UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRECONSTRUCTION AND POSTCONSTRUCTION GROUND-WATER LEVELS, LOCK AND DAM 5 AND 6, RED RIVER VALLEY, LOUISIANA

Open-File Report 79-922

Prepared in cooperation with the

U.S. Army Corps of Engineers

and the U.S. Soil Conservation Service

Cooperative Ground-Water Study

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Baton Rouge, Louisiana

June 1979

PREFACE

This report was originally released to the U.S. Army Corps of Engineers, New Orleans District, as an administrative report, for official use only, in December 1975. This open-file version is unchanged from the original administrative report except for minor editing and addition of a more comprehensive and updated list of "Selected References."

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) OF METRIC UNITS

For those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply inch-pound units	By	To obtain SI units
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/year)
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

PRECONSTRUCTION AND POSTCONSTRUCTION GROUND-WATER LEVELS, LOCK AND DAM 5 AND 6, RED RIVER VALLEY, LOUISIANA

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ABSTRACT

Proposed construction of a series of locks and dams in the Red River in Louisiana will cause a permanent increase in average river stage. The potentiometric surface of the shallow alluvial aquifer and the water table in the fine-grained material confining the aquifer will be affected. The purpose of this study, using digital-modeling techniques, was to predict the postconstruction potentiometric surface and the water table so that potential effects of the water-level changes could be evaluated.

Plans for Lock and Dam 5 at mile 243 (kilometer 390) above the mouth of the Red River call for a pool elevation of 145 feet (44 meters) and will cause an average increase in river stage of 23 feet (7.0 meters). As a result, ground-water levels in the pool area will be raised to near land surface in much of the area between the river and Bayou Pierre and as much as 2 miles (3.2 kilometers) east of the river from the dam upstream to realined mile 220 (kilometer 350). Areas of Barksdale Air Force Base where levels are now near land surface would be enlarged and extend downstream along Flat River to near Curtis. The potentiometric surface may be above land surface near Howard, Anderson Island, and Dixie Gardens.

INTRODUCTION

The navigation plans of the U.S. Army Corps of Engineers include a series of locks and dams on the Red River between the confluence of the Red and Black Rivers and Shreveport, La. Various plans that include arrangements of either five or six locks and dams have been proposed. The locations of the proposed dams are shown in figure 1. Plans for a modified version of the arrangement for five locks and dams, called the B-3 modified plan, have been adopted by the Corps. The U.S. Geological Survey is evaluating the effects of each proposal on ground-water levels. The results of this investigation are being used by the Corps of Engineers and the U.S. Soil Conservation Service to evaluate the beneficial or adverse effects of changes in ground-water levels.

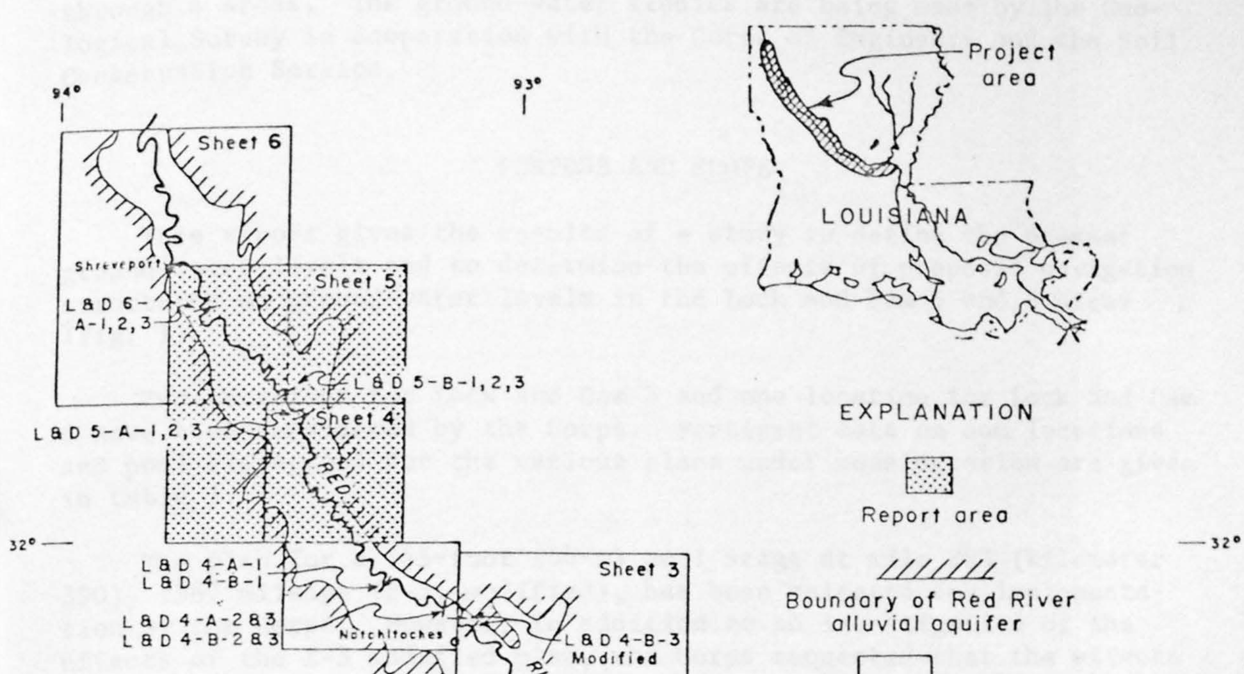


Figure 1.—Location of report area.

This report is the last in a series of five reports that present analyses of preconstruction and postconstruction ground-water conditions in the Red River Valley, La. Previous reports covered Lock and Dam 1 through 4 areas. The ground-water studies are being made by the Geological Survey in cooperation with the Corps of Engineers and the Soil Conservation Service.

PURPOSE AND SCOPE

This report gives the results of a study to define the present ground-water levels and to determine the effects of proposed navigation structures on ground-water levels in the Lock and Dam 5 and 6 areas (fig. 1).

Two locations for Lock and Dam 5 and one location for Lock and Dam 6 have been considered by the Corps. Pertinent data on dam locations and pool elevations for the various plans under consideration are given in table 1.

The plan for a 145-foot (44-m) pool stage at mile 243 (kilometer 390), 1967 mileage (B-3, modified), has been selected for implementation by the Corps. However, in addition to an investigation of the effects of the B-3 modified plan, the Corps requested that the effects of each of the alternate plans be analyzed. For purposes of discussion later in the report, the plans have been grouped as follows: plans A-1, A-2, and A-3; plans B-1, B-2, and B-3; and plan B-3, modified. Because of the selection by the Corps of the plan for five locks and dams (B-3, modified), the area covered by this report is hereinafter referred to as the Lock and Dam 5 area except for specific references to Lock and Dam 6.

Two types of analyses were made in this investigation, steady and nonsteady state. The steady-state analysis was used to determine the change from average preconstruction to average postconstruction potentiometric surface in the aquifer. The potentiometric surface refers to the level to which water will rise in wells tapping the coarse sand and gravel aquifer beneath the Red River Valley. This report presents maps showing contour lines that represent (1) the average preconstruction potentiometric surface and (2) the projected postconstruction potentiometric surface determined from the steady-state analysis for each of the plans listed in table 1. Nonsteady-state analysis refers to the variations in the position of the potentiometric surface and the water table with time. The water table is the upper surface of the zone of saturation. In the Red River Valley, this surface generally lies in the fine-grained material above the aquifer. Nonsteady-state analyses include a computation of the preconstruction and postconstruction water table for the B-3 modified plan. Examples of the results of the nonsteady-state analyses are shown as hydrographs later in the report.

Table 1.--Locations of damsites and elevations of pool stages for alternate plans, Lock and Dam 5 and 6

[River mile: Distance, in miles, upstream from the mouth of Old River. Pool stage: Elevation of pool at the proposed damsite, in feet above mean sea level]

Plan	River mile		Pool stage	
	1967	Realined	Lower	Upper
Lock and Dam 5				
A-1, A-2, and A-3----------------	243	199	115	135
B-1, B-2, and B-3----------------	250	203	120	145
B-3, modified--------------------	243	198	115	145
Lock and Dam 6				
A-1, A-2, and A-3----------------	270	221	135	150

The maps showing the results of the steady-state analyses are to be used by the Corps as a basis for comparing the effects of implementation of the various plans on ground-water levels in the valley. Data obtained from the nonsteady-state analysis are to be used by the Soil Conservation Service to determine the effects of implementation of the B-3 modified plan on agriculture in the valley.

Steady- and nonsteady-state analyses were made with the use of digital-modeling techniques, which are discussed later in the report.

DESCRIPTION OF THE AQUIFER SYSTEM

The Red River in the Lock and Dam 5 area flows within an alluvial valley ranging from 7 to 10 mi (11 to 16 km) in width. Formations of Tertiary age underlie the valley alluvium and form the upland bordering the valley. The Wilcox Group, which underlies most of the alluvial valley in the area, is composed primarily of clay and silt. Water-bearing sands, some of which may be hydraulically connected with the alluvial aquifer, constitute an estimated 30 percent of the unit (Page and May, 1964; Newcome, 1960). In some places, terraces overlie the Tertiary outcrops in the uplands. Terrace deposits are most prevalent along the east edge of the valley.

The alluvium in the valley is as thick as 100 ft (30 m) and averages about 70 ft (21 m). The alluvium can be divided into two parts: a lower unit, or aquifer, which is generally composed of coarse sand and gravel, grading upward to fine sand, and an upper confining layer, which is composed of clay, silt, and fine sand (fig. 2). The aquifer is as thick as 70 ft (21 m) and averages about 50 ft (15 m), and the upper confining layer is as thick as 60 ft (18 m).

Recharge to the alluvial aquifer is derived primarily from infiltration of rainfall on the flood plain. Locally, the alluvial aquifer may be recharged by water from the terrace deposits. Red Chute Bayou and Bayou Pierre are discharge points for water moving downgradient from the terrace deposits and from the alluvial aquifer.

Water levels in wells tapping the aquifer rise above the base of the fine-grained material, an indication that the water is under artesian or semiartesian conditions. A zone of saturation in the upper fine-grained material, extending from near the land surface down to the aquifer, suggests the presence of water-table conditions. These two conditions exist simultaneously because of the great difference in hydraulic conductivity between the confining beds and the aquifer.

The water table may be above or below the potentiometric surface, depending on the direction of the resultant vertical flow or accretion through the fine-grained material. Accretion, as defined by Stallman (1956), is the rate at which water is gained or lost through the aquifer surface in response to precipitation or evapotranspiration. Positive accretion or recharge takes place where the vertical hydraulic gradient is downward. Conversely, negative accretion, or discharge, takes place where the vertical hydraulic gradient is upward. The head difference between the water table and potentiometric surface is generally less than 5 ft (1.5 m), but as much as 9 ft (2.7 m) of difference has been noted in places in the Lock and Dam 5 area.

Movement of water in the alluvial aquifer is toward the Red River and Red Chute Bayou and Bayou Pierre, the principal tributaries to the Red River in the area. Pumpage of water from wells in the area is not significant.

The recharge, movement, and discharge of water from the alluvial aquifer are shown graphically in the idealized alluvial section in figure 2. The direction of water movement, indicated by arrows, shows that the aquifer is being recharged by infiltration in zone 1 through the clay and silt. Discharge takes place to the Red River, to Bayou Pierre, and vertically upward in zone 2. The flow conditions shown in the diagram may change. At any given location, the rate of accretion is neither constant nor in the same direction at all times. Seasonal weather changes and changes in river stage may cause variations in the magnitude and direction of water movement in the aquifer.

MODELING PROCEDURE

Digital-modeling techniques were used to analyze the river-induced effects of a permanent change in river stage on ground-water levels in

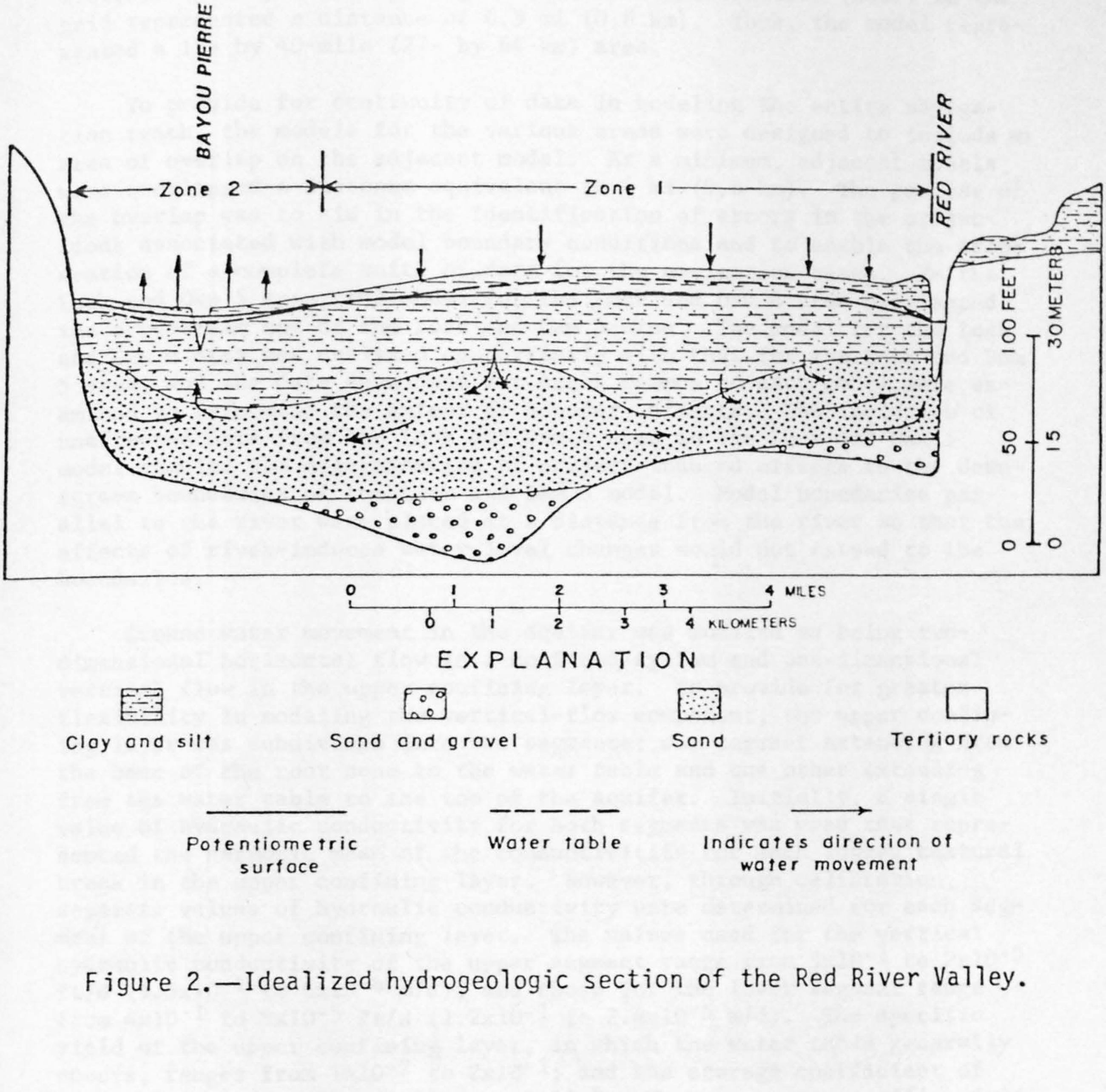


Figure 2.—Idealized hydrogeologic section of the Red River Valley.

the Lock and Dam 5 area. The framework for the digital model of the aquifer consisted of a rectangular grid of 34 rows and 80 columns, superimposed on a map of the Lock and Dam 5 area having a scale of 1:62,500 (pl. 1). The spacing between each intersection (node) in the grid represented a distance of 0.5 mi (0.8 km). Thus, the model represented a 17- by 40-mile (27- by 64-km) area.

To provide for continuity of data in modeling the entire navigation reach, the models for the various areas were designed to include an area of overlap on the adjacent model. At a minimum, adjacent models were overlapped a distance equivalent to 6 mi (9.6 km). The purpose of the overlap was to aid in the identification of errors in the projections associated with model boundary conditions and to enable the preparation of a complete suite of data for the navigation reach. In the Lock and Dam 5 area, the model for the Lock and Dam 4 area overlapped the downstream end of the Lock and Dam 5 area. The model for the Lock and Dam 4 area was analyzed concurrently with that for the Lock and Dam 5 area, and the data developed for areas common to each model were examined to determine the extent of boundary effects. The inclusion of unaffected data from the Lock and Dam 4 area in the Lock and Dam 5 model enabled the determination of project-induced effects to the downstream boundaries of the Lock and Dam 5 model. Model boundaries parallel to the river were placed at a distance from the river so that the effects of river-induced water-level changes would not extend to the boundaries.

Ground-water movement in the aquifer was modeled as being two-dimensional horizontal flow in a confined system and one-dimensional vertical flow in the upper confining layer. To provide for greater flexibility in modeling the vertical-flow component, the upper confining layer was subdivided into two segments: one segment extending from the base of the root zone to the water table and the other extending from the water table to the top of the aquifer. Initially, a single value of hydraulic conductivity for both segments was used that represented the harmonic mean of the conductivities for each logged textural break in the upper confining layer. However, through calibration, separate values of hydraulic conductivity were determined for each segment of the upper confining layer. The values used for the vertical hydraulic conductivity of the upper segment range from $5x10^{-1}$ to $2x10^{-5}$ ft/d ($1.5x10^{-1}$ to $6x10^{-6}$ m/d), and those for the lower segment range from $4x10^{-1}$ to $8x10^{-5}$ ft/d ($1.2x10^{-1}$ to $2.4x10^{-5}$ m/d). The specific yield of the upper confining layer, in which the water table generally occurs, ranges from $1x10^{-2}$ to $2x10^{-1}$; and the storage coefficient of the aquifer ranges from $1x10^{-3}$ to $1x10^{-5}$. The ranges in specific yield and aquifer storage cited above also represent the plausibility limits used in the model for these parameters.

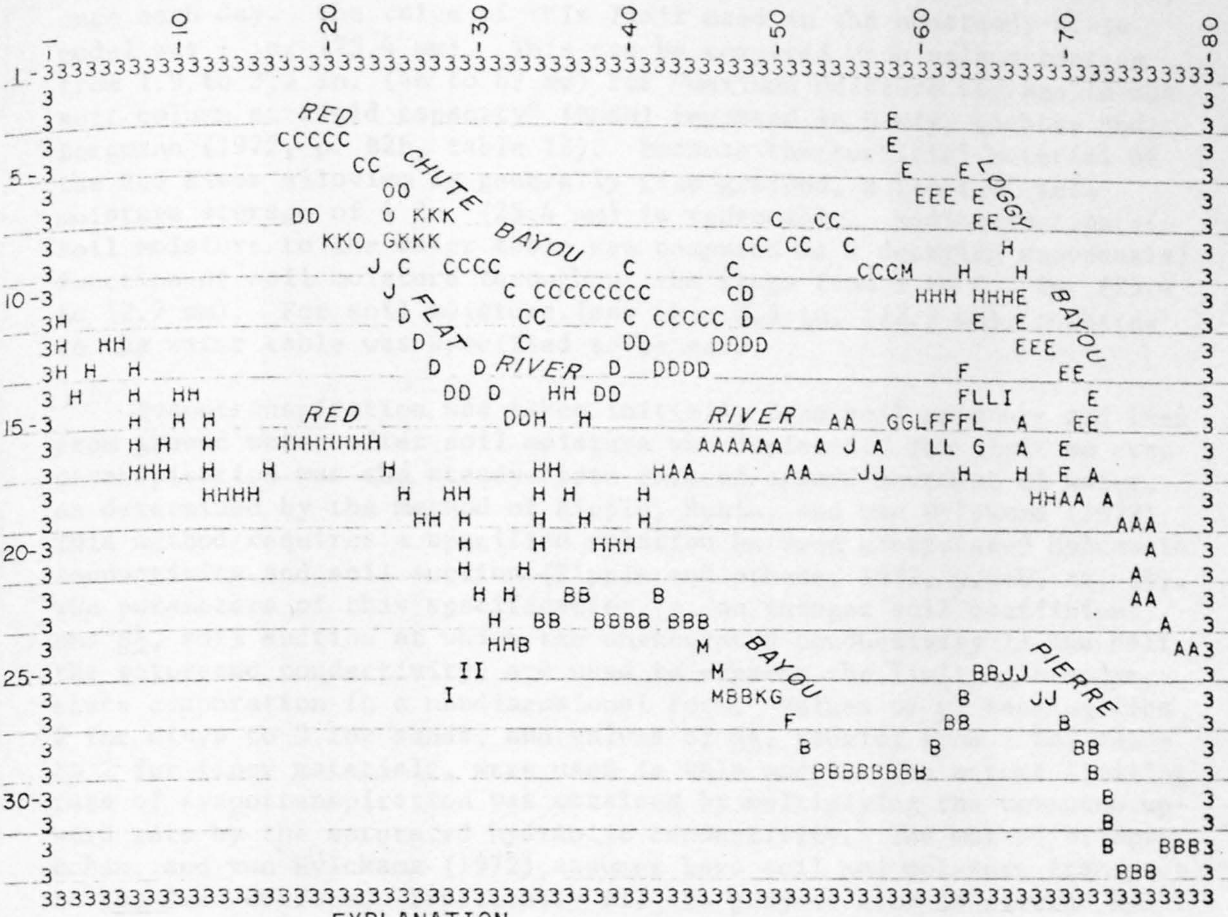
The average hydraulic conductivity of the aquifer, determined from aquifer tests and from laboratory analysis of aquifer samples, is 147 ft/d (45 m/d); and the transmissivity used in the model ranges from 3,000 to 11,000 ft^2/d (280 to 1,025 m^2/d). Approximately 95 samples of material from the aquifer were collected in and near the project area and were analyzed for hydraulic conductivity and particle size. A relationship was developed between hydraulic conductivity and particle size using the method of Bedinger, Reed, Wells, and Swafford (1970). From this relationship an average value of hydraulic conductivity was developed for the alluvial aquifer. Transmissivity of the aquifer was determined by multiplying the average value of hydraulic conductivity by the thickness of aquifer material found from logs of test holes in the area. Test-hole logs were available from the sites shown as control points on plate 1. Transmissivity values were checked at two locations near the river (wells Bo-287 and RR-188) by the method of river-induced fluctuations (Bedinger and others, 1973). Transmissivity maps were prepared from these data and used as input to the model.

The Red River and its tributaries in the Lock and Dam 5 area do not fully penetrate the alluvial aquifer in all places along their courses. Model analysis indicates that in many places the streams are separated from the aquifer by several feet of fine-grained material. Figure 3 shows, in symbolic map form, the distribution of modeled thicknesses of fine-grained material determined from the calibration of the model. Separate symbols were used for each of the streams in the area to represent streambed thicknesses, and a single value of 5 ft (1.5 m) was assigned initially to all of the symbols. During calibration, additional symbols, representing different thicknesses, were introduced; but in places where changes were not required, the symbols used initially were retained to provide for ease in identifying the various modeled stream channels. A symbol on the map can be referenced to a location along a stream (pl. 1) by first determining its node location (row and column) in figure 3, and then locating the same position on the grid outline on plate 1.

The thicknesses shown do not necessarily indicate the physical thickness of fine-grained material at a given location. A single hydraulic conductivity value of 5×10^{-3} ft/d (1.5×10^{-3} m/d) was used in the model for the fine-grained material. Therefore, the thickness was adjusted to obtain the correct ratio of hydraulic conductivity to thickness for calibration. A symbol representing zero thickness of streambed material indicates that at that point the river and aquifer are in perfect hydraulic connection.

The climatic data used in the model were taken from National Weather Service records at the Shreveport station. Daily rainfall amounts recorded at the Shreveport station were applied uniformly to all points in the model.

Infiltration of rainfall was computed using a modified version of a routine from the model by Dawdy, Lichty, and Bergmann (1972, p. B5-B8). This routine was modified to correspond to the 1-day rainfall periods used in this model as contrasted with the 15-minute period used in the original model. Overland runoff, or infiltration residual, was dropped from the accounting procedure of the nonsteady-state model. Due to the 1-day rainfall period, it was necessary to impose an upper limit on



EXPLANATION

Map of thickness of streambed and lakebed material

SYMBOL	THICKNESS (FEET)
3	(OUTSIDE SYSTEM)
A	5
B	5
C	5
D	5
E	5
F	5
G	10
H	0
I	15
J	2
K	8
L	20
M	1
N	18
O	12

Figure 3.—Symbolic map showing modeled thickness of streambed material, Lock and Dam 5.

soil-moisture storage because redistribution of moisture occurred only once each day. The value of this limit used in the nonsteady-state model was 1 in. (25.4 mm). This can be compared with values ranging from 1.9 to 3.5 in. (48 to 89 mm) for "maximum moisture storage in the soil column at field capacity" (BMSM) reported in Dawdy, Lichty, and Bergmann (1972, p. B26, table 12). Because the surficial material of the Red River alluvium is generally fine grained, a limit of soil-moisture storage of 1 in. (25.4 mm) is reasonable. Redistribution of soil moisture to the water table was computed as a decaying exponential function of soil moisture throughout the range from 1 to 0.5 in. (25.4 to 12.7 mm). For soil moisture less than 0.5 in. (12.7 mm), recharge to the water table was specified to be zero.

Evapotranspiration was taken initially from soil moisture and then from ground water after soil moisture was depleted. The limit on evapotranspiration was the steady-state rate of upward movement of water, as determined by the method of Ripple, Rubin, and van Hylckama (1972). This method requires a specified relation between unsaturated hydraulic conductivity and soil suction (Ripple and others, 1972, p. A6, eq. 10). Two parameters of this specification, $\underline{n}$, an integer soil coefficient, and $\underline{S\frac{1}{2}}$, soil suction at which the unsaturated conductivity is one-half the saturated conductivity, are used to express the limiting steady-state evaporation in a nondimensional form. Values of $\underline{n}$, ranging from 2 for clays to 5 for sands, and values of $\underline{S\frac{1}{2}}$, ranging from 1 for sands to 2 for finer materials, were used in this model. The actual limiting rate of evapotranspiration was obtained by multiplying the computed upward rate by the saturated hydraulic conductivity. The method of Ripple, Rubin, and van Hylckama (1972) assumes bare soil and moisture transport to the land surface. Practically all the project area is covered by vegetation. Therefore, moisture transport was calculated to the base of the root zone. Maps were prepared by the Soil Conservation Service, who delineated vegetal cover and root depths for each type of cover. From these data, root-depth maps were prepared as input to the model.

An essential part of the analysis involved the calibration procedure to insure that the aquifer model would respond properly to changes in river stage and accretion. The model was calibrated using the nonsteady-state procedure in the following manner: (1) Observed river-stage fluctuations and accretion rates were simulated in the aquifer model, and the resultant head distribution in the aquifer was computed. Accretion was computed in the model as a function of the hydraulic conductivity and thickness of the upper confining layer, precipitation, and potential evapotranspiration. River-stage and climatic data for 1969 through 1972 and test-hole logs were used in the computation of accretion. The simulation of stage fluctuations and accretion in the model resulted in synthetic hydrographs of potentiometric and water-table fluctuations for 60 nodes in the model. Water-table hydrographs for two of the nodes are used as examples later in the report. The nodes in the aquifer model corresponded approximately with the physical locations of observation wells in the field. (2) The computed water-level values were compared with the observed measurements for the same period of time. Computations were made for the full 4-year period of record. However, the final year of the period, 1972, was used for calibration to provide sufficient time for inclusion of antecendent conditions. (3) The values of the modeled parameters (for example, hydraulic conductivity and storage of the upper confining layer and aquifer and the degree of connection between streams and the aquifer) were adjusted, and a new head distribution in the aquifer was computed. This sequence of steps was repeated until a suitable match between computed and observed water-table and potentiometric levels was obtained.

Values of 3.0 and 1×10^{-5} ft/d (0.9 and 3×10^{-6} m/d) were selected as being the physical plausibility limits within which adjustments could be made to the vertical hydraulic conductivity of the upper confining layer. This range represents the conductivity of materials ranging from fine sand to dense clay. Because of the extreme lateral variability of the upper alluvial materials, the initial conductivity values, as determined from test-hole logs, are not necessarily representative of the entire area as modeled. Therefore, the only constraints on adjusting vertical hydraulic-conductivity values was to remain within the physical plausibility limits.

Results of the calibration for Lock and Dam 5 are given in tables 2 and 3. These tables are reproductions of model output showing comparisons of computed and observed water-table and potentiometric levels for the spring and fall of 1972. The observed depth of the water table below land surface at some sites is shown as being within a range of values. This convention is necessary because of the differences in readings taken from the battery of shallow piezometers at a given location. For example, at the site of well Bo-146, the depth of the water table for the fall of 1972 (table 3) ranged from 9.5 to 10.5 ft (2.9 to 3.2 m) below the land surface. At other sites, the depth of the water table is shown as being greater or less than a given value. Piezometers were installed at depths of from 1 ft (0.3 m) to about 20 ft (6.1 m) below the land surface.

STEADY-STATE ANALYSIS

The steady-state projections of the potentiometric surface were made by using modeling techniques originally developed for similar studies in the Arkansas River valley (Bedinger and others, 1970). These techniques were developed for use with analog models but were later adapted in this study for use with digital models (Bedinger and others, 1973). The model representation of the aquifer for the steady-state analysis basically includes three parameters: transmissivity of the aquifer, the change in evapotranspiration from the aquifer with change in head in the aquifer, and the hydrologic boundaries of the aquifer (fig. 4). The relation between evapotranspiration and depth to water was determined from the nonsteady-state model calibration. The change in river stage from average preconstruction to average postconstruction conditions was simulated to produce the resultant changes in the potentiometric surface in the artesian aquifer.

Table 2.—*Comparison of computed and observed water levels, spring of 1972*

[Well number: B, Bossier Parish; C, Caddo Parish; R, Red River Parish]

	POTENTIOMETRIC SURFACE (IN FEET)		
WELL NUMBER	MEASURED DEPTH BELOW LAND SURFACE	COMPUTED DEPTH BELOW LAND SURFACE	DIFFERENCE •
B146	12.3	14.2	-1.9
B153	8.0	9.2	-1.2
B154	10.4	12.3	-1.9
B188	13.5	11.5	2.0
B220	6.6	7.5	-0.9
B283	7.6	7.9	-0.3
B284	9.0	8.2	0.8
B285	10.0	8.2	1.8
B286	9.5	10.2	-0.7
B287	20.8	19.2	1.6
B288	18.6	16.6	2.0
B289	15.4	14.9	0.5
B290	17.5	17.8	-0.3
B291	16.4	15.8	0.6
B292	15.5	14.3	1.2
B293	14.2	14.8	-0.6
B294	20.0	18.4	1.6
B295	21.8	16.8	5.0
B296	14.0	14.4	-0.4
B297	13.5	15.1	-1.6
B298	14.4	13.9	0.5
B299	21.8	17.9	3.9
B300	13.0	13.2	-0.2
B305	13.8	14.5	-0.7
B306	12.0	11.6	0.4
C328	12.2	14.4	-2.2
C330	10.8	12.4	-1.6
C331	14.3	15.5	-1.2
C461	9.8	11.6	-1.8
C462	8.4	9.0	-0.6
C463	12.0	13.0	-1.0
C464	14.0	15.1	-1.1
C465	25.0	22.1	2.9
C466	16.0	14.2	1.8
C471	10.0	10.7	-0.7
C472	14.0	14.9	-0.9
C473	21.2	20.8	0.4
C474	9.0	10.6	-1.6
C476	20.8	18.5	2.3
C477	27.9	25.5	2.4
C478	12.8	12.7	0.1
C479	14.7	16.1	-1.4
C480	5.0	4.4	0.6
C481	9.3	10.9	-1.6
C482	10.0	10.7	-0.7
C483	9.2	9.6	-0.4
C484	15.4	13.5	1.9
R188	17.8	17.3	0.5
R215	9.0	10.0	-1.0
R217	15.6	15.5	0.1
R218	9.2	10.6	-1.4
R219	9.2	9.1	0.1
R220	17.1	17.9	-0.8
R221	17.2	16.1	1.1
R222	8.9	10.4	-1.5
R223	8.8	10.2	-1.4
R224	14.5	14.1	0.4
R225	10.0	10.4	-0.4
R227	7.1	8.4	-1.3

	WATER TABLE (IN FEET)	
WELL NUMBER	MEASURED DEPTH BELOW LAND SURFACE	COMPUTED DEPTH BELOW LAND SURFACE
B146	3.5	5.7
B153	**	5.1
B154	10.7	11.6
B188	**	12.3
B220	**	6.9
B283	7.2	7.8
B284	5.8	7.9
B285	11.4	7.8
B286	9.0	8.5
B287	20.0	19.6
B288	18.8	16.7
B289	14.7	14.7
B290	18.2	16.1
B291	11.0<WL< 14.0	14.3
B292	**	14.7
B293	2.7<WL< 4.0	4.2
B294	**	18.7
B295	**	18.9
B296	7.0<WL< 15.0	10.0
B297	13.6	15.1
B298	8.4	11.3
B299	**	18.2
B300	**	6.1
B305	**	14.7
B306	**	3.4
C328	**	11.6
C330	11.2<WL< 11.5	10.9
C331	**	9.0
C461	9.4<WL< 10.2	9.5
C462	2.5	2.5
C463	11.8	11.9
C464	13.6	15.0
C465	**	23.2
C466	**	15.1
C471	9.4	10.7
C472	**	1.0
C473	**	18.3
C474	**	6.3
C476	**	18.5
C477	**	26.4
C478	3.8<WL< 4.3	5.9
C479	**	14.5
C480	3.6<WL< 4.0	3.3
C481	**	3.0
C482	1.0<WL< 3.0	3.0
C483	12.0<WL	9.3
C484	**	10.0
R188	**	14.1
R215	**	5.0
R217	15.2	14.9
R218	11.8	10.3
R219	9.9	9.1
R220	9.2<WL< 14.7	15.2
R221	15.0<WL	13.1
R222	10.3<WL< 12.7	8.8
R223	8.6	6.3
R224	**	10.6
R225	**	6.4
R227	**	4.4

**No data available.

Table 3.—*Comparison of computed and observed water levels, fall of 1972*

[Well number: B, Bossier Parish; C, Caddo Parish; R, Red River Parish]

WELL NUMBER	POTENTIOMETRIC SURFACE (IN FEET) MEASURED DEPTH BELOW LAND SURFACE	COMPUTED DEPTH BELOW LAND SURFACE	DIFFERENCE *
B146	17.7	17.1	0.6
B153	13.1	12.9	0.2
B154	15.0	14.8	0.2
B188	17.9	16.2	1.7
B220	13.0	13.0	-0.0
B283	11.0	13.0	-2.0
B284	11.8	10.1	1.7
B285	12.7	11.9	0.8
B286	12.7	13.0	-0.3
B287	25.0	26.9	-1.9
B288	20.6	20.5	0.1
B289	17.0	19.2	-2.2
B290	21.0	21.7	-0.7
B291	18.0	16.5	-0.5
B292	16.8	16.3	0.5
B293	18.5	20.0	-1.5
B294	23.0	23.2	-0.2
B295	27.3	23.5	3.8
B296	16.6	16.1	0.5
B297	17.0	16.4	0.6
B298	18.4	19.1	-0.7
B299	23.3	21.9	1.4
B300	16.8	17.8	-1.0
B305	15.0	16.2	-1.2
B306	20.4	21.6	-1.2
C328	18.7	16.2	2.5
C330	14.6	15.8	-1.2
C331	16.4	17.3	-0.9
C461	16.2	15.2	1.0
C462	12.6	13.2	-0.6
C463	17.5	16.0	1.5
C464	19.0	16.9	2.1
C465	31.1	29.5	1.6
C466	21.2	20.9	0.3
C471	11.5	12.2	-0.7
C472	25.0	23.9	1.1
C473	25.5	24.4	1.1
C474	16.8	13.8	3.0
C476	24.8	22.5	2.3
C477	26.6	30.7	-2.1
C478	14.7	16.0	-1.3
C479	19.2	19.0	0.2
C480	12.8	11.3	1.5
C481	16.3	14.4	1.9
C482	15.6	14.7	0.9
C483	13.4	12.3	1.1
C484	16.9	15.9	1.0
R188	24.1	23.0	1.1
R215	13.8	14.0	-0.2
R217	18.8	17.8	1.0
R218	11.8	11.5	0.3
R219	12.0	10.2	1.8
R220	20.6	19.7	0.9
R221	26.4	27.0	-0.6
R222	17.8	17.6	0.2
R223	14.8	13.1	1.7
R224	18.8	16.9	1.9
R225	15.2	14.1	1.1
R227	16.5	15.5	1.0

WELL NUMBER	WATER TABLE (IN FEET) MEASURED DEPTH BELOW LAND SURFACE	COMPUTED DEPTH BELOW LAND SURFACE
B146	9.5<WL< 10.5	10.9
B153	**	9.5
B154	15.2	13.0
B188	**	13.7
B220	**	12.4
B283	10.6	13.3
B284	8.2	8.7
B285	13.6	11.2
B286	12.5	9.0
B287	22.0<WL	24.0
B288	20.0<WL	20.4
B289	16.0	17.0
B290	19.0<WL< 21.0	18.2
B291	WL< 18.0	15.4
B292	**	15.5
B293	13.0<WL< 13.4	13.0
B294	**	22.8
B295	**	20.5
B296	8.0<WL< 16.0	10.2
B297	15.5<WL< 17.5	16.1
B298	12.0<WL< 15.0	14.7
B299	**	21.3
B300	**	7.7
B305	**	15.8
B306	**	20.8
C328	**	15.5
C330	14.6<WL< 15.0	13.4
C331	**	10.3
C461	15.5	11.3
C462	8.2<WL< 8.8	12.5
C463	16.2	13.7
C464	17.0<WL< 18.8	16.7
C465	**	23.8
C466	**	17.1
C471	11.2	12.2
C472	**	20.1
C473	**	19.8
C474	**	13.4
C476	**	22.5
C477	**	28.4
C478	7.2<WL< 7.8	8.6
C479	**	14.8
C480	7.6<WL< 13.0	10.7
C481	**	11.9
C482	5.0<WL< 7.0	9.3
C483	12.0<WL< 14.0	11.9
C484	**	10.9
R188	**	14.2
R215	**	8.6
R217	17.0<WL	17.3
R218	18.0<WL	11.3
R219	12.7	10.0
R220	12.7	15.4
R221	15.0<WL	26.3
R222	14.4	16.4
R223	14.7	12.2
R224	**	12.5
R225	**	9.7
R227	**	10.9

**No data available.

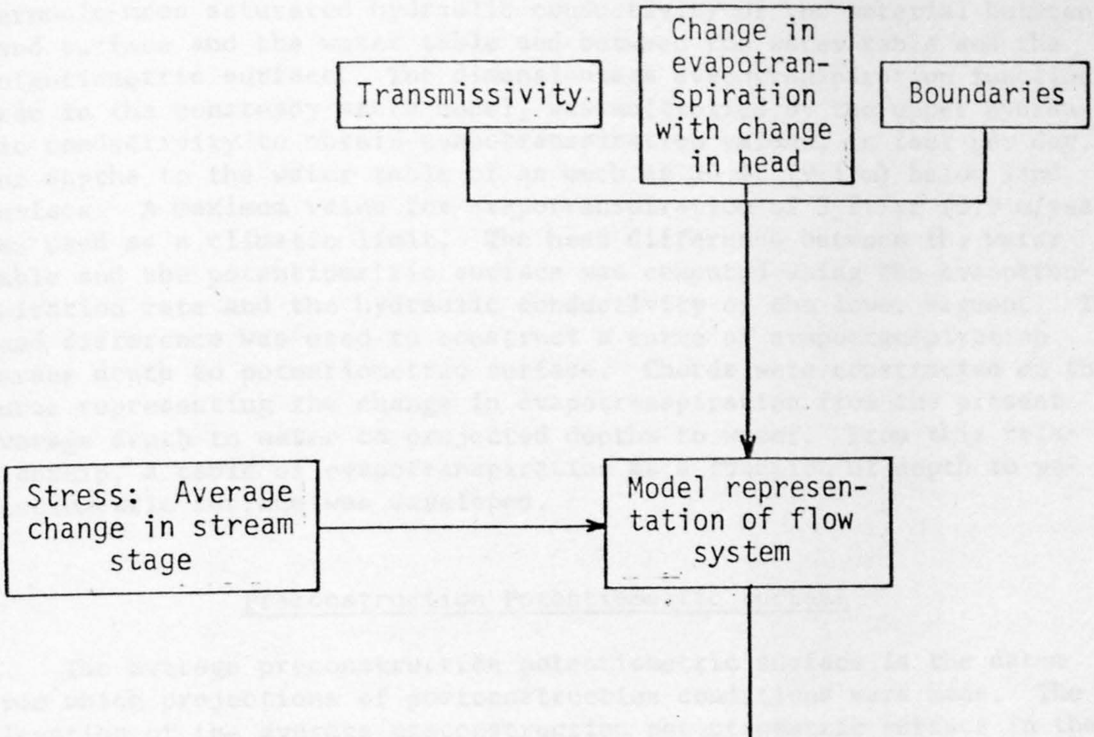


Figure 4.—Flow diagram of digital-model procedure for steady-state analysis.

The relation between evapotranspiration and depth to water uses the two values of vertical hydraulic conductivity as determined from the nonsteady-state model calibration. These two values represent the harmonic-mean saturated hydraulic conductivity of the material between land surface and the water table and between the water table and the potentiometric surface. The dimensionless evapotranspiration function, used in the nonsteady-state model, was multiplied by the upper hydraulic conductivity to obtain evapotranspiration values, in feet per day, for depths to the water table of as much as 30 ft (9.1 m) below land surface. A maximum value for evapotranspiration of 3 ft/yr (0.9 m/year) was used as a climatic limit. The head difference between the water table and the potentiometric surface was computed using the evapotranspiration rate and the hydraulic conductivity of the lower segment. The head difference was used to construct a curve of evapotranspiration versus depth to potentiometric surface. Chords were constructed on the curve representing the change in evapotranspiration from the present average depth to water to projected depths to water. From this relationship, a table of evapotranspiration as a function of depth to potentiometric surface was developed.

Preconstruction Potentiometric Surface

The average preconstruction potentiometric surface is the datum from which projections of postconstruction conditions were made. The elevation of the average preconstruction potentiometric surface in the Lock and Dam 5 area was determined from data collected from the joint Geological Survey-Soil Conservation Service observation-well network. The preconstruction potentiometric surface (pl. 1) was contoured manually using time-weighted averages of monthly water-level readings taken during the period January 1971 through December 1974.

The average potentiometric surface in the Lock and Dam 5 area ranges from 120 to 164 ft (37 to 50 m) above mean sea level. The contour lines (pl. 1) indicate potentiometric "highs" or recharge areas parallel to and along both sides of the Red River between Bayou Pierre on the west and Red Chute Bayou on the east. The hydraulic gradient in the alluvial aquifer, which is normal to the contour lines, is toward these three streams. Bayou Pierre and Red Chute Bayou, as well as the Red River, are discharge points for water from the alluvial aquifer.

Average water levels in the valley range from about 3 to 34 ft (0.9 to 10 m) below land surface. In most areas the potentiometric surface is more than 10 ft (3.0 m) below land surface, but is less than 5 ft (1.5 m) below land surface in several places in the lock and dam area. A comparison of the average elevation of the preconstruction potentiometric surface with land-surface elevations indicates the following areas in which the potentiometric surface is near (5 ft, or 1.5 m, or less below) the land surface: the Cannisnia Lake basin west of Lachute, areas around Dixie Gardens and Anderson Island near Shreveport, and in places between the Flat River and Red Chute Bayou on the east side of Barksdale Air Force Base.

Postconstruction Potentiometric Surface

The projected average potentiometric surfaces for the plans analyzed are shown on plates 2 through 4. The contour lines define the resultant of the river-induced head change in the aquifer imposed on the present average potentiometric surface (pl. 1). The maximum change in river stage is at the upstream side of the dam. For the plans included in this study, the maximum average change ranges from 13 to 23 ft (4.0 to 7.0 m). The change in stage decreases to zero at a point upstream from Shreveport. In most places the change in ground-water levels at the river will be approximately equal to the change in river stage. However, because of the imperfect connection that exists locally between the river and the aquifer and because of the increase in evapotranspiration, the change in ground-water levels may be less than the change in river stage. The difference between pool stages and ground-water levels is most apparent in the vicinity of the proposed damsites in the Lock and Dam 5 area where the contours indicate a gradual slope of the potentiometric surface from the level of the upper pool to the lower pool. As a result, for a distance upstream from the damsite, the pool level would be above the potentiometric surface, and the resultant hydraulic gradient would be from the river to the aquifer. The convergence of contour lines at the Lock and Dam 6 site indicates that the river and aquifer are hydraulically connected at that site and all of the head loss takes place at the dam.

The induced change in ground-water levels would decrease with distance from the river because of increased evapotranspiration and because of discharge to tributary streams. However, the projected potentiometric surface would be near or above the land surface in some places, in addition to the areas previously noted as having shallow water levels, as a result of the increased river stage. A comparison of the projected potentiometric surface with land surface for each of the plans studied is given as follows.

Locks and Dams 5 and 6, plans A-1, 2, and 3 (pl. 2): A 135-foot (41-m) pool stage upstream from proposed Lock and Dam 5, at realined mile 199 (kilometer 320), would cause a permanent change in river stage of 13 ft (4.0 m) at the dam. As a result of the increased stage, the potentiometric surface would be raised to a level at or near the land surface in areas west of and parallel to Red River, from the damsite to the vicinity of realined mile 210 (kilometer 340). The areas approximately coincide with the potentiometric "high" (pl. 1), which parallels the west side of the river. The potentiometric surface would be at or near the land surface in low-lying areas along the east side of the Red River and along the Flat River. The potentiometric surface would be above the land surface in isolated low-lying areas around cutoff lakes near the river and along drainage channels.

A 150-foot (46-m) pool stage upstream from the proposed damsite (Lock and Dam 6), at realined mile 221 (kilometer 360), would cause a permanent average change in stage of 13 ft (4.0 m) at the dam. The potentiometric surface would be raised to a level above the land surface in most places in the flood plain west of the river, upstream from the damsite to Anderson Island. The areas around Barksdale Air Force Base, in which the potentiometric surface is presently near the land surface, would be extended laterally to the east edge of Bossier City and downstream along the Flat River to the vicinity of Curtis.

Lock and Dam 5, plans B-1, 2, and 3 (pl. 3): A 145-foot (44-m) pool stage upstream from the proposed damsite, at realined mile 203 (kilometer 330), would cause a permanent average change in stage of 21 ft (6.4 m) at the dam. The potentiometric surface would be raised to a level at or near the land surface in much of the area between Red River and Bayou Pierre, upstream from the damsite. Areas in the Cannisnia Lake basin and on Barksdale Air Force Base, where present water levels are near the land surface, would be enlarged. The potentiometric surface would be above the land surface in low-lying areas in the flood plain in much of Anderson Island and Dixie Gardens, near Shreveport.

Lock and Dam 5, plan B-3, modified (pl. 4): A 145-foot (44-m) pool stage upstream from the proposed damsite, at realined mile 198 (kilometer 320), would cause a permanent average change in river stage of 23 ft (7.0 m) at the dam. The potentiometric surface would be raised to a level at or near land surface in a large part of the area between the Red River and Bayou Pierre, upstream from the dam to about realined mile 220 (kilometer 350). The potentiometric surface would be above the land surface in much of the area around Howard and in the Anderson Island and Dixie Gardens area. East of the river, the potentiometric surface would be at or near the land surface for as much as 2 mi (3.2 km) from the river, upstream from the dam, and in places near the Flat River. The areas near Barksdale Air Force Base where the potentiometric surface is presently near the land surface would increase in size and would extend downstream along the Flat River to the vicinity of Curtis.

NONSTEADY-STATE ANALYSIS

Nonsteady-state analyses were made by using digital-modeling procedures recently developed by the Geological Survey (Reed and others, 1976). The nonsteady-state model has the same map representation as the steady-state model but incorporates several additional parameters, as shown in figure 5. Data for each of these parameters were assigned to the appropriate node or nodes in the model. Accretion and river stage, the major stresses on the aquifer, were applied to the model in successive 10-day time increments. Accretion was determined as stated previously in the discussion on modeling procedure. River-stage data for preconstruction and computed postconstruction conditions were developed by the Corps. The computations resulted in potentiometric and water-table elevations at all nodal points in the model for each time increment. The actual output from the analysis consisted of data, punched on computer cards, giving the computed depth of the water table below land surface at each node in the model for a specified series of calendar dates during a period of 1 year. The dates were selected by the Soil Conservation Service to coincide with the planting, growing, harvesting, and dormant

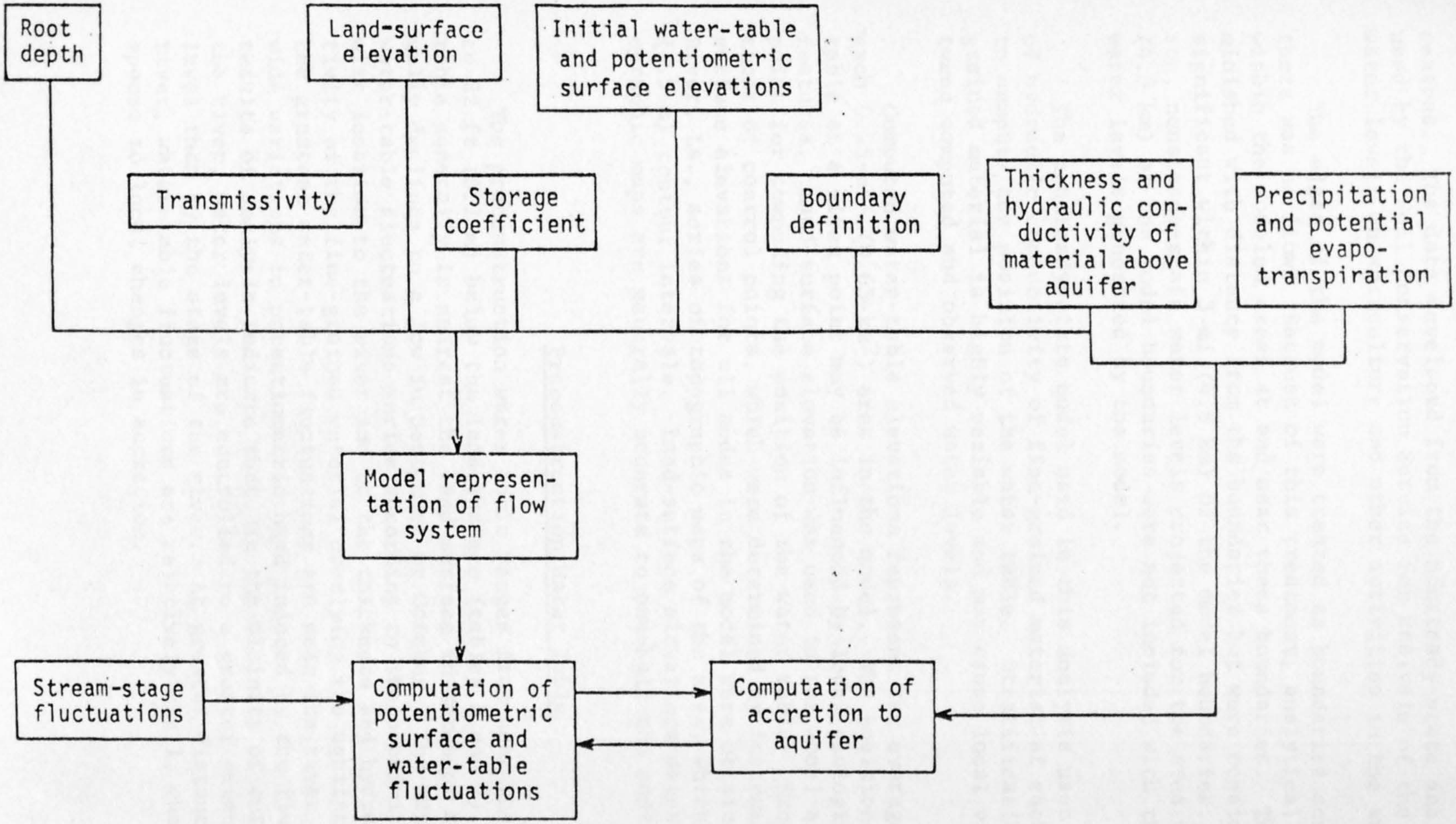


Figure 5.—Flow diagram of digital-model procedure for nonsteady-state analysis.

seasons. The data developed from the nonsteady-state analysis are to be used by the Soil Conservation Service for analysis of the effects of water levels on agriculture and other activities in the area.

The edges of the model were treated as boundaries across which there was no flow. Because of this treatment, analytical errors occurred within the modeled areas at and near these boundaries. The errors diminished with distance from the boundaries but were considered to be significant within 3 mi (4.8 km) of the model boundaries. For this reason, nonsteady-state water levels projected for the area within 3 mi (4.8 km) of the model boundaries were not included with the projected water levels generated by the model.

The nonsteady-state model used in this analysis uses average values of hydraulic conductivity of fine-grained material at each control point to compute the position of the water table. Stratification of the fine-grained material is highly variable and may cause local variations between computed and observed water levels.

Computed water-table elevations represent the average conditions in each 0.25-mi^2 (0.65-km^2) area in the model. The position of the water table at a given point may be influenced by local geologic and drainage features. Land-surface elevation was used in the model as a reference point for computing the position of the water table. Except for elevations of control points, which were determined by instrument, land-surface elevations for all nodes in the model were obtained from the Red River, La., series of topographic maps of the area, which have 5-foot (1.5-m) contour intervals. Land-surface elevations determined from topographic maps are generally accurate to one-half the contour interval.

Preconstruction Water Table

The preconstruction water table ranges from near the land surface to 22 ft (6.7 m) below the land surface (tables 2 and 3). The water table generally is nearest the land surface in March or April and gradually declines to a low in September or October. The magnitude of water-table fluctuations varies according to the proximity of a particular location to the river and to the thickness and hydraulic conductivity of the fine-grained material overlying the aquifer. Generally, the greatest water-table fluctuations are near the river because of the wide variations in potentiometric head induced by the river. However, results of analysis indicate that, in the vicinity of cutoff lakes near the river, water levels are controlled to a greater extent by the lake level than by the stage of the river. At greater distances from the river, water-table fluctuations are relatively small, changing in response to local changes in accretion.

Postconstruction Water Table

The computed postconstruction water table reflects the attenuation of river-stage fluctuations and the increase in head resulting from the formation of a pool upstream from the proposed lock and dam site. Near the river, the water table is expected to fluctuate less than half the magnitude of preconstruction fluctuations; however, the water table would be closer to the land surface. Computed water-table hydrographs for well sites Bo-287 and Cd-471 (figs. 6 and 7) show, respectively, a representation of postconstruction conditions near and at a distance from the river. The hydrograph for the site of well Bo-287 shows a water-table fluctuation of 1.4 ft (0.4 m), ranging from 15.2 to 16.6 ft (4.6 to 5.1 m) below the land surface. By comparison, the observed preconstruction water table at that site (tables 2 and 3) is from 20 ft (6.1 m) to about 22 ft (6.7 m) below the land surface. The computed postconstruction water table at the site of well Cd-471 ranges from 9.0 to 10.4 ft (2.7 to 3.2 m) below the land surface, whereas the observed preconstruction water table at that site ranges from 9.4 to 11.2 ft (2.9 to 3.4 m) below land surface. Although the difference between observed preconstruction and computed postconstruction values is less than 1 ft (0.3 m), the actual change in water levels at that site would be about 1.8 ft (0.6 m) or the difference between the computed preconstruction and postconstruction values.

SUMMARY

Two sites for Lock and Dam 5 and one site for Lock and Dam 6 were studied. These include sites at river miles 243 and 250 (kilometers 390 and 400), 1967 mileage, for Lock and Dam 5 and at river mile 270 (kilometer 430), 1967 mileage, for Lock and Dam 6. The plan for a 145-foot (44-m) pool stage at mile 243 (kilometer 390), 1967 mileage (B-3, modified), has been selected by the Corps. The average pool stage at the dam would be 23 ft (7 m) higher than the present average river stage. Formation of a navigation pool upstream from the proposed damsite would reduce the magnitude of ground-water-level fluctuations, but the water levels would be closer to the land surface. Ground-water levels in the pool area would be raised to a level at or near the land surface in much of the area west of the river to Bayou Pierre, and as much as 2 mi (3.2 km) east of the river from the dam upstream to the vicinity of realined mile 220 (kilometer 350). The areas on Barksdale Air Force Base in which water levels are presently near the land surface would be enlarged and would extend downstream along Flat River to the vicinity of Curtis. The potentiometric surface may be above land surface in much of the area in the vicinity of Howard and in the Anderson Island and Dixie Gardens area near Shreveport.

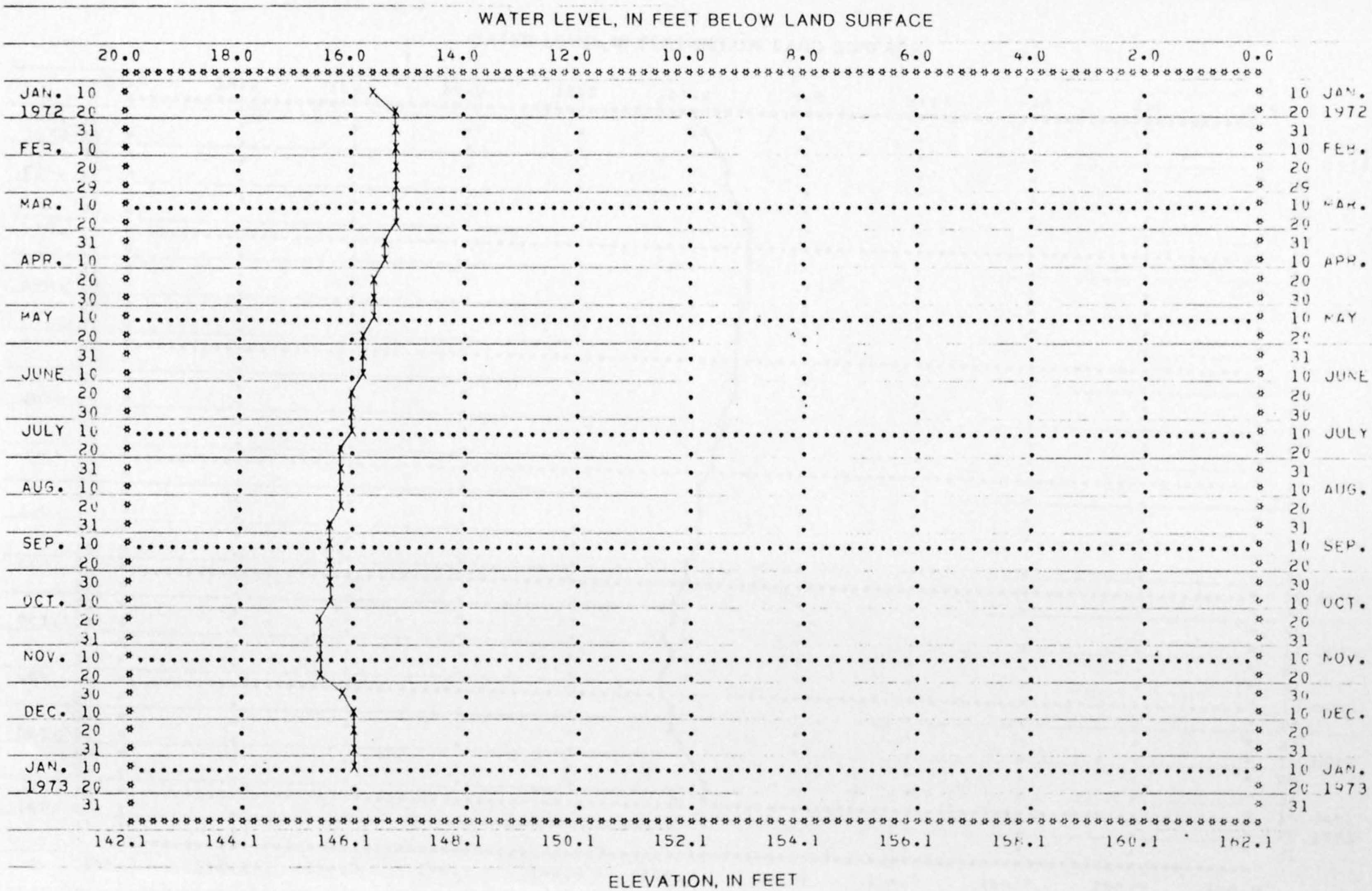


Figure 6.—Computed postconstruction water-table hydrograph, well Bo-287.

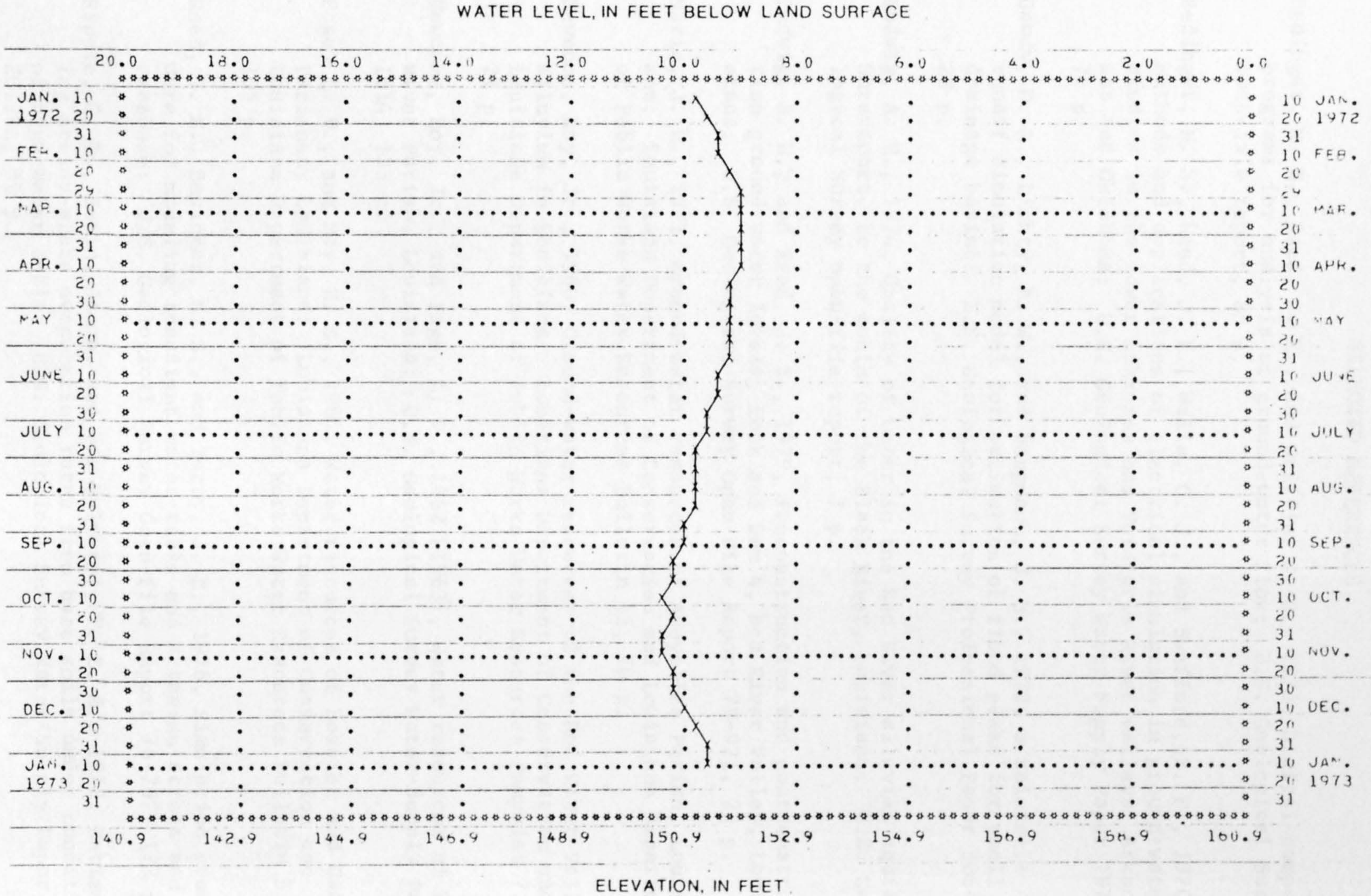


Figure 7.—Computed postconstruction water-table hydrograph, well Cd-471.

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