EFFECTS OF PROPOSED HIGHWAY EMBANKMENT MODIFICATIONS ON WATER-SURFACE ELEVATIONS IN THE LOWER PEARL RIVER FLOOD PLAIN NEAR SLIDELL, LOUISIANA

By J.J. Gilbert, and R.E. Schuck-Kolben

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ABSTRACT

Major flooding in the lower Pearl River basin in recent years has caused extensive damage to homes and highways in the area. In 1980 and 1983, Interstate Highway 10 and U.S. Highway 190 were overtopped. In 1983, the Interstate Highway 10 crossing was seriously damaged by the flood. The U.S. Geological Survey, in cooperation with the Louisiana Department of Transportation and Development, Office of Highways, used a two-dimensional finite-element surface-water flow model to evaluate the effects of proposed embankment modifications at Interstate Highway 10 and U.S. Highway 90 on the water-surface elevations in the lower Pearl River flood plain near Slidell, Louisiana.

The proposed modifications that were considered for the 1983 flood are: (1) Removal of all highway embankments, the natural condition, (2) extension of the West Pearl River bridge by 1,000 feet at U.S. Highway 90, (3) construction of a new 1,000-foot bridge opening in the Interstate Highway 10 embankment between the West Pearl River and Middle Pearl River bridge openings, and (4) construction of a new 250-foot bridge opening in U.S. Highways 190 and 90, west of the intersection of the highways. The proposed highway bridge modifications also incorporated lowering of ground-surface elevations under the new bridges to sea level.

The modification that provided the largest reduction in backwater, about 35 percent, was a new bridge in Interstate Highway 10. The modification of the West Pearl River bridge at U.S. Highway 90 and replacement of the bridge in U.S. Highway 190 provide about a 25 percent reduction in backwater each.

For the other modification conditions that required structural modifications, maximum backwater computed on the west side of the flood plain ranges from 0.0 to 0.8 foot and on the east side from 0.0 to 0.6 foot. Results show that although backwater is greater on the west side of the flood plain than on the east side, upstream of highway embankments, backwater decreases more rapidly in the upstream direction on the west side of the flood plain than on the east side. Analysis of the proposed modifications indicates that backwater would still occur on the east and west sides of the flood plain, but values would be less than those computed with highway embankments in place.

INTRODUCTION

In April 1983, extreme flooding was caused by precipitation ranging from 4.7 to 18.3 in. over the entire lower Pearl River basin. Flooding along the lower Pearl River caused extensive property damage on the flood plain in the area of Slidell, La. Damage in the Slidell area due to the 1983 flood, a 200-year flood, was estimated to be $16.338 million (T.M. Creaghan, Louisiana State Office of Emergency Preparedness, oral commun., 1983). Interstate Highway 10 (I-10), U.S. Highway 90 (U.S. 90), and U.S. Highway 190 (U.S. 190) were closed while the flood crest passed. U.S. 190 and I-10 were overtopped and the eastbound lanes of I-10 were closed for a week for structural repair work on the Middle Pearl River bridge.

Roadways leading to bridges that cross wide flood plains are generally constructed on top of earthen approaches to provide access to the bridge during floods. When approach embankments significantly encroach upon the flood plain, large amounts of backwater may result. Many residents attribute part of the flooding in the Slidell area to backwater caused by highway embankments that cross the Pearl River flood plain.

The U.S. Geological Survey, in cooperation with the Louisiana Department of Transportation and Development, Office of Highways, and the U.S. Department of Transportation, Federal Highway Administration, investigated the effect of proposed modifications of highway embankments on water-surface elevations on the lower Pearl River near Slidell. The investigation was undertaken in response to excessive flooding, highway overtopping, and the concern of area residents.

Floods and the effect of highway embankment modifications on flooding were simulated using the FESWMS-2DH (Finite-Element Surface-Water Modeling System for Two-Dimensional Flow in the Horizontal Plane). Traditionally, one-dimensional methods have been used for hydraulic analysis of multiple-opening bridge crossings on wide flood plains, providing only longitudinal variations in velocity and water-surface elevation. Methods for selecting the distribution of flow through multiple openings in embankments and procedures for determining backwater are based on laboratory investigations and practical experience.

Wide flood plains, however, generally exhibit a two-dimensional flow pattern (in the horizontal plane) especially at high stages. The flow distribution is complicated further by structural modifications, such as highway embankments, and the existence of more than one river channel in the flood plain.

Purpose and Scope

This report describes the results of a study to evaluate the effects of present (1984 in this report) highway embankment conditions as well as four proposed modifications of highway embankments on water-surface elevations in the lower Pearl River flood plain using data from the flood of April 1983. The analysis illustrates the usefulness of the FESWMS-2DH model, which simulates flow with both lateral and longitudinal variations in water-surface elevation and velocity, in studying the impacts of complex highway crossings on flood flows. Constrictions of the flood plain created by highway embankments, together with other physical features of the flood plain, caused significant lateral variations in water-surface elevation and flow distribution during the 1983 flood.

In the hydraulic simulations of the highway crossings, modifications were made to the model network to simulate different highway embankment modifications. The proposed modifications that were considered for the 1983 flood are: (1) Removal of all highway embankments, the natural condition, (2) extension of the West Pearl River bridge by 1,000 feet at U.S. Highway 90, (3) construction of a new 1,000-foot bridge opening in the I-10 embankment between the West Pearl River and Middle Pearl River bridge openings, and (4) construction of a new 250-foot bridge opening in U.S. Highways 190 and 90, west of the intersection of the highways. The proposed highway bridge modifications also incorporated lowering of ground-surface elevations under the new bridges to sea level.

A comparison of water-surface elevations and discharges and various locations in the study area was made to evaluate the effect of the proposed modifications. The model network for any modification is identical to the network for the present condition with the exception of changes made to simulate the modifications. The geometry and hydraulic conditions for any modifications were consistent with conditions which exist elsewhere in the system. The simulations were performed using the entire network, even if only one highway crossing was modified, to allow comparison to any other modification considered in this study.

Previous Studies

In a study by Lee and others (1982), data collected during and after the 1980 flood were used to calibrate the FESWMS model of the Pearl River above U.S. 90. Wiche and others (1984) used the FESWMS model to evaluate the impact of structural and nonstructural modifications to the flood plain and I-10 embankment on backwater and flow distribution using only a part of the calibrated model. The modifications considered were (1) removal of vegetation to accelerate flows in areas of interest, (2) construction of two alternate bridge structures, and (3) removal of spoil in control sections within the flood plain.

The U.S. Geological Survey and the U.S. Army Corps of Engineers conducted a coordinated flood-frequency analysis for eight gaging stations on the Pearl River (Vernon Sauer, U.S. Geological Survey, written commun., 1980). Skew values and historical flood data used in the analysis were mutually agreed upon by both agencies.

Acknowledgments

The assistance of H.J. Barousse and H.C. Shah, Louisiana Department of Transportation and Development, Office of Highways, and Mitchell Smith, U.S. Department of Transportation, Federal Highway Administration, is gratefully acknowledged.

DESCRIPTION OF THE STUDY AREA

General Setting

The study area includes the lower part of the Pearl River basin along the Mississippi-Louisiana border. The study area, approximately 14 mi long, is bounded on the north by old U.S. Highway 11 (old U.S. 11) and Interstate Highway 59 (I-59) and ends approximately 2 mi south of U.S. 90 (fig. 1). The eastern and western boundaries are the natural bluffs at the edge of the flood plain, where ground-surface elevations rise abruptly to 15 to 25 ft above sea level in the northern part of the study reach and to 5 to 15 ft above sea level in the southern part.

Within the study area, the axis of the flood plain trends south-southeast, and the flood plain varies in width from about 4 to 7 mi. The flood plain is covered by dense woods, mixed with underbrush in many places. Vegetative cover in the study area is shown in figure 2. Ground-surface elevations of the flood plain range from 0.5 ft above sea level in the southern part of the study area to 15 ft above sea level in the northwestern part. Between the upstream boundary and I-10, ground-surface elevations are higher near the West Pearl River than on the east side of the flood plain. Low natural levees border most of the channels in the study area. The flood plain has a slope of about 1 ft/mi.

The major channels in the study area are the Pearl, East Middle, Middle, West Middle, and West Pearl Rivers, and Wastehouse Bayou. The Pearl River flows along the east side of the flood plain, and the West Pearl River along the west side. West Pearl River is the largest channel in the flood plain in the northern part of the study area. The Pearl River becomes the largest near I-10 and remains the largest to the mouth of the river system.

On the West Pearl River, a distributary channel, the Middle Pearl River, forms and flows southeastward approximately 3.9 mi, where it divides into the Middle and West Middle Pearl Rivers. Approximately 6.3 mi farther south, the Middle Pearl River divides again, and another distributary channel, the East Middle Pearl River, forms. The East Middle and Middle Pearl Rivers flow into the Pearl River about 1.3 mi north of Little Lake. Wastehouse Bayou forms within the flood plain and is tributary to the Pearl River just north of I-10.

The main river channels flow generally southward and south-southeastward to the mouth of the Pearl River system. The Pearl River flows into Lake Borgne; the West Middle Pearl River and the East Mouth of the West Pearl River flow into Little Lake; and the West Mouth of the West Pearl River flows into the Rigolets (fig. 1). The drainage area of the Pearl River system is 8,670 mi^2 at the mouth of the system (Shell, 1981, p. 232).

Flow enters the study area through the old U.S. 11 bridge opening at the Pearl River, through the I-59 bridge opening at the West Pearl River, and through numerous small openings in the old U.S. 11 embankments. The I-59 bridge opening at the West Pearl River is 2,630 ft in width, and the old U.S. 11 bridge opening at the Pearl River is 570 ft in width.

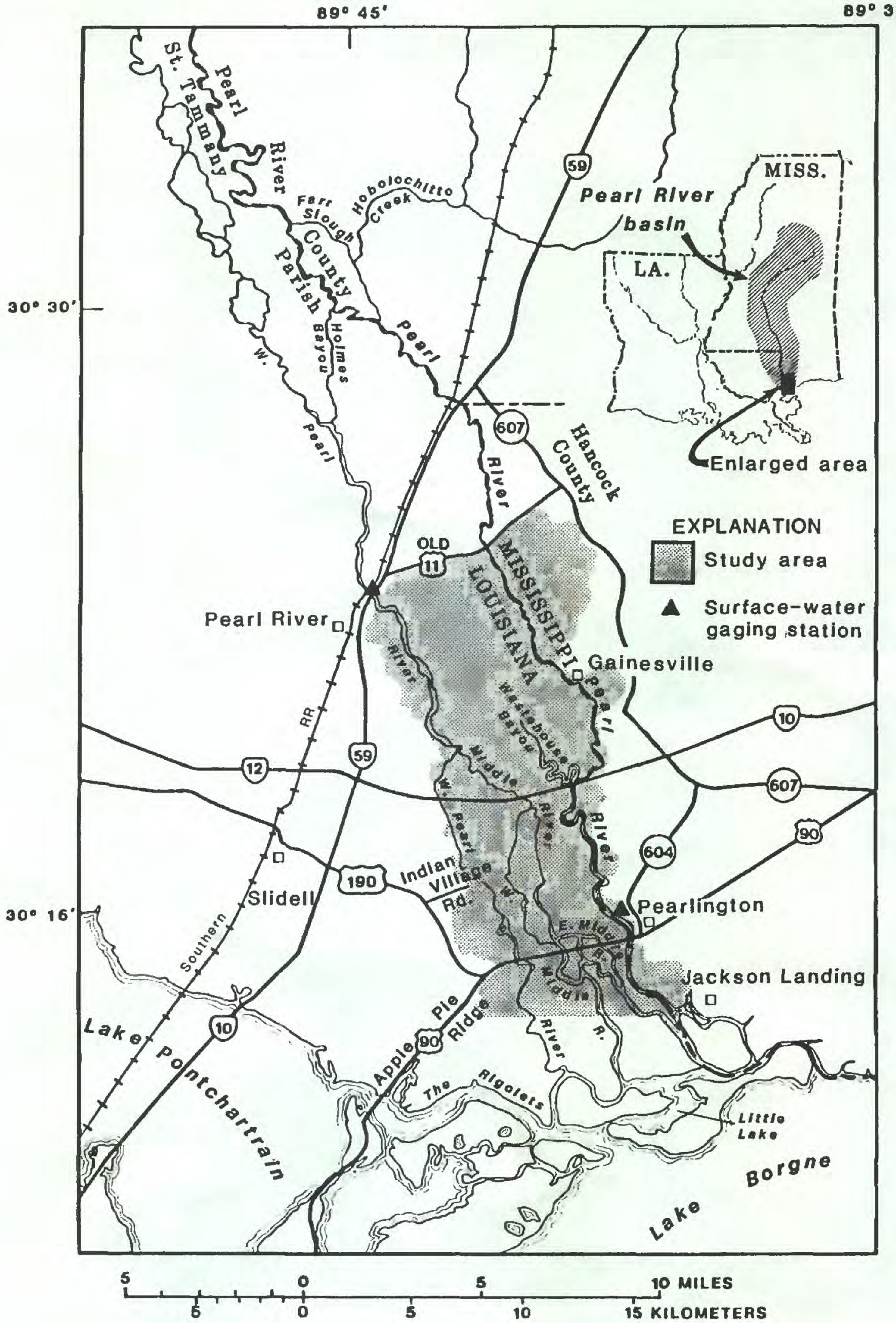

Figure 1.--Study area, lower Pearl River basin, Louisiana and Mississippi.

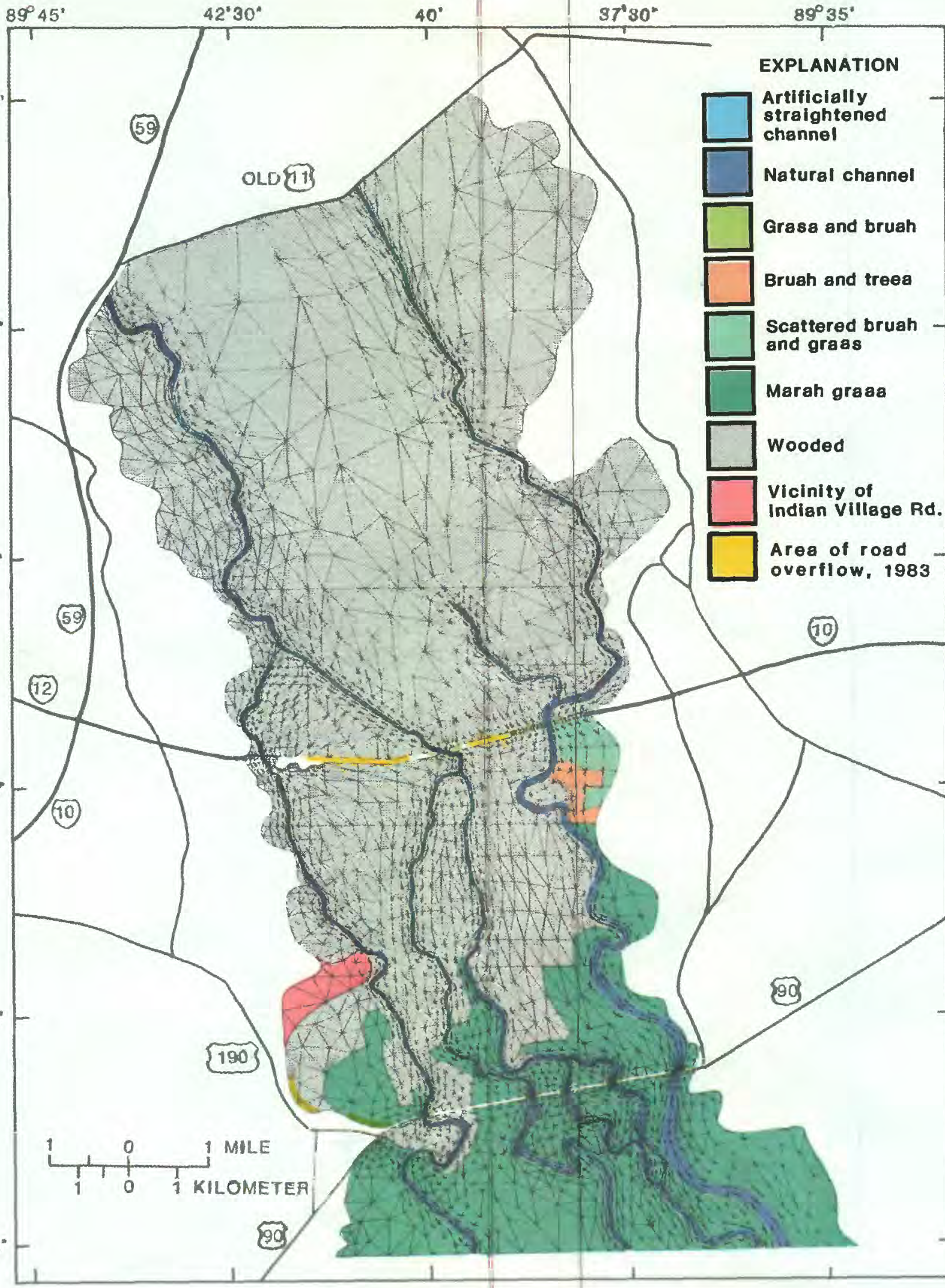

Figure 2.--Finite-element grid network showing areas of simulation of different vegetative cover.

The I-10 crossing, about 4.4 mi long, spans the flood plain in an east-west direction in the middle of the study reach. There are bridge openings at the Pearl, Middle, and West Pearl Rivers, with widths of 4,980, 770, and 2,240 ft, respectively. The embankment between the Pearl and Middle Pearl Rivers is about 0.8 mi long, and the embankment between the Middle and West Pearl Rivers is about 2.1 mi long. The embankments are about 300 ft wide, and the elevation of the roadway is between 12 and 13 ft above sea level. Natural flood-plain elevations near I-10 range from 1 to 3 ft above sea level.

Flow passes through five openings in the U.S. 90 embankments. The opening widths are 960 ft at the Pearl River, 630 ft at the East Middle Pearl River, 580 ft at the Middle Pearl River, 580 ft at the West Middle Pearl River, and 570 ft at the West Pearl River. The embankment crest elevations range from 6.5 to 9.5 ft above sea level with ground surfaces sloping gradually away from the embankment to the flood plain. Natural flood-plain elevations near U.S 90 range from 0 to 2 ft above sea level. The U.S. 90 embankment was not overtopped in 1980 or 1983. Some flow over U.S. 190 occurs during large floods near the U.S. 90-U.S. 190 intersection.

Flow leaves the study area approximately 2 mi south of the U.S. 90 highway crossing, near Jackson Landing on the east bank and near the south edge of Apple Pie Ridge on the west bank.

Water-Surface Elevations and Discharges

Water-surface elevations have ranged from 1.5 to 21.1 ft above sea level during the period 1899-1984, according to gage-height records collected at the gaging station, Pearl River at Pearl River, La. The maximum water-surface elevation at the Pearl River gage was 19.7 ft above sea level during the 1980 flood and 21.1 ft above sea level during the 1983 flood.

Water-surface elevations have ranged from about 2.0 ft below sea level to about 8.4 ft (September 10, 1965) above sea level during the 23-year period 1961-84, according to records collected at the Corps of Engineers gaging station, Pearl River at Pearlington, Miss. (R. Fitzgerald, U.S. Army Corps of Engineers, written commun., 1982, 1984). The maximum water-surface elevation observed at the Pearlington gage during the 1983 flood was 6.8 ft above sea level.

Discharges measured at various sites in the study area during the 1979, 1980, and 1983 floods are shown in table 1. Peak discharge for the April 1983 flood was 230,000 ft^3/s based on the peak stage and the rating curve developed for the West Pearl River at Pearl River as well as measurements made at I-59, I-10, and U.S. 90. The recurrence interval for the 1983 flood is greater than 200 years. The flood-frequency relation for the West Pearl River at Pearl River is shown in figure 3.

Table 1.--Discharges measured during the 1979, 1980, and 1983 floods on the lower Pearl River

[I-59, Interstate Highway 59; I-10, Interstate Highway 10; U.S. 90, U.S. Highway 90; U.S. 190, U.S. Highway 190. The bridge openings are numbered from left to right as an observer faces downstream. Discharge, in cubic feet per second]

Date	I-59 bridge openings								Total
	1 (Pearl River)	2	3	4	5	6	7	8 (West Pearl River)	
4-24-79	14,800	2,800	5,500	9,100	4,300	5,100	9,600	91,000	142,000
4-26-79	17,700	3,600	7,400	11,200	5,400	5,800	11,600	92,000	155,000
4-10-83	24,500	6,200	12,100	15,900	10,300	5,000	9,300	112,800	196,000
4-11-83	16,300	3,000	7,500	11,500	4,000	4,900	8,200	89,800	145,000

Date	I-10 bridge openings				Total
	Pearl River	Middle River	West Pearl River	Road overflow	
4-26-79	88,600	29,000	33,800	0	151,000
5- 1-79	55,000	16,600	18,700	0	90,000
4- 2-80	103,000	30,000	40,800	0	174,000
4-10-83	118,900	30,600	40,100	33,900	223,500

Date	U.S. 90 bridge openings						Total
	Pearl River	East Middle River	Middle River	West Middle River	West Pearl River	U.S. 190 road overflow	
4-22-80	51,900	11,800	16,700	16,600	6,800	0	104,000
4-11-83	78,100	23,000	29,200	34,200	23,200	8,900	196,900

Recurrence interval (yr)	2	5	10	25	50	100	200	500
Discharge (ft^3/s)	56,500	87,400	111,000	143,000	169,000	198,000	228,000	272,000

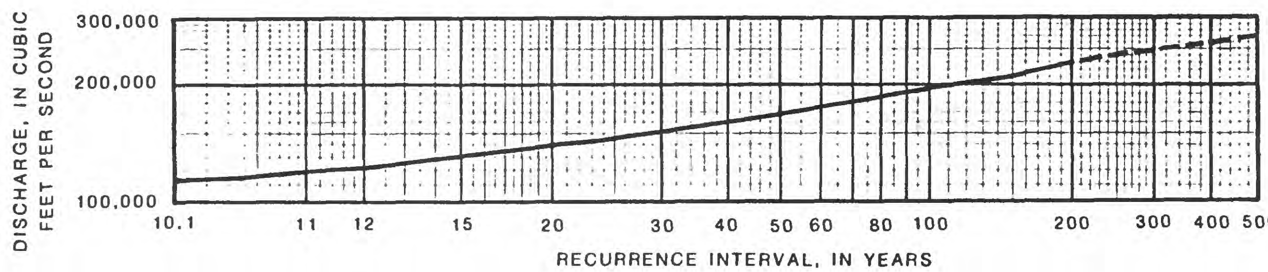

Figure 3.--Flood-frequency curve for West Pearl River at Pearl River, Louisiana.

DESCRIPTION OF MODEL

The FESWMS-2DH is a modular set of computer programs developed specifically for modeling surface-water flows where the flow is essentially two-dimensional in the horizontal plane. The modules include preprocessing and postprocessing programs in addition to the central flow model. Preprocessing programs edit and plot input data and arrange them in appropriate formats for use by the flow model. Postprocessing programs plot maps of velocity vectors and water-surface and backwater contours.

The flow model solves the vertically-averaged equations of motion and continuity using the finite-element method of analysis to obtain the depth-averaged velocities and flow depths. A detailed description of the modeling system is beyond the scope of this report; therefore, only the governing equations and a brief outline of the solution technique are presented here.

Flow Equations

The equations that govern surface-water flow are based on the classical concepts of conservation of mass and momentum. For most applications, knowledge of the full three-dimensional flow structure is not required and it is sufficient to use mean-flow quantities in two dimensions. By integrating the three-dimensional equations over the water depth and assuming a hydrostatic-pressure distribution and constant fluid density, a set of three equations appropriate for modeling flow in shallow water bodies is obtained. Because the flow is assumed to be in a horizontal direction, it is convenient to use a right-hand Cartesian coordinate system with the x- and y-axes in the horizontal plane and the z-axis directed upwards as shown in figure 4. The x-, y-, and z-components of velocity are denoted by u, v, and w, respectively; z_b is the bed or ground-surface elevation, z_s is the water-surface elevation, and H is the depth of flow.

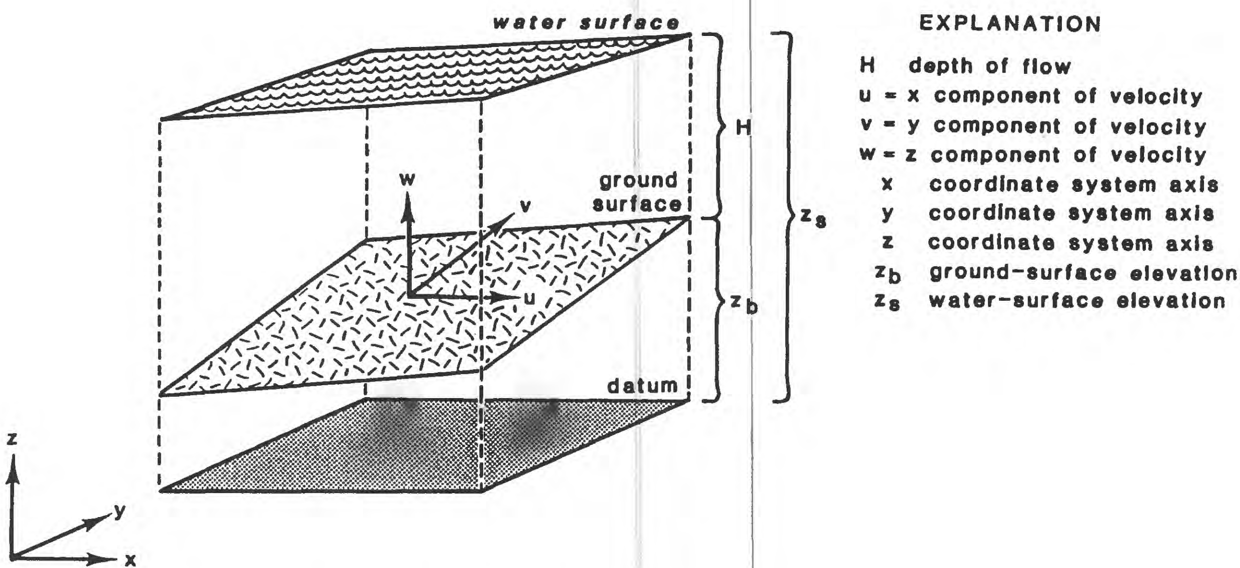

Figure 4.--Coordinate system definition.

The depth-averaged continuity equation is

$$\frac{\partial H}{\partial t} + \frac{\partial}{\partial x} (UH) + \frac{\partial}{\partial y} (VH) = 0 \qquad (1)$$

in which U and V are the depth-averaged values of the horizontal velocities u and v, respectively. The depth-averaged conservation-of-momentum equation in the x-direction is

$$\frac{\partial}{\partial t} (HU) + \frac{\partial}{\partial x} (\alpha_{uu} HUU) + \frac{\partial}{\partial y} (\alpha_{uv} HUV) + gH \frac{\partial}{\partial x} (H + z_b) - \Omega HV - \frac{\rho_a}{\rho} c_w W^2 \cos \psi +$$

$$c_f U (U^2 + V^2)^{1/2} - \frac{\partial}{\partial x} [\hat{\nu} H (\frac{\partial U}{\partial x} + \frac{\partial U}{\partial x})] - \frac{\partial}{\partial y} [\hat{\nu} H (\frac{\partial U}{\partial y} + \frac{\partial V}{\partial x})] = 0 \qquad (2)$$

and the depth-averaged equation of motion in the y-direction is

$$\frac{\partial}{\partial t} (HV) + \frac{\partial}{\partial x} (\alpha_{uv} HVU) + \frac{\partial}{\partial y} (\alpha_{vv} HVV) + gH \frac{\partial}{\partial y} (H + z_b) + \Omega HU - \frac{\rho_a}{\rho} c_w W^2 \sin \psi +$$

$$c_f V (U^2 + V^2)^{1/2} - \frac{\partial}{\partial x} [\hat{\nu} H (\frac{\partial U}{\partial y} + \frac{\partial V}{\partial x})] - \frac{\partial}{\partial y} [\hat{\nu} H (\frac{\partial V}{\partial y} + \frac{\partial V}{\partial y})] = 0 \qquad (3)$$

in which

α_{uu}, α_{uv}, α_{vv}, = momentum correction coefficients (dimensionless),
Ω = Coriolis parameter (radians per second),
g = gravitational acceleration (foot per second squared),

ρ = density of water (slugs per cubic foot),
ρ_a = density of air (slugs per cubic foot),
c_w = wind friction coefficient (dimensionless),
c_f = bottom friction coefficient (dimensionless),
$\hat{\nu}$ = depth-averaged kinematic eddy viscosity (square foot per second),
W = local wind velocity (foot per second),
ψ = angle between the wind direction and the positive x-axis (degrees), and
t = time (seconds).

The bottom friction coefficient can be computed either as

$$c_f = g/C^2 \tag{4}$$

in which C is the Chézy discharge coefficient (foot to the one-half power per second) or as

$$c_f = gn^2/2.208\ H^{1/3} \tag{5}$$

where n is the Manning roughness coefficient (second per foot to the one-third power).

The effect of turbulence is modeled using Boussenesq's eddy-viscosity concept, which assumes the turbulent stresses to be proportional to the mean-velocity gradients. The kinematic eddy viscosity, $\hat{\nu}$, is not a true depth-averaged quantity in the mathematical sense. Rather, this value is defined in such a way that when multiplied by the mean-velocity gradients, the appropriate depth-averaged stress due to turbulence is obtained.

For the simulation of steady-state flow in the study reach of the Pearl River, the time derivative terms in equations 1 through 3 were set to zero. In addition, the Coriolis force due to the Earth's rotation as well as wind friction were deemed negligible and also set to zero. Momentum correction factors (α_{uu}, α_{uv}, and α_{vv}) were all assumed to equal unity.

Boundary conditions for the set of equations consist of velocity (or unit discharge) components or water-surface elevations at open boundaries and zero velocity components or zero normal flow at all other boundaries. For a time-dependent problem, initial conditions must also be specified.

Flow over highway embankments is calculated using the broad-crested weir flow equation

$$Q = C_d L h^{3/2} \tag{6}$$

in which Q is the total discharge over a section of embankment of length L, C_d is a discharge coefficient, and h is the difference between the elevation of the total energy head on the upstream side of the highway embankment and the crest elevation of the embankment.

Numerical Technique

The numerical technique used to solve the governing equations is based on the Galerkin finite-element method. In this method, the area being modeled is divided into a network of elements that may be either triangular or quadrangular in shape and can be arranged easily to fit complex boundaries. The elements are defined by a series of node points located at their vertices, midside points, and, in the instance of nine-node quadrilaterals, at their centers. Values of the dependent variables then are defined uniquely within each element in terms of the nodal values by a set of interpolation or shape functions.

Approximations of the dependent variables then are substituted into the governing equations, forming a residual, as the equations usually are not satisfied exactly. Weighted averages of the residuals over the entire solution region are computed using numerical integration. Requiring the weighted residuals to vanish permits one to solve for the nodal values of the dependent variables. In Galerkin's method, the weighting functions are chosen to be the same as those used to interpolate values of the dependent variables within each element.

Because the system of hydrodynamic flow equations is nonlinear, Newton's iterative method is used to obtain a solution. In order to apply Newton's method, it is necessary to evaluate not only the governing equations, but also a matrix of derivatives with respect to each of the dependent variables for each of the governing equations. This matrix is called the Jacobian or tangent matrix and is computed at each iteration in the solution.

If a finite-element network is not well designed, errors in conservation of mass can be significant because there are only approximately half as many equations for conservation of mass as there are for conservation of momentum in either the x or y direction. For a well-designed network, however, errors in mass conservation are small. The model has the capability of integrating the discharge across a line (called a continuity-check line) following element sides and beginning and ending at element vertices. Therefore, conservation of mass can be checked (King and Norton, 1978).

Gee and MacArthur (1982) completed a cursory study of continuity-check errors with a two-dimensional finite-element model similar to the one used in this study. They concluded that the solution is acceptable if the discharge at continuity-check lines does not deviate from the input discharge by more than plus or minus 5 percent.

Grid Network

The finite-element grid network, shown in figure 2, was designed to closely represent the nonuniform boundary of the area inundated by the 1983 flood. The upstream boundary was located at old U.S. 11 and I-59, and the downstream boundary was located south of U.S. 90, where hydraulic conditions could be specified. The I-10 crossing is near the middle of the study reach. The U.S. 90 crossing is approximately 2.5 mi upstream of the downstream boundary.

After the boundaries were defined, the study area was divided into a network of triangular elements. Subdivision lines between elements were located where abrupt changes in vegetative cover or topography occurred. Each element was designed to represent an area of nearly homogeneous vegetative cover. Chézy discharge coefficients assigned to elements in specific locations of the network are listed in table 1. In areas where velocity, depth, and water-surface gradients were expected to be large, such as near bridge openings and in areas between overbanks and channel bottoms, network detail was increased to provide better simulation of the large gradients by the flow model. The complex geometry of the flood plain of the lower Pearl River was modeled in detail and most measured lengths and widths were realistically represented in the model. Some approximations were made in order to minimize the number of elements in the network for the desired accuracy.

Only the larger channels were included in the network. Measured channel cross sections were represented in the model by either triangular or trapezoidal cross sections with cross-sectional areas equal to the measured areas. Some meandrous channel reaches that have relatively small flows were replaced with artificially straightened, but hydraulically equivalent, reaches. To allow coding of the grid network legibly on a map that has a reasonable scale, the width of simulated stream channels was kept to a minimum of 200 ft. Grid network in the vicinity of Indian Village Road (fig. 2), an area that was not necessary in previous studies of the 1980 flood, was included in the network for the 1983 flood. The network for the 1983 flood contained a total of 7,554 triangular elements and 10,772 computational node points, requiring the simultaneous solution of approximately 35,000 nonlinear algebraic equations. Given the natural boundaries of the system, this is the best network that reasonably can be achieved.

Boundary Conditions

The peak discharge used as input to the model at the upstream boundary was obtained from discharge measurements made in 1983 and the stage-discharge relation of Pearl River at Pearl River gaging station. The discharge at the inflow boundary was 230,000 ft^3/s for 1983 flood. Inflow was concentrated at the old U.S. 11 bridge across the Pearl River and the I-59 bridge across the West Pearl River. Flow into the study reach through numerous small openings in old U.S. 11 was represented as continuous inflow between the east edge of the flood plain and the Pearl River and between the Pearl and West Pearl Rivers. The distribution of discharge along the upstream boundary of the model is given in table 2.

Water-surface elevations were specified along the downstream (outflow) boundary. Elevations were based on high-water marks located on the boundary near Apple Pie Ridge on the west bank of the flood plain and near Jackson Landing on the east bank. The water-surface elevations along the downstream boundary of the model are given in table 3. At all closed boundaries, except where weir flow was permitted, zero flow normal to the boundary was specified.

Table 2.--Distribution of discharge at the upstream model boundary

Section of upstream boundary	1980		1983	
	Discharge, in cubic feet per second	Discharge, as percent of total discharge	Discharge, in cubic feet per second	Discharge, as percent of total discharge
Flood plain between east edge of flood plain and Pearl River-------------	22,100	12.7	29,200	12.7
Pearl River bridge opening-----------	22,000	12.6	29,000	12.6
Flood plain between Pearl and West Pearl Rivers------	32,900	18.9	43,400	18.9
West Pearl River channel-----------	69,100	39.6	91,200	39.6
Flood plain between West Pearl River and west edge of flood plain-------	28,200	16.2	37,200	16.2
Total---------------	174,300	100.0	230,000	100.0

Table 3.--Water-surface elevations at the downstream model boundary

Location[1]	1980	1983
	Water-surface elevation, in feet above sea level	
Jackson Landing (east side)--	4.0	3.2
Apple Pie Ridge (west side)--	4.0	3.4

[1] Water-surface elevation along the downstream boundary between the east and west sides of the flood plain were linearly interpolated.

Weir flow was simulated in locations where significant flow over roadways occurred. The weir length associated with each node along the embankment in areas of roadway overflow was determined from field-survey data and topographic maps. Weir-crest elevations were based on field-survey data. A weir coefficient of 3.0 was used throughout. The value of 3.0 is reasonable to apply for weir computations for the paved roadways in the study area (Hulsing, 1967, p. 27).

Along I-10, weir flow was simulated over the roadway as an outflow from the system on the upstream side of the embankment and an inflow to the system on the downstream side of the embankment. Along U.S. 190 north of the intersection with U.S. 90, weir flow was simulated to exit the study reach. Road overflow in each of these areas was considered significant for modeling purposes in the 1983 flood.

Flow across roadways was simulated at two highways in the study area for the 1983 flood. Two weir segments were simulated at the I-10 and two at U.S. 190. Weir flow is simulated with the model by specifying the nodal location in the network where weir flow is to be computed, weir length to be simulated at that node, a discharge coefficient, and weir-crest elevation for that segment. Flow is computed for weir segments using the computed water-surface elevation at the specified node number and weir data for that node using equation 6. Weir flow may be specified to re-enter the model network at another node or to leave the system.

The road overflow simulated at I-10 was approximately 15 percent of the total flow and agrees with measured road overflow within 10 percent error. The road overflow simulated at U.S. 190 was only 5 percent of the total flow and the simulated flow is 36 percent greater than the measured flow. Weir data are presented in table 4.

Table 4.--Weir specifications

[I-10, Interstate Highway 10; U.S. 190, U.S. Highway 190; U.S. 90, U.S. Highway 90]

Location	Number of nodes representing weir	Weir-crest elevation, in feet above sea level	Weir length, in feet
I-10 embankment between Pearl and Middle Rivers----------------	10	12.7	4,980
I-10 embankment between Middle River and West Pearl-----------------	20	12.7	8,070
U.S. 190 near U.S. 90 junction-------------	3	7.0	930
U.S. 190 approximately 0.5 mile west of U.S. 90 junction-----	3	7.2	1,800

ANALYSIS OF HYDRAULICS UNDER PRESENT AND PROPOSED MODIFICATION OF HIGHWAY EMBANKMENTS

Present Highway Embankment Condition

The model simulation of flood elevations for the 1983 flood with present highway conditions was used as a starting point in simulating the hydraulic effects of the proposed highway modifications. Computed values of water-surface elevations when compared with measured values throughout the study area have a root-mean-square error of about 0.3 ft. The simulation of the 1983 flood with a root-mean-square error of 0.3 ft is verification of the model, which was calibrated to 1980 flood data with a root-mean-square error of 0.2 ft. The model also distributed the total discharge among the highway embankment openings within 3 percent of total flow. Computed water-surface elevations resulting from various proposed highway modifications can be compared to the computed elevations in the present condition to determine the change that might be expected from a proposed modification.

Water-surface elevation contours for the present conditions are shown in figure 5. Water-surface elevations at selected locations for the present and modified conditions are shown in table 5. Discharges through the bridge openings in the study area are shown in table 6.

The contours shown in figure 5 are not perpendicular to the axis of the flood plain between the 9 ft contour and U.S. 90, indicating a lateral water-surface slope and lateral flows across the flood plain. Upstream of I-10, the lateral water-surface slope is not as severe as at U.S. 90; however, I-10 was overtopped in the flood of 1983. Lee and others (1983) show severe lateral water-surface slope at I-10 for the 1980 flood, when I-10 was not overtopped. This transfer of flow from the west side to the east side of the flood plain is natural considering the geometry of the flood plain without highway crossings; manmade highway crossings tend to expedite this transfer of flow. (See Lee and others, 1983, table 9 and tables 1 and 6 in this report.) Upstream of U.S. 90, at the 10 ft contour, the water surface has little slope perpendicular to the flood plain axis, indicating little lateral flow at that position.

NATURAL CONDITIONS, REMOVAL OF INTERSTATE HIGHWAY 10 AND U.S. HIGHWAY 90 EMBANKMENTS

The removal of I-10 and U.S. 90 represents expected flow under natural conditions in the study area. That is, flow conditions that would be expected if both the I-10 and U.S. 90 embankments had never been constructed.

Previous investigations of the effects of I-10 on flood flows (Lee and others, 1983) compared present conditions to those expected with only the I-10 embankment removed. The "natural" condition simulated by Lee and others does not remove the U.S. 90 embankment; therefore, any influence of U.S. 90 that extends upstream from U.S. 90 were not identifiable in that study.

A similar situation exists in the previous study by Gilbert and Froehlich (1987). In the investigation of the effects of U.S. 90, only the U.S. 90 embankment was removed. Any influence of the I-10 embankment that extends downstream from I-10 were not identifiable in that study.

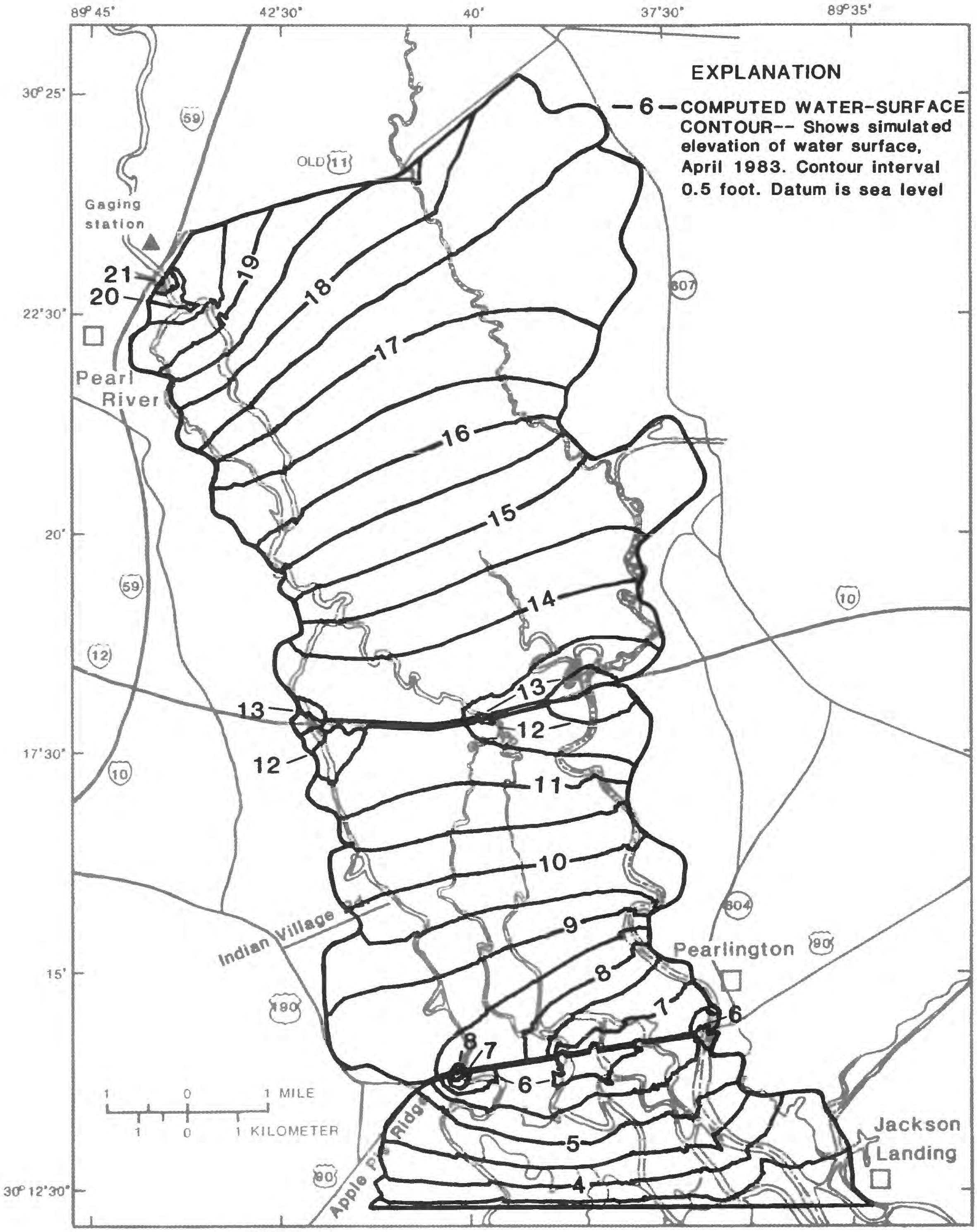

Figure 5.--Computed water-surface elevation contours for the present condition.

The natural condition simulated in this study is a more comprehensive analysis of the impacts of the I-10 and U.S. 90 embankments on flood flows. The impacts of both embankments are identifiable in this study and are discussed in the following sections.

Table 5.--Computed water-surface elevations at selected locations for simulations of the 1983 flood

[I-10, Interstate Highway 10; U.S. 190, U.S. Highway 190; U.S. 90, U.S. Highway 90]

Location	Simulation				
	A[1]	B[2]	C[3]	D[4]	E[5]
About 2.0 miles upstream of I-10 on the west bank	15.7	15.6	15.4	15.4	14.9
About 0.2 mile upstream of I-10 on the west bank	13.8	13.8	13.5	13.5	12.6
About 2.0 miles upstream of U.S. 90 on the west bank (near Indian Village Road)	9.9	9.8	9.9	9.8	9.6
Upstream side of the U.S. 90-U.S. 190 intersection	8.6	8.5	8.6	8.3	7.5
Upstream side of U.S. 90, 1,000 feet east of West Pearl River bridge	8.3	8.0	8.0	8.0	7.1
Upstream side of the U.S. 90 embankment on the east bank	6.0	6.0	6.0	6.0	5.8
About 2.0 miles upstream of U.S. 90 on the east bank	9.7	9.7	9.7	9.7	9.3
Upstream side of the I-10 embankment on the east bank	13.5	13.5	13.3	13.3	12.6
About 2.0 miles upstream of I-10 on the east bank	14.7	14.7	14.5	14.5	13.9

[1] Present conditions.
[2] Extension of the West Pearl River bridge at U.S. 90 to the east by 1,000 feet.
[3] Construction of a new 1,000-foot opening in I-10 in addition to simulation B, above.
[4] Construction of a new 250-foot bridge in U.S. 190 and in U.S. 90 in addition to simulation C, above.
[5] All highways removed, "natural condition."

Table 6.--Percent of total discharge at bridge openings and areas of road overtopping for the 1983 flood simulations

[Cubic feet per second, (percent of total flow). I-10, Interstate Highway 10; U.S. 190, U.S. Highway 190; U.S. 90, U.S. Highway 90]

Location	Simulation A[1]	B[2]	C[3]	D[4]
West Pearl River at I-10-----------	43,600 (19)	43,700 (19)	37,700 (17)	38,700 (17)
Middle Pearl River at I-10---------	32,300 (14)	30,900 (14)	26,600 (12)	27,100 (12)
Pearl River at I-10----------------	123,200 (53)	122,900 (53)	113,000 (50)	114,200 (50)
Roadway overflow at I-10-----------	33,200 (14)	32,100 (14)	11,000 (5)	12,200 (5)
New 1,000-foot bridge at I-10------	0 (0)	0 (0)	36,500 (16)	35,100 (16)
Totals[5]--------------------------	232,300 (100)	229,600 (100)	224,800 (100)	227,300 (100)
West Pearl River at U.S. 90--------	29,900 (13)	34,600 (15)	35,100 (15)	31,100 (13)
West Middle Pearl River at U.S. 90-	46,900 (20)	45,500 (19)	42,800 (18)	41,500 (18)
Middle Pearl River at U.S. 90------	35,700 (15)	35,000 (15)	34,600 (15)	33,700 (15)
East Middle Pearl River at U.S. 90-	25,900 (11)	25,700 (11)	24,800 (11)	24,300 (10)
Pearl River at U.S. 90-------------	81,600 (35)	82,500 (35)	82,300 (36)	81,600 (35)
Roadway overflow at U.S. 190-------	14,600 (6)	11,700 (5)	12,500 (5)	11,900 (5)
New 250-foot bridges at U.S. 190 and U.S. 90.	0 (0)	0 (0)	0 (0)	8,700 (4)
Totals[5]--------------------------	234,600 (100)	235,000 (100)	232,100 (100)	232,800 (100)

[1] Present conditions.
[2] Extension of the West Pearl River bridge at U.S. 90 to the east by 1,000 feet.
[3] Construction of a new 1,000-foot bridge opening in I-10 in addition to simulation B, above.
[4] Construction of a new 250-foot bridge opening in U.S. 190 and in U.S. 90 in addition to simulation C, above.
[5] The reason for the discrepancy among the total computed discharges and the total inflow is discussed in the section, "Numerical technique."

Model Alterations

The simulation of flow for a natural condition was performed by altering the model-grid network so that the highway embankment areas for I-10 and U.S. 90 were replaced with elements simulating natural conditions; the new elements were assigned discharge coefficients equal to that of the surrounding flood plain. Ground-surface elevations at nodes located where highways are removed were assigned elevations of the surrounding flood plain. Model specifications to simulate flow over U.S. 190 remain the same as in the present condition, permitting simulation of road overflow provided the computed water-surface elevation on the upstream side of the roadway is greater than the roadway elevation.

Results of the Hydraulic Simulation

The results of the simulation for natural conditions indicate reduced water-surface elevations throughout the study reach except in small areas just downstream of either highway embankment at the west edge of the flood plain. These areas would experience increased water-surface elevations if the highways were removed. Water-surface elevation contours for simulation of natural conditions are shown in figure 6.

COMPARISON OF THE HYDRAULICS OF PRESENT AND MODIFIED CONDITIONS

After determining the hydraulics of the present and natural conditions, three other proposed modifications of highway embankment conditions during the 1983 flood were analyzed: (1) Extension of the West Pearl River bridge by 1,000 ft at U.S. Highway 90, (2) construction of a new 1,000-foot bridge opening in the I-10 embankment between the West and Middle Pearl River bridges, and (3) construction of a new 250-foot bridge opening in U.S. Highways 190 and 90, west of the intersection of the highways. The modifications (1), (2), and (3) also incorporated lowering of ground-surface elevations under the new bridges to sea level.

The effects of a highway embankment modifications are evaluated by comparing the results of the modified highway embankment condition simulation to the results of the present condition simulation, or a natural condition simulation. Comparison of a modified condition to the present condition, indicates that the difference in water-surface elevation between the two simulations is the change in water-surface elevation because of the modification simulated. If the present condition is compared to the natural condition, the difference in water-surface elevations between the two simulations is the backwater and drawdown for the present condition. If the modified condition is compared to the natural condition, the difference in water-surface elevation between the two simulations is the backwater and drawdown caused by highway embankments for the modification simulated.

The model-grid networks used to simulate modifications are identical to the grid used in the simulation of the 1983 flood (present conditions), except for relatively minor alterations required to represent each modification. For each analysis, modification of the grid networks and model parameters are discussed in model alterations, and water-surface elevation, discharge, backwater, and drawdown are discussed in results of the hydraulic simulation.

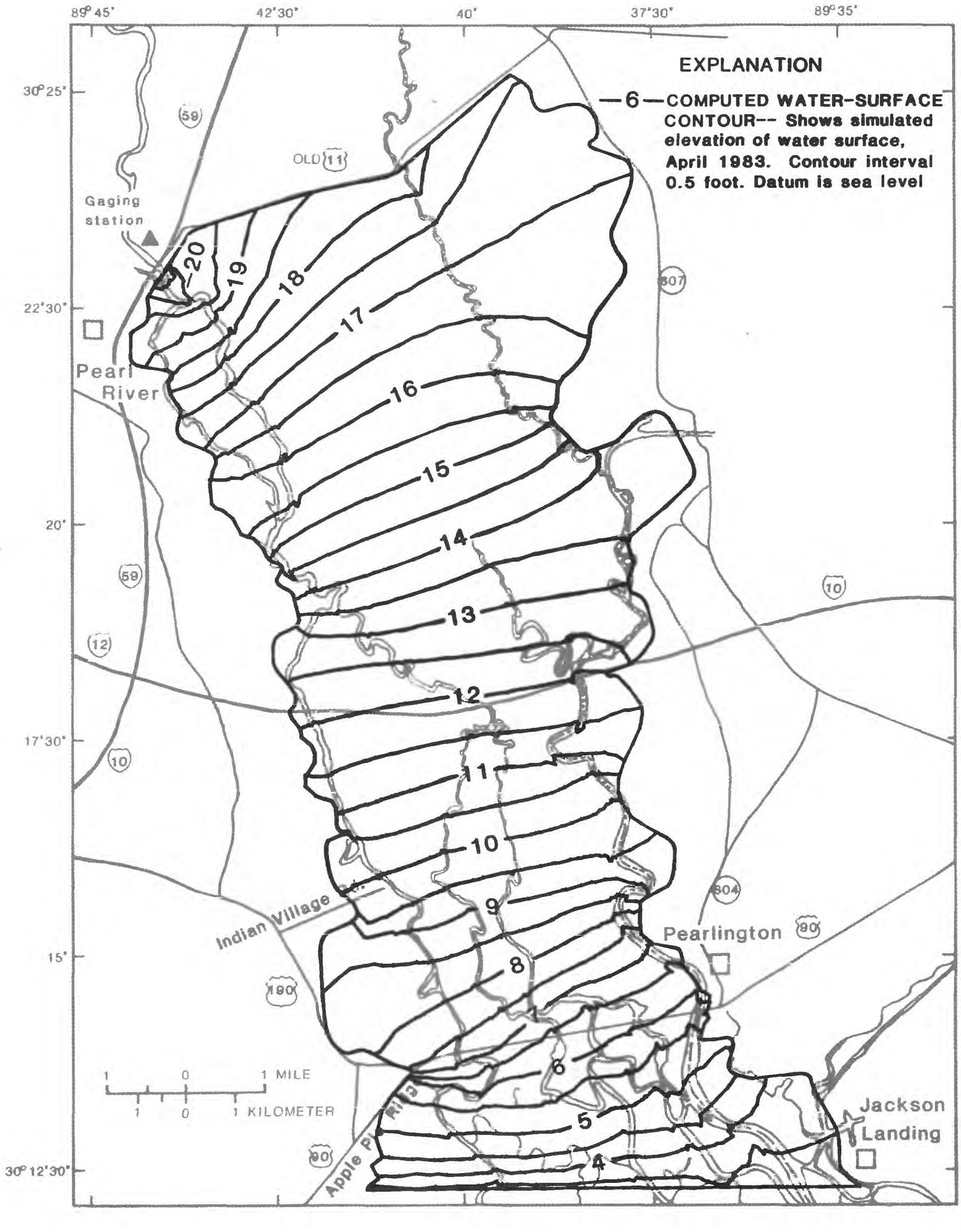

Figure 6.--Computed water-surface elevation contours for the natural condition.

Results and conclusions obtained from simulations using the grid networks and model specifications in this report may differ from results presented in Wiche and others (1982) and Lee and others (1982) which used different boundary conditions and grid networks. However, due to the expanded hydraulic network the simulations presented in this report are believed to represent the system more accurately than previous investigations.

Computation of Backwater and Drawdown

The backwater or drawdown at each node in the finite-element network may be determined by subtracting the water-surface elevation computed in the simulation without the highway embankments (natural condition) from values computed at corresponding nodes in the simulation of present or modified conditions. If, at a given location, the water-surface elevation with the embankments in place is higher than the water-surface elevation without the embankments, giving a positive difference, the effect of the embankment in place is backwater at that location. If the water-surface elevation with the embankments is lower than the water-surface elevation without the embankments, giving a negative difference, the effect of the embankments is drawdown. In general, backwater occurs upstream of highway embankments and drawdown occurs downstream of embankments; however, in wide flood plains with multiple bridge openings in the embankment, complex variations of this general effect can occur.

Analysis of Backwater, Present Highway Embankment Condition

Lines of equal backwater or drawdown computed for the present condition are shown in figure 7. The maximum backwater computed at I-10 is 1.8 ft located on the upstream side of the embankment between the West and Middle Pearl Rivers. Maximum drawdown computed at I-10 is 0.4 ft located on the downstream side of the embankment between the West and Middle Pearl Rivers. At U.S. 90, the maximum backwater of 1.2 ft is located on the upstream side of the embankment between the West and West Middle Pearl Rivers. Maximum drawdown is 1.2 ft located on the downstream side of the embankment near the west edge of the flood plain. Model results show that although backwater is greater on the west side of the flood plain than on the east side, backwater decreases more rapidly in the upstream direction on the west side of the flood plain than on the east side. Backwater contours shown in figure 7 indicate that 1 mi upstream of U.S. 90 backwater is less than it is 1 mi upstream of I-10 and backwater is more uniform across the flood plain at these locations. The lateral variation, more than the magnitude, of the backwater at I-10 suggests a greater redistribution of flow imposed by I-10 than by U.S. 90. This can be seen in figure 7 by examining the number of contours which contact the west bank but do not span the flood plain, contacting the embankment instead. If backwater was caused uniformly across the width of the flood plain, no contours which contact the edge of the flood plain would contact the embankment. At I-10, the 1.0 and 1.2 ft backwater lines contact the west bank and the I-10 embankment. The area of backwater greater than 1.0 ft at I-10 impacts the west bank only, not a uniform impact east and west.

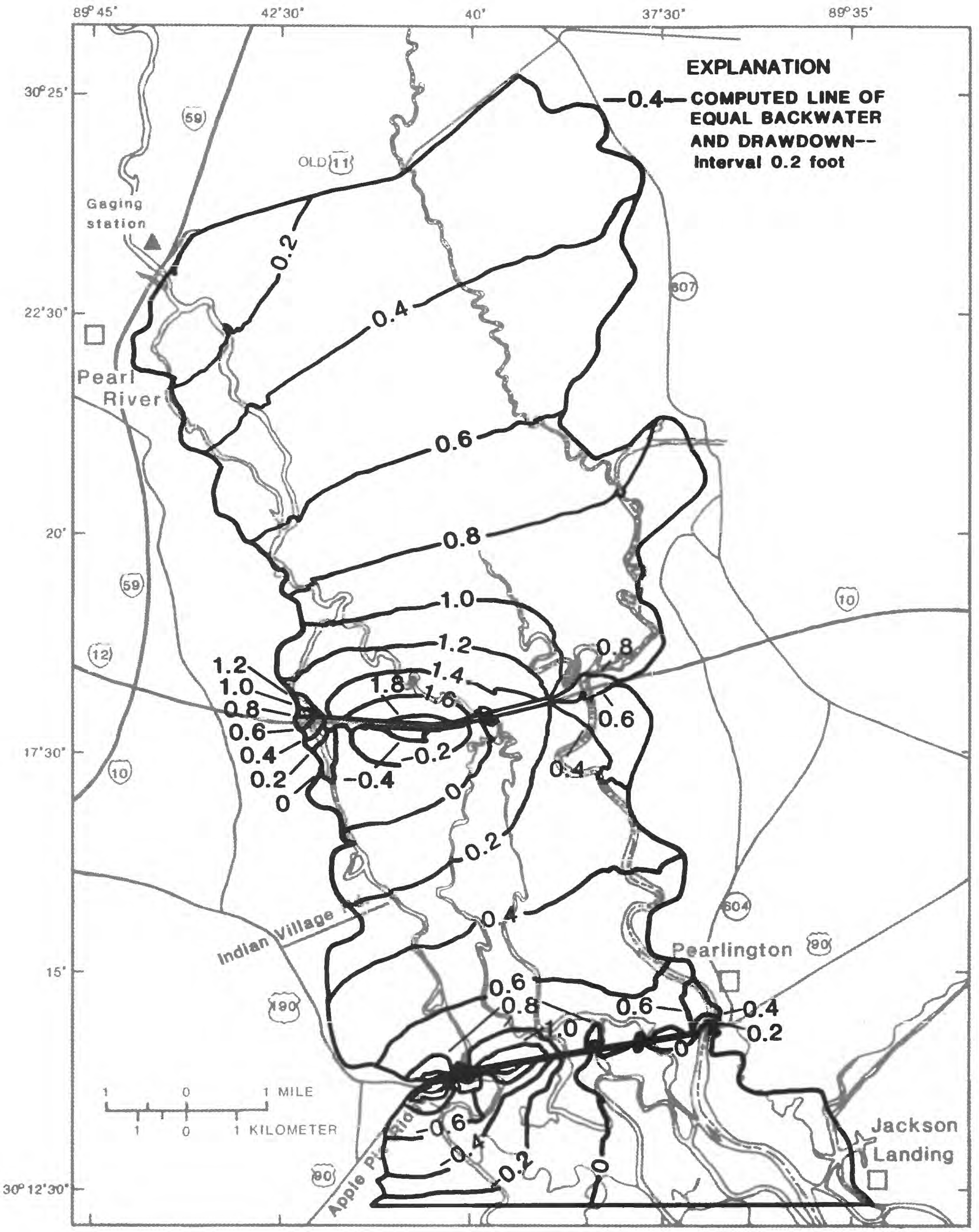

Figure 7.--Lines of equal backwater and drawdown computed for the present condition.

At U.S. 90, no backwater contours which contact the west bank span a significant part of the flood plain and contact the embankment. The 0.8 ft backwater line intersects the embankment, but at the west edge of the flood plain, without spanning a channel or major part of the flood plain. Backwater is more uniformly distributed across the flood plain about 1 mi upstream of U.S. 90 than it is about 1 mi upstream of I-10.

EXTENSION OF THE WEST PEARL RIVER BRIDGE AT U.S. HIGHWAY 90

Model Alterations

The first proposed modification simulated was a 1,000-foot extension of the West Pearl River bridge at U.S. 90, which required the addition of elements to the grid network in the area of the U.S. 90 embankment. Elements were added from the east end of the existing opening to a point 1,000 ft to the east. Ground-surface elevations at model node points within the right-of-way of the bridge extension were reduced to sea level. Elements in the bridge extension were assigned values of roughness coefficients similar to existing bridge overbank areas corresponding to grass and scattered brush (table 7). Spoil accumulations in a small area just downstream of the bridge extension also were simulated as being removed by reducing the ground-surface elevations specified at a few nodes immediately downstream of the opening.

Table 7.--Values of Chézy coefficients

Element description or location	Chézy coefficient (feet$^{1/2}$ per second)
Flood plain	
Woods--	20
Low marsh grass in southern part of study area---------	32
High marsh grass in southern part of study area--------	25
Marsh grass and brush downstream from I-10 bridge across Pearl River-----------------------------------	27
Brush and trees south of preceding marsh-grass area----	19
Pearl River	
Natural channel between river miles 6.0 and 9.0--------	105
Natural channel between river miles 9.0 and 15.9-------	95
Natural channel between river miles 15.9 and 19.2------	77
Straightened channel between river miles 19.2 and 20.3-	77
Natural channel between river miles 20.3 and 20.9------	77
Straightened channel between river miles 20.9 and 26.3-	77

Table 7.--Values of Chézy coefficients--Continued

Element description or location	Chézy coefficient (feet$^{1/2}$ per second)
Wastehouse Bayou	
Straightened channel between river miles 0.0 and 4.4----	54
East Middle Pearl River	
Natural channel between river miles 1.8 and 2.7---------	77
Middle Pearl River	
Natural channel between river miles 2.3 and 5.4---------	77
Straightened channel between river miles 5.4 and 9.0----	60
Natural channel between river miles 9.0 and 10.0--------	77
Straightened channel between river miles 10.0 and 12.9--	62
West Middle River	
Natural channel between river miles 5.9 and 8.0---------	77
Straightened channel between river miles 8.0 and 12.7---	68
West Pearl River	
Natural channel between river miles 7.9 and 14.9--------	77
Straightened channel between river miles 14.9 and 15.9--	46
Natural channel between river miles 15.9 and 19.4-------	91
Straightened channel between river miles 19.4 and 20.4--	85
Natural channel between river miles 20.4 and 21.4-------	91
Natural channel between river miles 21.4 and 21.9-------	105
Old Pearl River	
Natural channel between river miles 0.0 and 2.5---------	77

Results of the Hydraulic Simulation

Simulated water-surface elevation contours resulting from the condition of a 1,000-foot extension of the West Pearl River bridge at U.S. 90 are shown in figure 8. This alteration to the West Pearl River bridge would reduce water-surface elevations on the west bank by about 0.3 ft at the embankment and by about 0.1 ft about 2 mi upstream (in the vicinity of Indian Village Road) (table 5). No significant change in water-surface elevation occurs upstream of I-10 or on the east bank of the flood plain.

The discharge at the bridge for the West Pearl River increases about 5,000 ft^3/s, (16 percent) from the present condition. Therefore, the West Pearl River, which carries 13 percent of the total flow in the present condition, carries 15 percent of the total flow when extended. The West Middle

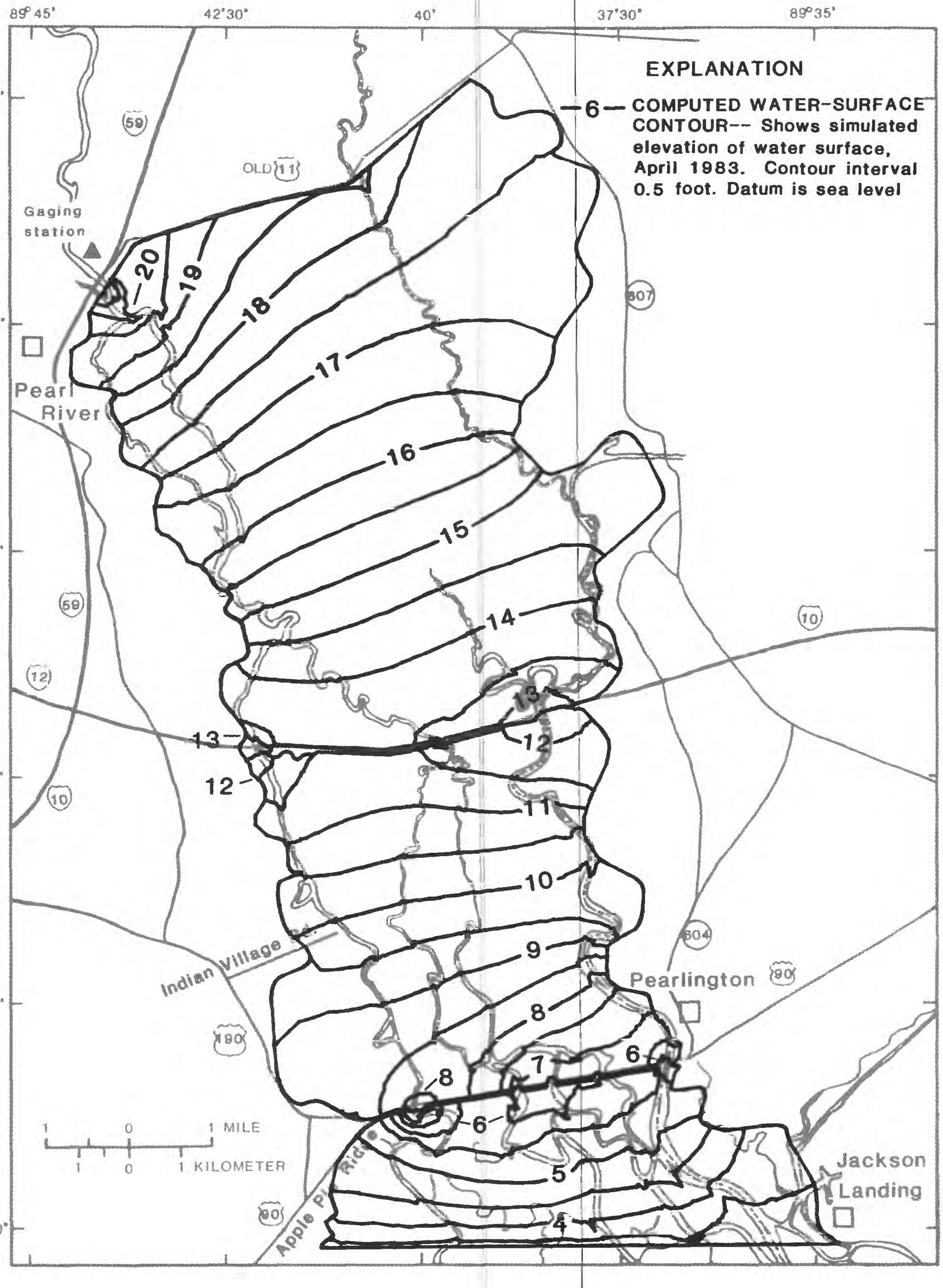

Figure 8.--Computed water-surface elevation contours for extension of the West Pearl River bridge at U.S. Highway 90.

Pearl River carries 20 percent in the present condition simulation and carries 19 percent in the modified condition simulation. About 6 percent of the total discharge flows over U.S. 190 in the present condition, and about 5 percent with the West Pearl River bridge extended at U.S. 90.

Lines of equal backwater and drawdown for the extension of the West Pearl River bridge at U.S. 90 are shown in figure 9. Comparison of the backwater for the extended bridge to backwater for the present condition shows that the 0.6 ft line of equal backwater for the condition of an extended bridge does not span the flood plain just above U.S. 90 as it does for the present condition, but intersects the highway embankment between the West Middle and Middle Pearl Rivers.

The 0.4 and 0.2 ft lines of equal backwater are slightly farther downstream than shown for the present condition, indicating a reduction in backwater on the west bank extending to the area of Indian Village Road. The backwater reduction between Indian Village Road and the U.S. 90-U.S. 190 intersection is about 0.1 ft. Reductions of drawdown on the west bank of about 0.1 ft extend about 2 mi downstream of the embankment. Backwater on the east bank, in the vicinity of Pearlington, Miss., remains essentially the same as the present condition.

CONSTRUCTION OF A NEW BRIDGE OPENING IN INTERSTATE HIGHWAY 10

Model Alterations

The second proposed modification simulated was construction of a 1,000-foot bridge opening in the I-10 embankment between the West and Middle Pearl River bridge openings. Elements were added in the I-10 embankment to the grid used to simulate the modification of the West Pearl River bridge at U.S. 90. Within the right-of-way, ground-surface elevations at model node points were reduced to above sea level, and vegetative cover representing scattered grass and brush (table 7) similar to other bridge overbank areas was specified.

Results of the Hydraulic Simulation

Simulated water-surface elevation contours, resulting from the condition of a new bridge opening in the I-10 embankment and the 1,000-foot extension of the West Pearl River bridge at the U.S. 90 embankment, are shown in figure 10. Simulation of flow for the condition of a new 1,000-foot bridge opening in I-10 embankment showed lower water-surface elevations on the west bank by as much as about 0.3 ft about 2 mi upstream of I-10. Water-surface elevations 0.2 ft lower occur on the upstream side of the embankment on the east edge of the flood plain, and 0.5 ft near the new bridge opening. The lowering in water-surface elevation upstream of I-10 corresponds to a reduction in backwater of about 35 percent. Water-surface elevations on the west bank, about 0.5 mi downstream of the embankment, are about 0.2 ft higher. Water-surface elevations near Indian Village Road, about 1 mi downstream of I-10, are about 0.1 ft higher. No change occurs on the east bank near Pearlington, Miss.

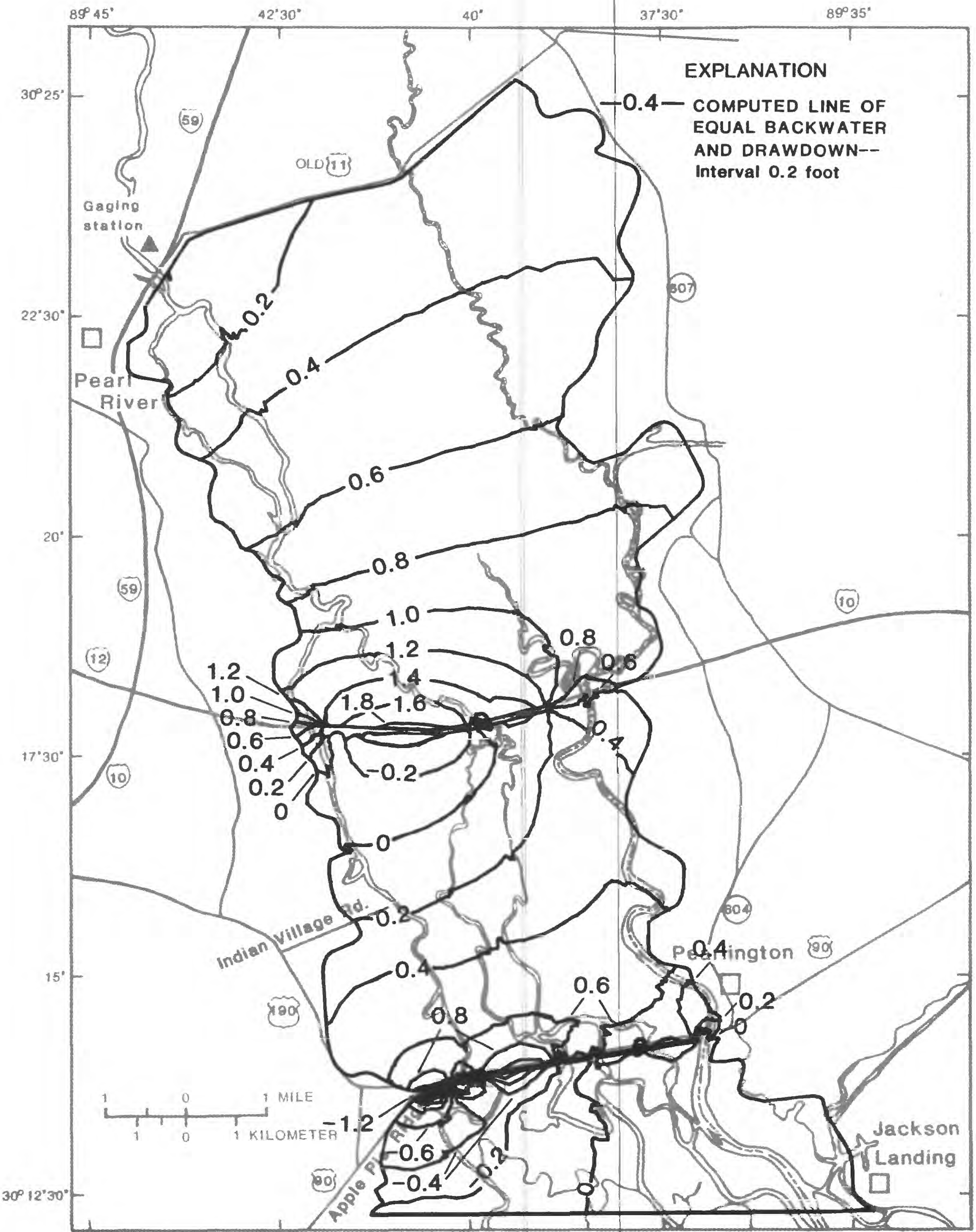

Figure 9.--Lines of equal backwater and drawdown computed for extension of the West Pearl River bridge at U.S. Highway 90.

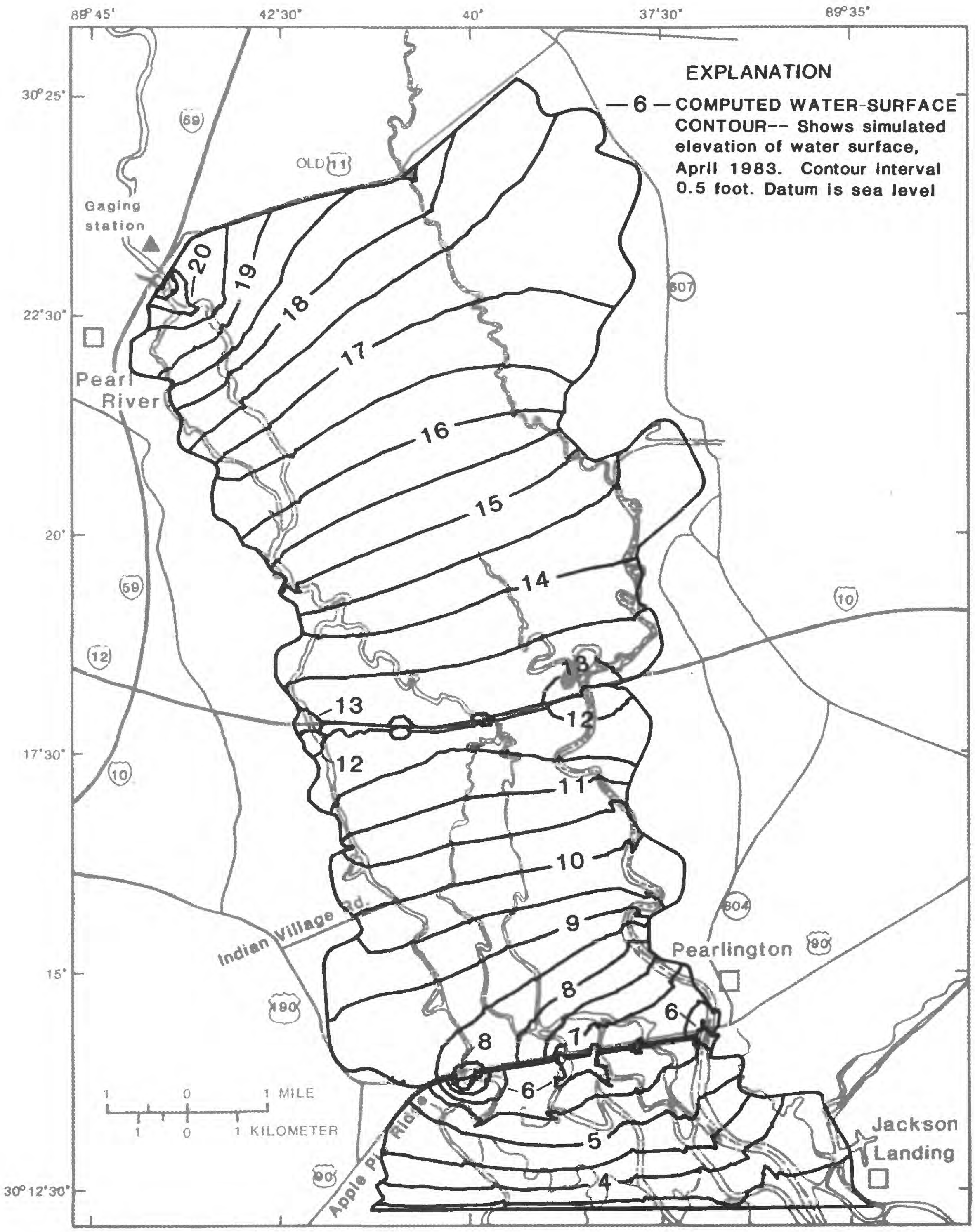

Figure 10.--Computed water-surface elevation contours for extension of the West Pearl River bridge at U.S. Highway 90 and construction of a new bridge at Interstate Highway 10.

Discharge through the new 1,000-foot bridge opening in the I-10 embankment is about 36,500 ft^3/s (16 percent of the total flow) (table 6). The discharge at the West Pearl, Middle Pearl, and Pearl Rivers decreases by about 2, 2, and 3 percent of the total flow, respectively. The discharge over the roadway is reduced from 32,100 ft^3/s (14 percent of total flow) to 11,000 ft^3/s (5 percent of total flow).

Simulated lines of equal backwater, resulting from the condition of a new bridge opening in the I-10 embankment and the extension of the West Pearl River bridge at U.S. 90, are shown in figure 11. Upstream of I-10, the 0.8 ft line of equal backwater no longer spans the flood plain but intersects the highway embankment. Backwater between 1.4 and 1.8 ft that occurs with the present condition simulation has been eliminated in this simulation. The 0.4 to 1.2 ft lines of equal backwater are located farther downstream in this simulation than shown in the present condition simulation, indicating a reduction in backwater extending about 3 mi upstream of the I-10 embankment. Water-surface elevations downstream of I-10 increase when the new bridge opening in I-10 is simulated, eliminating the area of drawdown on the west bank. The 0.0 line of equal backwater shown in figure 11 does not intersect the west bank as it did without the new bridge opening in I-10 (fig. 9).

CONSTRUCTION OF NEW BRIDGE OPENINGS IN U.S. HIGHWAYS 190 AND 90

Model Alterations

The last proposed modification simulated was construction of new bridge openings in the U.S. 190 and 90 embankments which required the addition of model network areas designed to represent:

1. A 250-foot bridge opening in the U.S. 190 embankment replacing the small existing bridge west of the U.S. 190 and 90 intersection.

2. A 250-foot bridge opening in U.S. 90 just southeast (downstream) of the opening replaced on U.S. 190.

3. Construction of a channel and overbank areas connecting the two new 250-foot bridge openings.

Results of the Hydraulic Simulation

Simulated water-surface elevation contours, resulting from the condition of the 250-foot bridge openings in U.S. 190 and 90 embankments, in addition to the new bridge opening in I-10 and the extension of the West Pearl River bridge at U.S. 90, are shown in figure 12. Results of simulation of flow for this condition show that the water-surface elevations are lowered about 0.1 ft near Indian Village Road and about 0.3 ft on the upstream side of the embankment near the U.S. 190 and 90 intersection. Reductions in water-surface elevations at these locations correspond to a reduction in backwater of about 25 percent. No major change in water-surface elevation occurs upstream at I-10 or on the east bank of the flood plain.

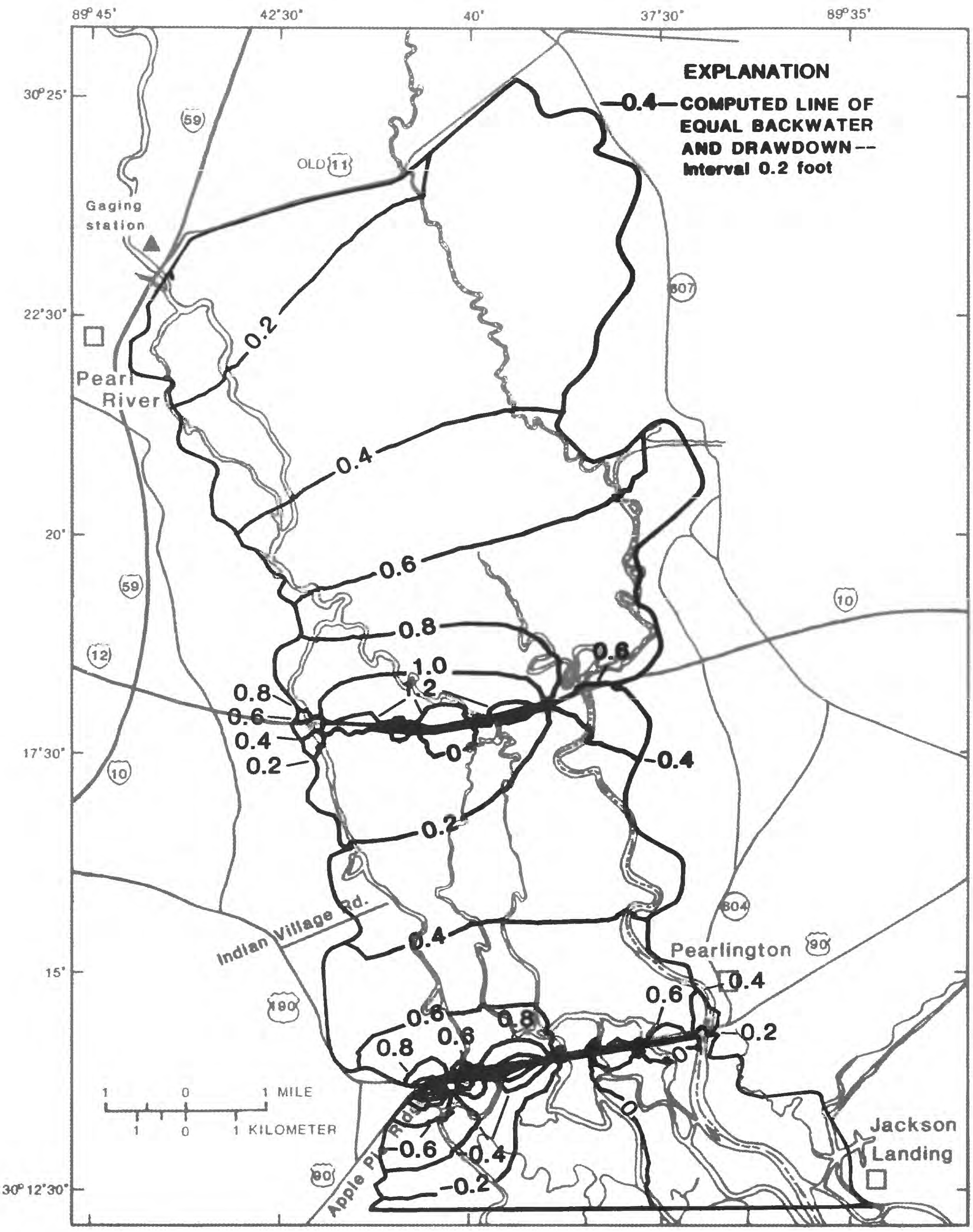

Figure 11.--Lines of equal backwater and drawdown computed for extension of the West Pearl River bridge at U.S. Highway 90 and construction of a new bridge at Interstate Highway 10.

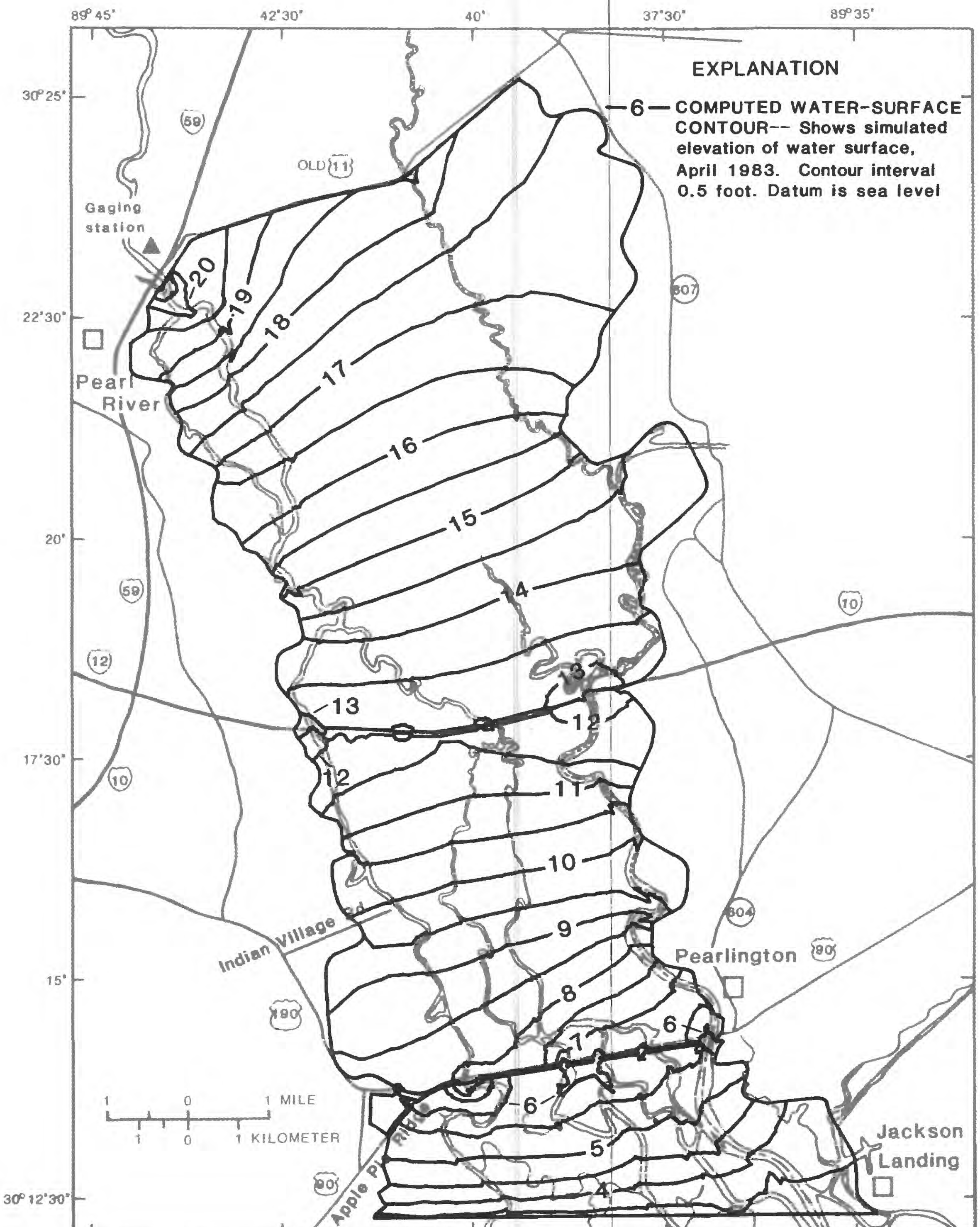

Figure 12.--Computed water-surface elevation contours for extension of the West Pearl River bridge, construction of a new bridge opening in Interstate Highway 10, and construction of new bridges at U.S. Highways 190 and 90.

Flow in the area of the new 250-foot bridge opening in U.S. 190 is about 9 percent of the total. Without the 250-foot bridge opening, about 6 percent of the total flow passed through this area. Roadway overflow in the areas simulated still would occur and is included in the values given above. Discharge at the West Pearl River at U.S. 90 decreases by about 4,000 ft^3/s, an 11 percent decrease (2 percent of total flow).

Simulated lines of equal backwater, resulting from the condition of the 250-foot bridge openings in U.S. 190 and 90 in addition to the new bridge opening in I-10 and the extension of the West Pearl River bridge at U.S. 90, are shown in figure 13. The 0.4 ft line of equal backwater no longer spans the flood plain as in any other conditions. All areas on the west bank between U.S. 90 and I-10 experience backwater less than or equal to 0.4 ft. The reduction in water-surface elevation due to the new 250-foot bridge opening at Indian Village Road and on the upstream side of the U.S. 190-U.S. 90 intersection are about 0.1 and 0.3 ft, respectively. An increase in water-surface elevation downstream of U.S. 90 is caused by the new 250-foot bridge opening. The new opening reduces the area of drawdown significantly. Areas that previously had drawdown greater than 0.4 ft now experience about 0.2 ft of drawdown. No major changes occur on the east bank or upstream of I-10.

SUMMARY AND CONCLUSIONS

The effect of proposed highway embankment modifications on water-surface elevations in the lower Pearl River flood plains were simulated using the model calibrated to the 1980 flood and verified using 1983 flood data. The results were compared with measured values of water-surface elevation and discharge to determine the accuracy of the model. The model was found to be sufficiently accurate to simulate flow for modified conditions of highway embankments during the 1983 flood and was used to evaluate resulting hydraulic changes.

The four proposed modifications of conditions during the 1983 flood that were analyzed are: (1) Removal of all highway embankments, the natural condition, (2) extension of the West Pearl River bridge opening by 1,000 ft in the U.S. 90 embankment, and (3) construction of a new 1,000-foot bridge opening in the I-10 embankment between the West and Middle Pearl River bridge openings, and (4) construction of new 250-foot bridge openings in U.S. 190 and 90, west of the intersection of the highways. The proposed modifications also incorporated lowering of ground-surface elevations under the new bridges to sea level.

The modification that provided the largest reduction in backwater, about 35 percent, was a new bridge in I-10. The modification of the bridge at U.S. 90 and West Pearl River and replacement of the bridge in U.S. 190 provide about a 25 percent reduction in backwater each.

Comparison of the present and natural water-surface elevations indicates a maximum backwater of 1.2 ft at U.S. 90 and 1.8 ft at I-10, on the west bank of the flood plain. Model results show that although backwater is greater on the west side of the flood plain than on the east side, backwater decreases more rapidly in the upstream direction on the west side of the flood plain

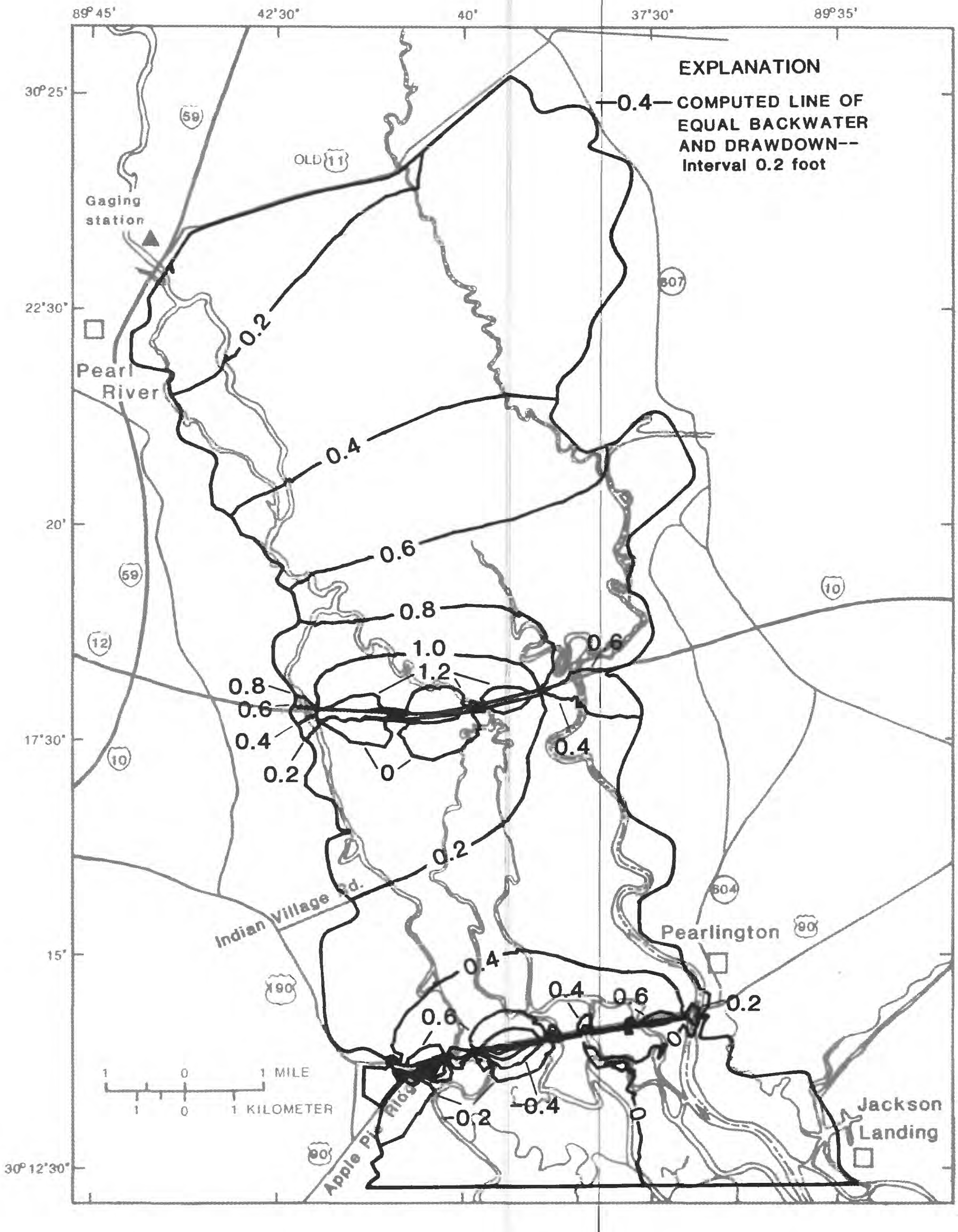

Figure 13.--Lines of equal backwater and drawdown computed for extension of the West Pearl River bridge at U.S. Highway 90, construction of a new bridge at Interstate Highway 10, and construction of new bridge openings in U.S. Highways 190 and 90.

than on the east side. The bridge at I-10 provides the largest reduction in water-surface elevation for the modifications analyzed. The new bridge opening at I-10 also carries the largest percentage of total discharge of any of the modifications simulated. The extension of the West Pearl River bridge at U.S. 90 and the new bridge openings at U.S. 190 and 90 both reduce water-surface elevations by approximately the same amount (0.1 ft) on the west bank of the flood plain. In general, water surfaces upstream of the I-10 and U.S. 90 embankments decrease by at least 0.3 ft in the condition simulated with all modifications, and elevations downstream of the embankments may increase by as much as 0.6 ft.

An increase in water-surface elevation occurs on the west bank downstream of the highways in all modifications simulated. Increases downstream of I-10 are in developed areas. Increases at I-10 of 0.1 ft may occur as far downstream as Indian Village Road. The maximum increase on the west bank downstream of I-10 is about 0.2 ft. No significant increase in water-surface elevation occurs on the east bank of the flood plain downstream of either I-10 or U.S. 90. Increases of about 0.2 ft may occur 1 mi downstream of U.S. 90. The maximum increase downstream of U.S. 90 is about 0.6 ft.

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