CHSL	ALPHA	Q
1.000	616.38	.00	616.68	16.95	54.04	5698.72	4800.19	2673.51	5.24	.00	1.19	10900.00
2.000	617.14	.00	618.53	17.34	162.14	10900.00	.00	1155.17	9.44	2.48	1.00	10900.00
3.000	617.91	.00	619.08	17.94	122.63	10900.00	.00	1256.10	8.68	5.43	1.00	10900.00
4.000	620.39	.00	620.48	18.39	12.59	3852.73	5990.06	4542.91	2.89	5.43	1.07	10900.00
5.000	620.60	.00	620.74	17.81	21.78	4450.49	5633.75	3749.20	3.61	5.43	1.11	10900.00

SITE 3 - CANEY RIVER

WASHINGTON COUNTY

```
C
T1      FLOODWAY ANALYSIS - CASE STUDY #       3WASHINGTOWN     HE2CA.DAT
T2      SPECIAL BRIDGE METHOD    RUN # 1                         SITE 3
T3       CANNEY RIVER    50, 100 AND 1986 FLOOD

J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

       0.        2.        0.        0.   .000400       .00        .0        0.      .000      .000

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

     1.000      .000      .000      .000      .000      .000      .000      .000      .000      .000

J3  VARIABLE CODES FOR SUMMARY PRINTOUT

    38.000     1.000     2.000     3.000     8.000     5.000    14.000    15.000    25.000    26.000


    33.000    57.000    58.000      .000      .000      .000      .000      .000      .000      .000

J6  IHLEQ     ICOPY

     3.000      .000      .000      .000      .000      .000      .000      .000      .000      .000


NC       .048       .048       .060       .300       .500       .000       .000       .000       .000       .000
QT      3.000  58316.000  69500.000 108000.000       .000       .000       .000       .000       .000       .000
         EXIT
X1      1.000     16.000       .000    500.000       .000       .000       .000       .000       .000       .000
GR    670.000       .000    652.000     60.000    650.000    100.000    640.000    160.000    617.000    200.000
GR    614.000    230.000    617.000    270.000    635.000    290.000    639.000    400.000    651.000    500.000
GR    645.000   1600.000    644.000   3047.000    644.000   5313.000    650.000   8282.000    660.000  10625.000
GR    670.000  11250.000       .000       .000       .000       .000       .000       .000       .000       .000
```

X1	3.000	18.000	.000	540.000	390.000	390.000	390.000	.000	.000	.000
GR	672.990	.000	665.460	70.000	618.000	80.000	617.000	125.000	618.000	170.000
GR	625.000	190.000	627.000	218.400	637.600	245.000	639.240	395.700	650.000	540.000
GR	649.230	550.200	642.600	3099.000	639.520	3345.000	640.220	3430.000	643.640	4857.500
GR	639.820	5457.000	648.230	9315.000	662.000	10765.000	.000	.000	.000	.000
X1	4.000	18.000	44.170	556.700	150.000	150.000	150.000	.000	.000	.000
GR	672.990	.000	668.230	17.300	668.230	44.170	617.250	81.250	618.000	156.000
GR	635.800	217.000	640.910	477.800	650.000	534.800	660.000	556.700	656.000	3300.000
GR	642.000	3333.730	642.000	3415.200	656.470	3450.500	660.000	5370.000	642.000	5404.340
GR	642.000	5513.000	661.000	5550.500	668.000	10765.000	.000	.000	.000	.000
SB	1.050	1.500	2.600	.000	450.000	21.500	14000.000	1.000	634.000	633.000
X1	5.000	.000	.000	.000	135.000	135.000	135.000	.000	.000	.000
X2	.000	.000	1.000	664.000	660.000	.000	.000	.000	.000	.000
BT	7.000	.000	672.000	668.000	580.000	664.000	660.000	3047.000	660.000	656.000
BT	3200.000	661.000	657.000	5313.000	665.000	660.000	5478.000	666.000	661.000	12346.000
BT	670.000	670.000	.000	.000	.000	.000	.000	.000	.000	.000
X1	6.000	18.000	.000	540.000	100.000	100.000	100.000	.000	.000	.000
GR	672.990	.000	665.460	70.000	618.000	80.000	617.270	125.000	618.000	170.000
GR	625.000	190.000	627.000	218.400	637.600	245.000	639.240	395.700	650.000	540.000
GR	649.230	550.200	642.600	3099.000	639.520	3345.000	640.220	3430.000	643.640	4857.500
GR	639.820	5457.000	648.230	9315.000	662.000	10765.000	.000	.000	.000	.000
X1	8.000	19.000	16.000	589.000	443.000	443.000	443.000	.000	.000	.000
GR	671.000	.000	665.700	16.000	638.000	70.000	638.000	200.000	618.000	230.000
GR	617.370	275.000	618.000	320.000	638.000	350.000	636.170	353.000	638.990	365.000
GR	639.500	589.000	643.650	626.000	647.900	1491.800	638.900	3381.000	642.540	4810.000
GR	641.670	5468.000	646.000	9308.000	654.000	9873.000	662.000	11629.000	.000	.000
EJ	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 1

IHLEQ = 3. THEREFORE FRICTION LOSS (HL) IS CALCULATED AS A FUNCTION OF THE GEOMETRIC MEAN FRICTION SLOPE. THAT IS,

HL = WLEN*(S*SLOPE)**.5

WHERE WLEN = DISCHARGE-WEIGHTED REACH LENGTH, S = FRICTION SLOPE AT CURRENT CROSS SECTION, SLOPE = FRICTION SLOPE AT PRECEDING CROSS SECTION.

CCHV= .300 CEHV= .500

*SECNO 1.000

2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED

3265 DIVIDED FLOW

EXIT

1.00	35.09	649.09	.00	.00	649.16	.07	.00	.00	670.00
58316.	0.	16600.	41716.	0.	5639.	26121.	0.	0.	651.00
.00	.00	2.94	1.60	.048	.060	.048	.000	614.00	105.46
.000406	0.	0.	0.	0	0	10	.00	7360.35	7831.84

0

*SECNO 3.000

3265 DIVIDED FLOW

3.00	32.23	649.23	.00	.00	649.25	.02	.08	.01	672.99
58316.	0.	10542.	47774.	0.	6926.	46400.	381.	75.	650.00
.10	.00	1.52	1.03	.048	.060	.048	.000	617.00	73.42
.000109	390.	390.	390.	1	0	0	.00	9327.78	9421.43

*SECNO 4.000

3265 DIVIDED FLOW

3301 HV CHANGED MORE THAN HVINS

4.00	31.70	648.95	.00	.00	649.69	.75	.08	.36	668.23
58316.	0.	50323.	7993.	0.	7016.	1531.	487.	92.	660.00
.10	.00	7.17	5.22	.048	.060	.048	.000	617.25	58.20
.002407	150.	150.	150.	2	0	0	.00	720.77	5526.71

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

SPECIAL BRIDGE

SB XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
1.05	1.50	2.60	.00	450.00	21.50	14000.00	1.00	634.00	633.00

*SECNO 5.000

3265 DIVIDED FLOW

CLASS A LOW FLOW

3420 BRIDGE W.S.= 649.34 BRIDGE VELOCITY=, 8.29 CALCULATED CHANNEL AREA=, 6808.

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD
.00	649.75	.07	0.	58316.	14000.	13755.	664.00	660.00

5.00	31.76	649.01	.00	.00	649.75	.74	.06	.00	668.23
58316.	0.	50254.	8062.	0.	7047.	1548.	514.	94.	660.00
.11	.00	7.13	5.21	.000	.060	.048	.000	617.25	58.15
.002369	135.	135.	135.	0	0	0	.00	721.82	5526.84

0

*SECNO 6.000

3265 DIVIDED FLOW

3301 HV CHANGED MORE THAN HVINS

6.00	32.73	650.00	.00	.00	650.01	.02	.04	.22	672.99
58316.	0.	9326.	48990.	0.	7263.	53131.	593.	106.	650.00
.14	.00	1.28	.92	.048	.060	.048	.000	617.27	73.26
.000075	100.	100.	100.	2	0	0	.00	9427.55	9500.92

0

*SECNO 8.000

8.00	32.66	650.03	.00	.00	650.04	.01	.03	.00	665.70
58316.	0.	9520.	48796.	0.	8541.	59384.	1246.	202.	639.50
.28	.00	1.11	.82	.048	.060	.048	.000	617.37	46.55
.000053	443.	443.	443.	2	0	0	.00	9545.91	9592.47

0

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PLOTTED POINTS (BY PRIORITY)-E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

ELEVATION   610.      620.      630.      640.      650.      660.      670.      680.      690.      700.
    SECNO   CUMDIS

     1.00     0.  C   I     .         .         .        E.R        .         L         .         .         .         .
             50.  C   I     .         .         .        E.R        .        ML         .         .         .         .
            100.  C    I    .         .         .        E.R        .       M .L        .         .         .         .
            150.  C    I    .         .         .        E.R        .      M  .L        .         .         .         .
            200.  C     I   .         .         .        ER         .     M   . L       .         .         .         .
            250.  C     I   .         .         .        ER         .    M    . L       .         .         .         .
            300.  C     I   .         .         .        ER         .   M     . L       .         .         .         .
            350.  C      I  .         .         .        ER         .  M      .  L      .         .         .         .
     3.00   400.  C      I  .         .         .        ER         . M       .  L      .         .         .         .
            450.  C      I  .         .         .        E.  R      .   M     .L        .         .         .         .
            500.  C      I  .         .         .        WE      R  .     M   L         .         .         .         .
     4.00   550.  C      I  .         .         .        WE         R       L .         .         .         .         .
            600.  C      I  .         .         .        WE         R       L .         .         .         .         .
            650.  C      I  .         .         .        WE         R       L .         .         .         .         .
     5.00   700.  C      I  .         .         .        WE         R       L .         .         .         .         .
            750.  C      I  .         .         .         E    R    .    M    .L        .         .         .         .
     6.00   800.  C      I  .         .         .         E         . M       .  L      .         .         .         .
            850.  C      I  .         .         .        RE         . M       . L       .         .         .         .
            900.  C      I  .         .         .       R E         . M       .L        .         .         .         .
            950.  C      I  .         .         .     R   E         . M       .L        .         .         .         .
           1000.  C      I  .         .         .    R    E         . M       L         .         .         .         .
           1050.  C      I  .         .         .   R     E         . M      L.         .         .         .         .
           1100.  C      I  .         .         .  R      E         . M     L .         .         .         .         .
           1150.  C      I  .         .         . R       E         . M    L  .         .         .         .         .
           1200.  C      I  .         .         .R        E         . M   L   .         .         .         .         .
     8.00  1250.  C      I  .         .         R         E         . M   L   .         .         .         .         .
```

T1 FLOODWAY ANALYSIS - CASE STUDY #3 HE2CA.DAT
T2 SPECIAL BRIDGE METHOD RUN # 1 SITE 3
T3 CANNEY RIVER 50, 100 AND 1986 FLOOD

J1	ICHECK	INQ	NINV	IDIR	STRT	METRIC	HVINS	Q	WSEL	FQ
	0.	3.	0.	0.	.000400	.00	.0	0.	.000	.000

J2	NPROF	IPLOT	PRFVS	XSECV	XSECH	FN	ALLDC	IBW	CHNIM	ITRACE
	2.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

*PROF 2

IHLEQ = 3. THEREFORE FRICTION LOSS (HL) IS CALCULATED AS A FUNCTION OF THE GEOMETRIC MEAN FRICTION SLOPE. THAT IS,

HL = WLEN*(S*SLOPE)**.5

WHERE WLEN = DISCHARGE-WEIGHTED REACH LENGTH, S = FRICTION SLOPE AT CURRENT CROSS SECTION, SLOPE = FRICTION SLOPE AT PRECEDING CROSS SECTION.

CCHV= .300 CEHV= .500
*SECNO 1.000
2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED

3265 DIVIDED FLOW

```
           EXIT
      1.00    35.72   649.72      .00      .00   649.79      .07      .00      .00   670.00
    69500.       0.   17414.   52086.       0.    5880.   30642.       0.       0.   651.00
       .00      .00     2.96     1.70     .048     .060     .048     .000   614.00   101.69
   .000400       0.       0.       0.        0        0       11      .00  7795.48  8142.77
0
 *SECNO 3.000

 3265 DIVIDED FLOW

      3.00    32.86   649.86      .00      .00   649.88      .02      .08      .01   672.99
    69500.       0.   11358.   58142.       0.    7215.   51985.     429.      77.   650.00
       .09      .00     1.57     1.12     .048     .060     .048     .000   617.00    73.29
   .000113     390.     390.     390.        1        0        0      .00  9410.62  9487.44
0
 *SECNO 4.000

 3265 DIVIDED FLOW


 3301 HV CHANGED MORE THAN HVINS

      4.00    32.23   649.48      .00      .00   650.44      .97      .09      .47   668.23
    69500.       0.   59332.   10168.       0.    7266.    1665.     546.      94.   660.00
       .10      .00     8.17     6.11     .048     .060     .048     .000   617.25    57.81
   .003011     150.     150.     150.        2        0        0      .00   729.10  5527.75

     SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS  BANK ELEV
     Q        QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA   LEFT/RIGHT
     TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN      SSTA
     SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID     ENDST

SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
     1.05      1.50      2.60       .00    450.00     21.50  14000.00      1.00    634.00    633.00
```

*SECNO 5.000

3265 DIVIDED FLOW

CLASS A LOW FLOW

3420 BRIDGE W.S.= 649.83 BRIDGE VELOCITY=, 9.57 CALCULATED CHANNEL AREA=, 7032.

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD
.00	650.53	.10	0.	69500.	14000.	13755.	664.00	660.00

5.00	32.32	649.57	.00	.00	650.53	.95	.08	.00	668.23
69500.	0.	59217.	10283.	0.	7312.	1690.	574.	97.	660.00
.10	.00	8.10	6.08	.000	.060	.048	.000	617.25	57.74
.002943	135.	135.	135.	0	0	0	.00	730.62	5527.95

0

*SECNO 6.000

3301 HV CHANGED MORE THAN HVINS

6.00	33.57	650.84	.00	.00	650.85	.02	.05	.28	672.99
69500.	0.	10012.	59488.	0.	7655.	60697.	662.	109.	650.00
.13	.00	1.31	.98	.048	.060	.048	.000	617.27	73.08
.000073	100.	100.	100.	2	0	0	.00	9516.31	9589.39

0

*SECNO 8.000

8.00	33.50	650.87	.00	.00	650.88	.01	.03	.00	665.70
69500.	0.	10359.	59141.	0.	8997.	66969.	1396.	206.	639.50
.26	.00	1.15	.88	.048	.060	.048	.000	617.37	44.92
.000053	443.	443.	443.	2	0	0	.00	9606.86	9651.78

PROFILE FOR STREAM   CANNEY RIVER   50, 100

PLOTTED POINTS (BY PRIORITY)-E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

```
ELEVATION   610.      620.      630.      640.      650.      660.      670.      680.      690.      700.
    SECNO   CUMDIS

     1.00      0.  C   I     .         .         .         ER        .         L         .         .         .         .
              50.  C   I     .         .         .         ER        .        ML         .         .         .         .
             100.  C    I    .         .         .         ER        .       M .L        .         .         .         .
             150.  C    I    .         .         .         ER        .      M  .L        .         .         .         .
             200.  C     I   .         .         .         E         .     M   . L       .         .         .         .
             250.  C     I   .         .         .         E         .    M    . L       .         .         .         .
             300.  C     I   .         .         .         E         .   M     . L       .         .         .         .
             350.  C      I  .         .         .         E         .  M      .  L      .         .         .         .
     3.00    400.  C      I  .         .         .         E         . M       .  L      .         .         .         .
             450.  C      I  .         .         .         E  R      .   M     .L        .         .         .         .
             500.  C      I  .         .         .         E      R  .     M   L         .         .         .         .
     4.00    550.  C      I  .         .         .        WE         R       L .         .         .         .         .
             600.  C      I  .         .         .         E         R       L .         .         .         .         .
             650.  C      I  .         .         .        WE         R       L .         .         .         .         .
     5.00    700.  C      I  .         .         .        WE         R       L .         .         .         .         .
             750.  C      I  .         .         .        WE    R    .    M    .L        .         .         .         .
     6.00    800.  C      I  .         .         .        RE         . M       .  L      .         .         .         .
             850.  C      I  .         .         .        R.E        . M       . L       .         .         .         .
             900.  C      I  .         .         .       R .E        . M       .L        .         .         .         .
             950.  C      I  .         .         .     R   .E        . M       .L        .         .         .         .
            1000.  C      I  .         .         .    R    .E        . M       L         .         .         .         .
            1050.  C      I  .         .         .   R     .E        . M      L.         .         .         .         .
            1100.  C      I  .         .         .  R      .E        . M     L .         .         .         .         .
            1150.  C      I  .         .         . R       .E        . M    L  .         .         .         .         .
            1200.  C      I  .         .         .R        .E        . M   L   .         .         .         .         .
     8.00   1250.  C      I  .         .         R         .E        . M   L   .         .         .         .         .
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T1      FLOODWAY ANALYSIS - CASE STUDY #3      HE2CA.DAT
T2      SPECIAL BRIDGE METHOD    RUN # 1                       SITE 3
T3       CANNEY RIVER    50, 100 AND 1986 FLOOD

J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS    Q         WSEL      FQ

      0.        4.        0.        0.    .000400      .00       .0       0.       .000      .000

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

     15.000     .000      .000      .000      .000      .000      .000      .000      .000      .000


       SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS   BANK ELEV
       Q        QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA   LEFT/RIGHT
       TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN     SSTA
       SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID    ENDST


    *PROF 3

    IHLEQ = 3.  THEREFORE FRICTION LOSS (HL) IS CALCULATED AS A FUNCTION OF THE
    GEOMETRIC MEAN FRICTION SLOPE.  THAT IS,

                HL  = WLEN*(S*SLOPE)**.5

    WHERE WLEN = DISCHARGE-WEIGHTED REACH LENGTH, S = FRICTION SLOPE AT CURRENT
    CROSS SECTION, SLOPE = FRICTION SLOPE AT PRECEDING CROSS SECTION.

    CCHV=     .300 CEHV=     .500
    *SECNO 1.000
    2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED
    3840 SECTION NOT HIGH ENOUGH    746.440    720.000    614.000    720.000    644.000       14
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SECNO	DEPTH	CWSEL	CRIWS	WSELK	EG	HV	HL	OLOSS	BANK ELEV
Q	QLOB	QCH	QROB	ALOB	ACH	AROB	VOL	TWA	LEFT/RIGHT
TIME	VLOB	VCH	VROB	XNL	XNCH	XNR	WTN	ELMIN	SSTA
SLOPE	XLOBL	XLCH	XLOBR	ITRIAL	IDC	ICONT	CORAR	TOPWID	ENDST

SPECIAL BRIDGE

SB	XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
	1.05	1.50	2.60	.00	450.00	21.50	14000.00	1.00	634.00	633.00

EXIT

1.00	37.40	651.40	646.71	.00	651.48	.08	.00	.00	670.00
108000.	0.	19524.	88476.	0.	6565.	43789.	0.	0.	651.00
.00	.00	2.97	2.02	.048	.060	.048	.000	614.00	71.99
.000396	0.	0.	0.	0	34	9	.00	8538.12	8610.11

0

*SECNO 3.000

3.00	34.55	651.55	.00	.00	651.58	.03	.09	.01	672.99
108000.	0.	14415.	93585.	0.	8003.	67232.	562.	81.	650.00
.07	.00	1.80	1.39	.048	.060	.048	.000	617.00	72.93
.000130	390.	390.	390.	0	0	0	.00	9592.19	9665.12

0

*SECNO 4.000

3265 DIVIDED FLOW

3301 HV CHANGED MORE THAN HVINS

4.00	33.49	650.74	.00	.00	652.64	1.90	.13	.94	668.23
108000.	0.	90035.	17965.	0.	7870.	1996.	709.	99.	660.00
.08	.00	11.44	9.00	.048	.060	.048	.000	617.25	56.89
.005408	150.	150.	150.	2	0	0	.00	745.99	5530.25

*SECNO 5.000

3265 DIVIDED FLOW

CLASS A LOW FLOW

3420 BRIDGE W.S.= 650.84 BRIDGE VELOCITY=, 13.97 CALCULATED CHANNEL AREA=, 7497.

EGPRS	EGLWC	H3	QWEIR	QLOW	BAREA	TRAPEZOID AREA	ELLC	ELTRD
.00	652.84	.28	0.	108000.	14000.	13755.	664.00	660.00

5.00	33.77	651.02	.00	.00	652.84	1.82	.20	.00	668.23
108000.	0.	89603.	18397.	0.	8002.	2069.	740.	101.	660.00
.08	.00	11.20	8.89	.000	.060	.048	.000	617.25	56.69
.005081	135.	135.	135.	0	0	0	.00	749.19	5530.80

0

*SECNO 6.000

3301 HV CHANGED MORE THAN HVINS

6.00	36.15	653.42	.00	.00	653.44	.02	.06	.54	672.99
108000.	0.	12162.	95838.	0.	8861.	84422.	858.	113.	650.00
.11	.00	1.37	1.14	.048	.060	.048	.000	617.27	72.54
.000066	100.	100.	100.	2	0	0	.00	9788.84	9861.38

0

*SECNO 8.000

8.00	36.08	653.45	.00	.00	653.47	.02	.03	.00	665.70
108000.	0.	12973.	95027.	0.	10408.	90605.	1846.	213.	639.50
.22	.00	1.25	1.05	.048	.060	.048	.000	617.37	39.88
.000052	443.	443.	443.	2	0	0	.00	9794.25	9834.13

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PLOTTED POINTS (BY PRIORITY)-E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-LOWER END STA

ELEVATION   610.      620.      630.      640.      650.      660.      670.      680.      690.      700.
   SECNO    CUMDIS

     1.00     0.  .   I     .         .         .      C  .E        .         L         .         .         .         M
             50.  C   I     .         .         .         .E        .         L         .         .         .         M
            100.  C    I    .         .         .         .WE       .         .L        .         .         .    M    .
            150.  C    I    .         .         .         .WE       .         .L        .         .       M .         .
            200.  C     I   .         .         .         RWE       .         . L       .         M         .         .
            250.  C     I   .         .         .         RWE       .         . L       .  M      .         .         .
            300.  C     I   .         .         .         R E       .         . L  M    .         .         .         .
            350.  C      I  .         .         .         R E       .       M . L      .         .         .         .
     3.00   400.  C      I  .         .         .         R E       . M       . L      .         .         .         .
            450.  C      I  .         .         .         .WER      .   M     .L        .         .         .         .
            500.  C      I  .         .         .         .WE    R  .     M   L         .         .         .         .
     4.00   550.  C      I  .         .         .         .W E      R       L .         .         .         .         .
            600.  C      I  .         .         .         .W E      R       L .         .         .         .         .
            650.  C      I  .         .         .         .W E      R       L .         .         .         .         .
     5.00   700.  C      I  .         .         .         .W E      R       L .         .         .         .         .
            750.  C      I  .         .         .         . WE R    .    M    .L        .         .         .         .
     6.00   800.  C      I  .         .         .         R  E      . M       .  L      .         .         .         .
            850.  C      I  .         .         .        R.  E      . M       . L       .         .         .         .
            900.  C      I  .         .         .       R .  E      . M       .L        .         .         .         .
            950.  C      I  .         .         .     R   .  E      . M       .L        .         .         .         .
           1000.  C      I  .         .         .    R    .  E      . M       L         .         .         .         .
           1050.  C      I  .         .         .   R     .  E      . M      L.         .         .         .         .
           1100.  C      I  .         .         .  R      .  E      . M     L .         .         .         .         .
           1150.  C      I  .         .         . R       .  E      . M    L  .         .         .         .         .
           1200.  C      I  .         .         .R        .  E      . M   L   .         .         .         .         .
     8.00  1250.  C      I  .         .         R         .  E      . M   L   .         .         .         .         .
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

CANNEY RIVER 50, 100

SUMMARY PRINTOUT

SECNO	CWSEL	CRIWS	EG	DEPTH	10K*S	QCH	QROB	AREA	VCH	K*CHSL	ALPHA	KRATIO
1.000	649.09	.00	649.16	35.09	4.06	16599.85	41716.15	31759.86	2.94	.00	1.27	.00
1.000	649.72	.00	649.79	35.72	4.00	17414.38	52085.62	36521.49	2.96	.00	1.20	.00
1.000	651.40	646.71	651.48	37.40	3.96	19524.15	88475.85	50353.85	2.97	.00	1.07	.00
3.000	649.23	.00	649.25	32.23	1.09	10541.67	47774.32	53326.72	1.52	7.69	1.08	1.93
3.000	649.86	.00	649.88	32.86	1.13	11357.61	58142.39	59199.63	1.57	7.69	1.05	1.88
3.000	651.55	.00	651.58	34.55	1.30	14415.49	93584.52	75234.25	1.80	7.69	1.02	1.74
4.000	648.95	.00	649.69	31.70	24.07	50323.24	7992.77	8547.65	7.17	1.67	1.03	.21
4.000	649.48	.00	650.44	32.23	30.11	59331.51	10168.49	8931.36	8.17	1.67	1.03	.19
4.000	650.74	.00	652.64	33.49	54.08	90034.70	17965.31	9866.15	11.44	1.67	1.02	.16
5.000	649.01	.00	649.75	31.76	23.69	50254.38	8061.62	8595.46	7.13	.00	1.03	1.01
5.000	649.57	.00	650.53	32.32	29.43	59217.11	10282.89	9001.92	8.10	.00	1.03	1.01
5.000	651.02	.00	652.84	33.77	50.81	89602.81	18397.18	10071.70	11.20	.00	1.02	1.03
6.000	650.00	.00	650.01	32.73	.75	9326.32	48989.68	60393.61	1.28	.20	1.05	5.62
6.000	650.84	.00	650.85	33.57	.73	10012.31	59487.69	68351.48	1.31	.20	1.03	6.36
6.000	653.42	.00	653.44	36.15	.66	12161.56	95838.44	93283.57	1.37	.20	1.01	8.75
8.000	650.03	.00	650.04	32.66	.53	9519.94	48796.06	67924.33	1.11	.23	1.04	1.19
8.000	650.87	.00	650.88	33.50	.53	10359.45	59140.55	75966.41	1.15	.23	1.03	1.17
8.000	653.45	.00	653.47	36.08	.52	12972.52	95027.48	101012.90	1.25	.23	1.01	1.13

VITA

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Master of Science

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