UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRECONSTRUCTION AND POSTCONSTRUCTION GROUND-WATER LEVELS, LOCK AND DAM 1, RED RIVER VALLEY, LOUISIANA

Open-File Report 79-918

Prepared in cooperation with the
U.S. Army Corps of Engineers
and the U.S. Soil Conservation Service

Cooperative Ground-Water Study

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRECONSTRUCTION AND POSTCONSTRUCTION GROUND-WATER LEVELS, LOCK AND DAM 1, RED RIVER VALLEY, LOUISIANA

By A. H. Ludwig

Open-File Report 79-918

Prepared in cooperation with the

U.S. Army Corps of Engineers

and the U.S. Soil Conservation Service

Cooperative Ground-Water Study

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."

CONTENTS

	Page
Preface	II
Factors for converting inch-pound units to International System (SI) of metric units	IV
Abstract	1
Introduction	1
Purpose and scope	3
Description of the aquifer system	3
Modeling procedure	6
Steady-state analysis	7
Preconstruction potentiometric surface	7
Postconstruction potentiometric surface	9
Nonsteady-state analysis	9
Preconstruction water table	11
Postconstruction water table	14
Summary	14
Selected references	17

ILLUSTRATIONS

[Plates are in pocket]

Plate 1. Map showing the average preconstruction potentiometric surface, 1969-73, Lock and Dam 1.

2. Map showing the projected postconstruction potentiometric surface, Lock and Dam 1.

		Page
Figure 1.	Index map showing location of report area	2
2.	Idealized hydrogeologic section of the Red River Valley	5
3.	Flow diagram of digital-model procedure for steady-state analysis	8
4.	Flow diagram of digital-model procedure for nonsteady-state analysis	10
5.	Computed and observed preconstruction water-table hydrographs, well Av-326	12
6.	Computed and observed preconstruction water-table hydrographs, well Av-337	13
7.	Computed postconstruction water-table hydrograph, well Av-326	15
8.	Computed postconstruction water-table hydrograph, well Av-337	16

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
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
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 1, RED RIVER VALLEY, LOUISIANA

By A. H. Ludwig

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 1 at mile 44 (kilometer 71) above the mouth of the Red River call for a pool elevation of 40 feet (12.2 meters) and will cause an average increase in river stage of 9 feet (2.7 meters). As a result, ground-water levels will be raised 1 foot (0.3 meter) or more within 4 miles (6.4 kilometers) of the river. The potentiometric surface may be near land surface in low-lying areas, and above land surface along the course of drainage features near the dam. The magnitude of ground-water-level fluctuations near the river will be reduced.

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, which include a five- or six-lock-and-dam arrangement, have been proposed. The locations of the proposed dams are shown in figure 1. Plans for a modified version of the five-lock-and-dam arrangement, 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. In the Lock and Dam 1 area, only one damsite and pool stage have been considered. The results of this investigation are being used by the U.S. Soil Conservation Service to evaluate the beneficial or adverse effects of changes in ground-water levels.

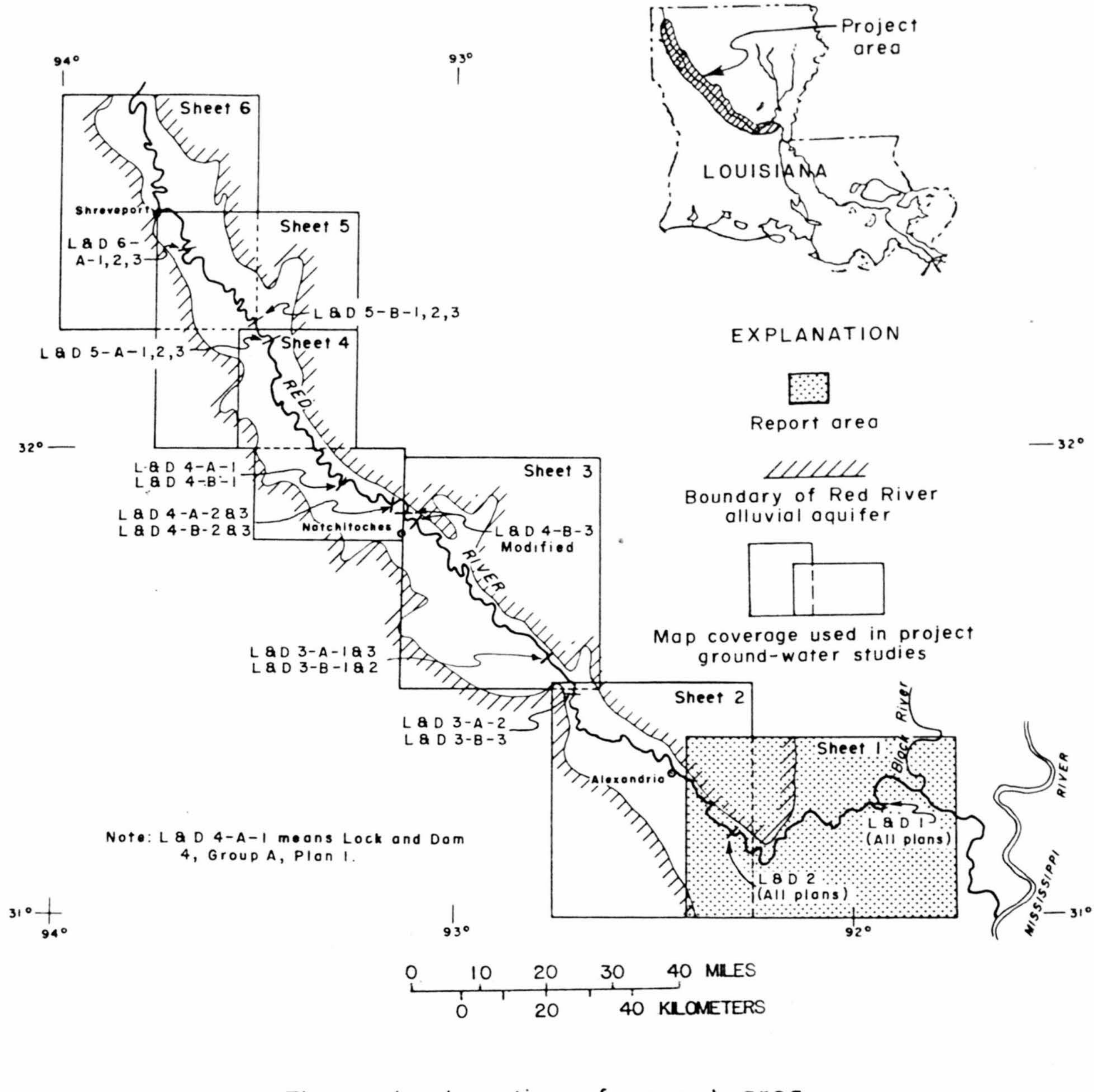

Figure 1.—Location of report area.

This report is the second in a series that will present analyses of preconstruction and postconstruction ground-water conditions in the Red River Valley, La. The initial report covered Lock and Dam 2 area. Subsequent reports on the lock and dam areas will be prepared in the following sequence: Lock and Dam 4, Lock and Dam 3, Lock and Dam 5, and Lock and Dam 6. 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 1 area (fig. 1).

Lock and Dam 1 is to be located at mile 44 (kilometer 71), 1967 mileage, on the Red River. The pool upstream from Lock and Dam 1 is to be at an elevation of 40 ft (12 m) above mean sea level.

Two types of analyses were made in this investigation, steady and nonsteady state. Steady-state analysis refers to the determination of 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 (1) the average preconstruction potentiometric surface and (2) the projected postconstruction potentiometric surface determined from the steady-state analyses. Nonsteady state 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 made for the report include a computation of the preconstruction and postconstruction water table. The report contains hydrographs showing examples of the results of the nonsteady-state analyses.

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 1 area flows within an alluvial valley ranging from 10 mi (16 km) in width in the west end of the area to about 20 mi (32 km) in the vicinity of Marksville. Downstream from Marksville the valley widens abruptly where the Red River and Mississippi River alluvial valleys coalesce. Terraces rising as high as 100 ft (30 m) above the flood plain border the valley in the western part of the area. Isolated terraces, including the terrace on which Marksville is situated, appear as low hills in the flood plain. The terraces are remnants of former alluvial surfaces, and the underlying deposits constitute an extension of the valley alluvium. Ground water in the terrace deposits is in hydraulic connection with that beneath the flood plain.

The alluvium in the valley is as thick as 200 ft (61 m) and averages about 120 ft (37 m). The thickest sections of alluvium are in the eastern part of the area where former Mississippi River channels have deeply incised the underlying beds of Miocene age. 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 silt, clay, and fine sand (fig. 2). The aquifer ranges in thickness from about 40 to 170 ft (12 to 52 m), and the upper confining layer is as thick as 140 ft (43 m).

Recharge to the alluvial aquifer is derived from infiltration of rainfall, underflow from adjacent terrace deposits, and during periods of high river stage, by recharge from the river. The geologic formations underlying the alluvial valley are not considered to be significant sources of recharge.

Water levels in wells tapping the aquifer in the flood plain rise above the base of the fine-grained material, an indication that the water is confined 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.

Movement of water in the alluvial aquifer is mainly toward the Red River, whose present bed is incised into the aquifer throughout its course in the area. At most times, water is discharged into the river. The 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 water from the terrace deposits and by infiltration in zone 1 through the clay and silt. Discharge takes place to the Red River and vertically upward in zone 2. The flow conditions shown in the diagram may change. At any given location, the

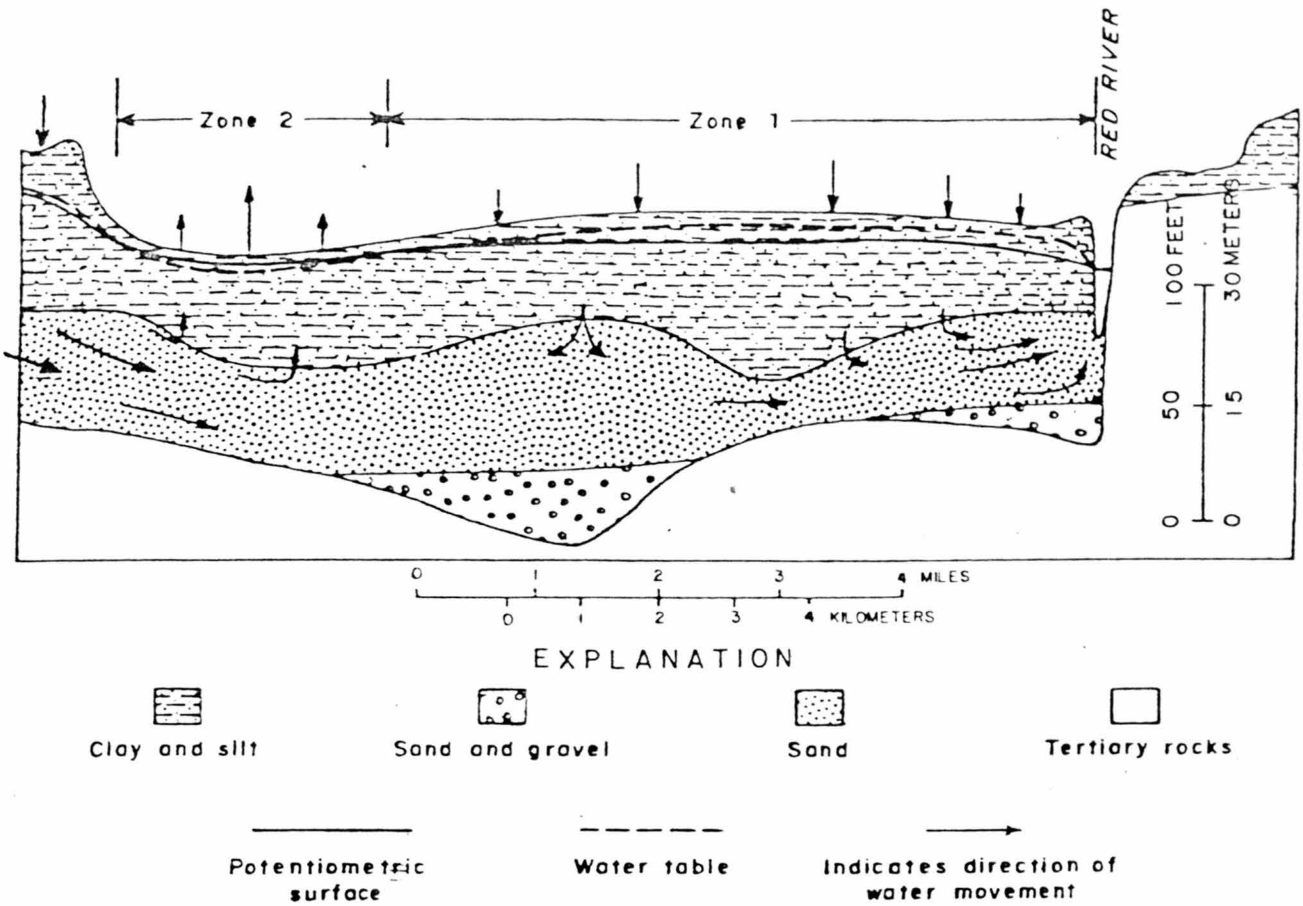

Figure 2.—Idealized hydrogeologic section of the Red River Valley.

rate of accretion is neither constant nor in the same direction at all times. Seasonal weather changes, changes in river stage, and pumping 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 the Lock and Dam 1 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 1 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.

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. Separate values of hydraulic conductivity were assigned to each segment of the upper confining layer. The hydraulic conductivity of the upper segment ranges from $5x10^{-1}$ to $8x10^{-4}$ ft/d ($1.5x10^{-1}$ to $2.4x10^{-4}$ m/d), and that of the lower segment ranges from $1x10^{-1}$ to $1x10^{-5}$ ft/d ($3x10^{-2}$ to $3x10^{-6}$ m/d). The specific yield of the upper confining layer, in which the water table generally occurs, ranges from $1x10^{-2}$ to $2.4x10^{-1}$. 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 6,200 to 24,000 ft^2/d (580 to 2,230 m^2/d). The storage coefficient of the aquifer ranges from $1x10^{-3}$ to $1x10^{-4}$. Hydraulic conductivity and specific yield values for the upper confining layer and storage values for the aquifer were estimated from the calibration of the model.

The Red River was assumed to penetrate the aquifer and to be hydraulically connected with it. Tributary streams, such as Saline Bayou, Spring Bayou, Larto Lake, and Chatlin Lake Canal, do not penetrate the aquifer and are separated from it by less permeable fine-grained materials. The fine-grained material ranges from 10 to 30 ft (3 to 9 m) in thickness, and laboratory analyses of soil samples indicated that it has an average hydraulic conductivity of $5x10^{-3}$ ft/d ($1.5x10^{-3}$ m/d).

The climatic data used in the model were taken from National Weather Service records at the Jonesville station, which is approximately 20 mi (32 km) north of the study area. Daily rainfall amounts recorded at the Jonesville station were applied uniformly to all points in 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 1968 through 1971 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 50 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 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. (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.

The procedure described here applies to the calibration of the nonsteady-state model, but the calibrated parameters were also used for the steady-state model.

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. 3). 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.

Preconstruction Potentiometric Surface

The average preconstruction potentiometric surface is the datum from which projections of postconstruction conditions were made. The

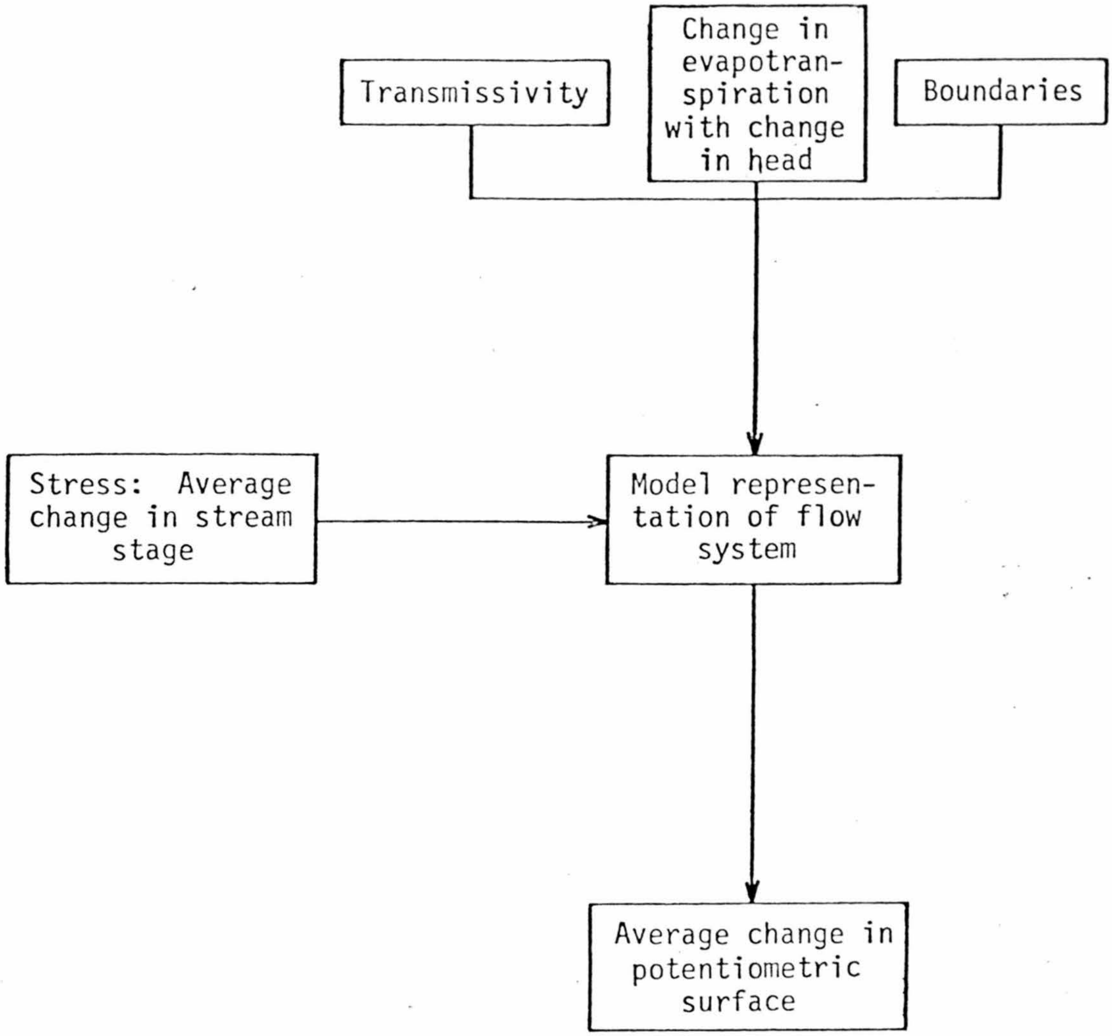

Figure 3.—Flow diagram of digital-model procedure for steady-state analysis.

elevation of the average preconstruction potentiometric surface in the Lock and Dam 1 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 1969 through December 1973.

Postconstruction Potentiometric Surface

A 40-foot (12-m) pool stage upstream from Lock and Dam 1 (pl. 2) would cause a permanent increase in average river stage, ranging from 9.0 ft (2.7 m) at the dam to 2.5 ft (0.8 m) above the present average river stage at the upper end of the pool. Ground-water levels would rise a similar amount adjacent to the river but would gradually diminish with distance from the river. Rises of at least 1 ft (0.3 m) in ground-water levels would occur as much as 4 mi (6.4 km) from the river. The projected average potentiometric surface is shown on plate 2.

The contour lines (pl. 2) show that the average postconstruction ground-water gradient would be toward the river, similar to the existing gradient, but the gradient would be less steep. The closely spaced contour lines radiating from the location of the proposed dams indicate that a strong potential would exist for ground-water seepage through the aquifer and around the dam.

Comparison of the projected potentiometric surface with land-surface elevations indicates that the potentiometric surface would be near the land surface in low-lying areas north and south of the river and would be above the land surface along the course of drainage features in the vicinity of the proposed damsite.

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. However, the nonsteady-state model incorporates several additional parameters, as shown in figure 4. 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 covering a period

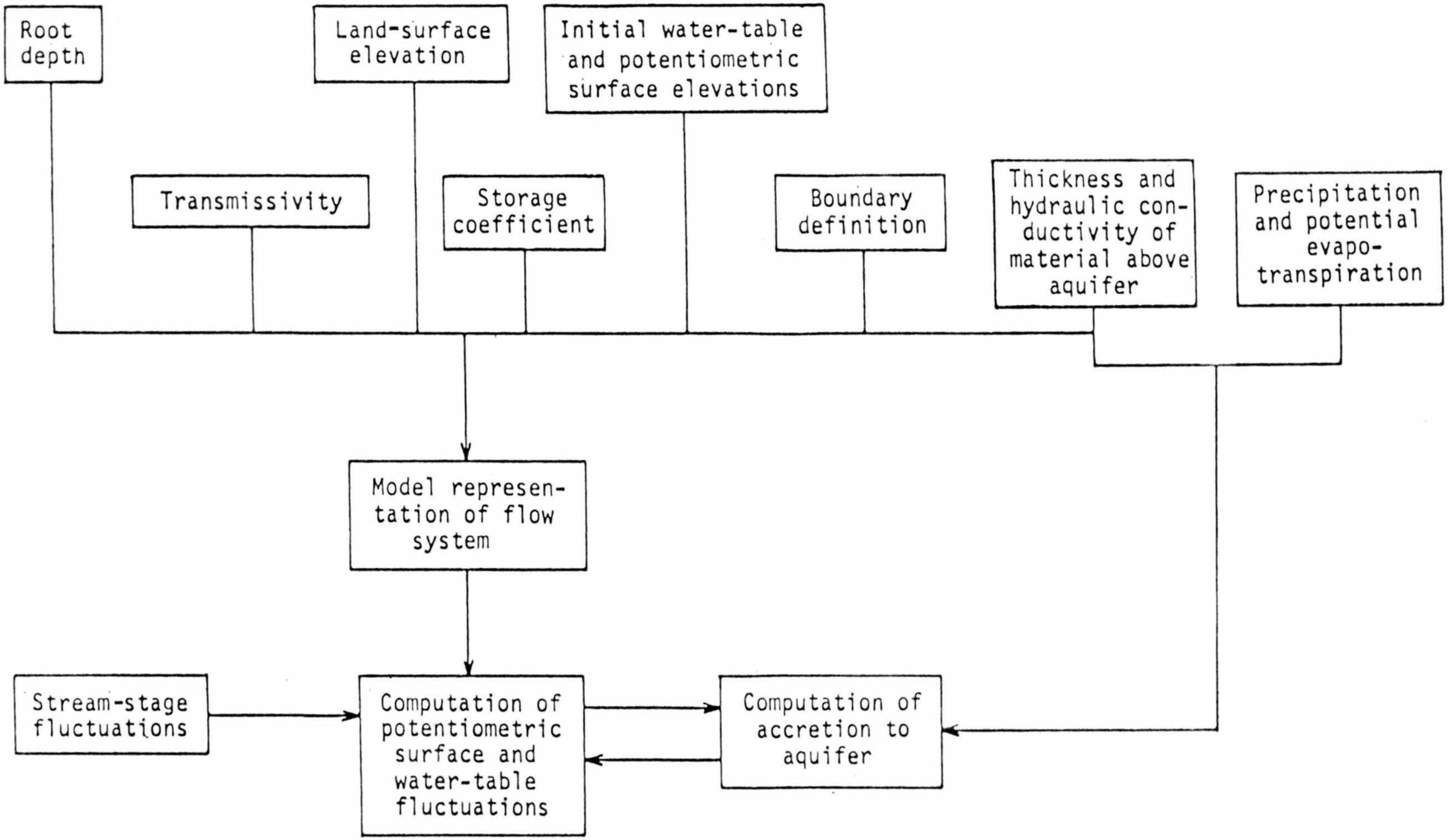

Figure 4.—Flow diagram of digital-model procedure for nonsteady-state analysis.

of 1 year. The dates were selected by the Soil Conservation Service to coincide with the planting, growing, harvesting, and dormant 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 a 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 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 computed preconstruction water table ranges from land surface to more than 21 ft (6 m) below the land surface. 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 occur at locations near the river because of the wide variations in potentiometric head induced by the river. However, where the hydraulic conductivity of the fine-grained material is low, water-table fluctuations may be controlled more by local climatic conditions than by river-stage fluctuations. At greater distances from the river, water-table fluctuations are relatively small, changing primarily in response to local changes in accretion. Computed hydrographs for two well sites, Av-326 and Av-337 (figs. 5 and 6), are given as

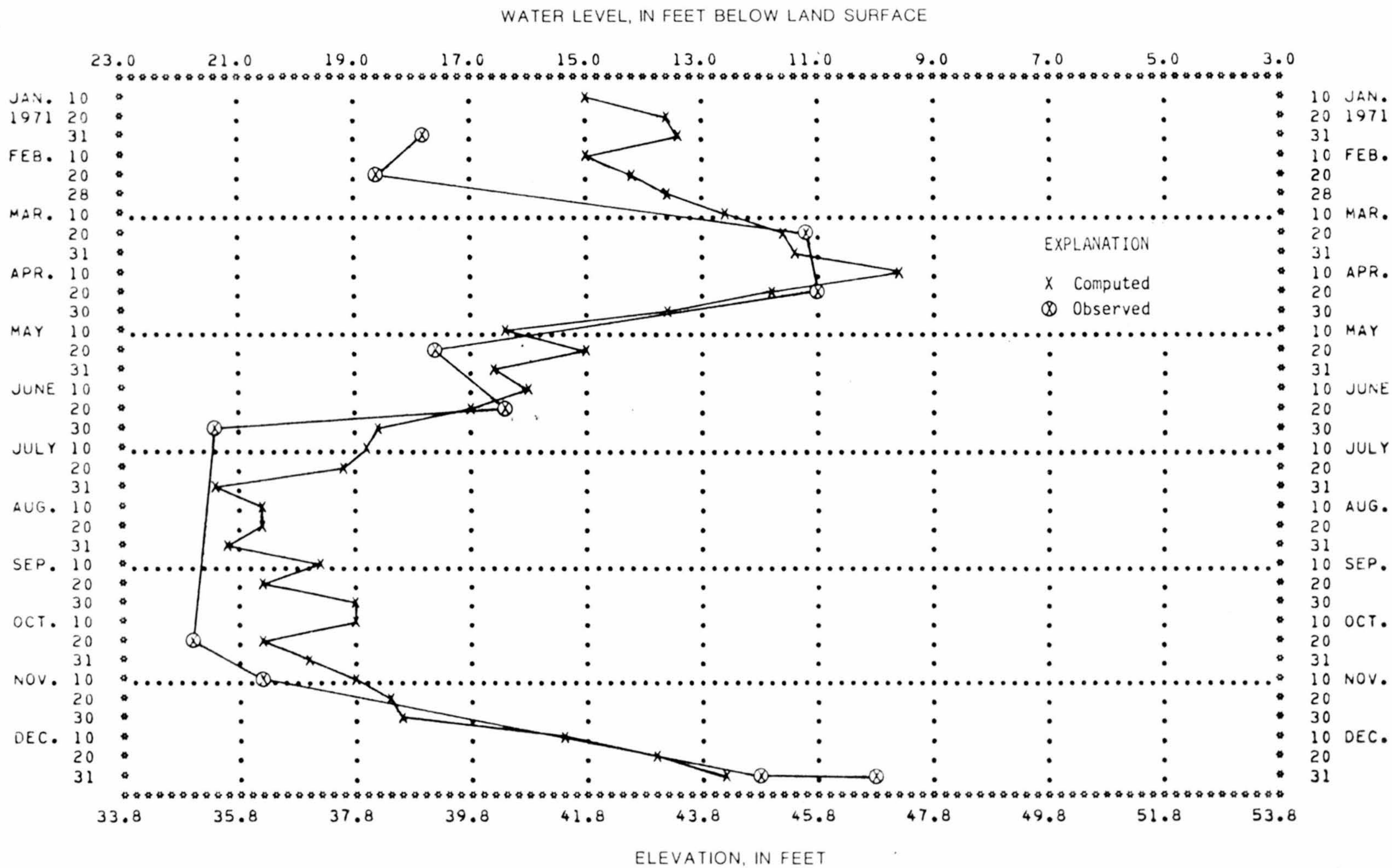

Figure 5.—Computed and observed preconstruction water-table hydrographs, well Av-326.

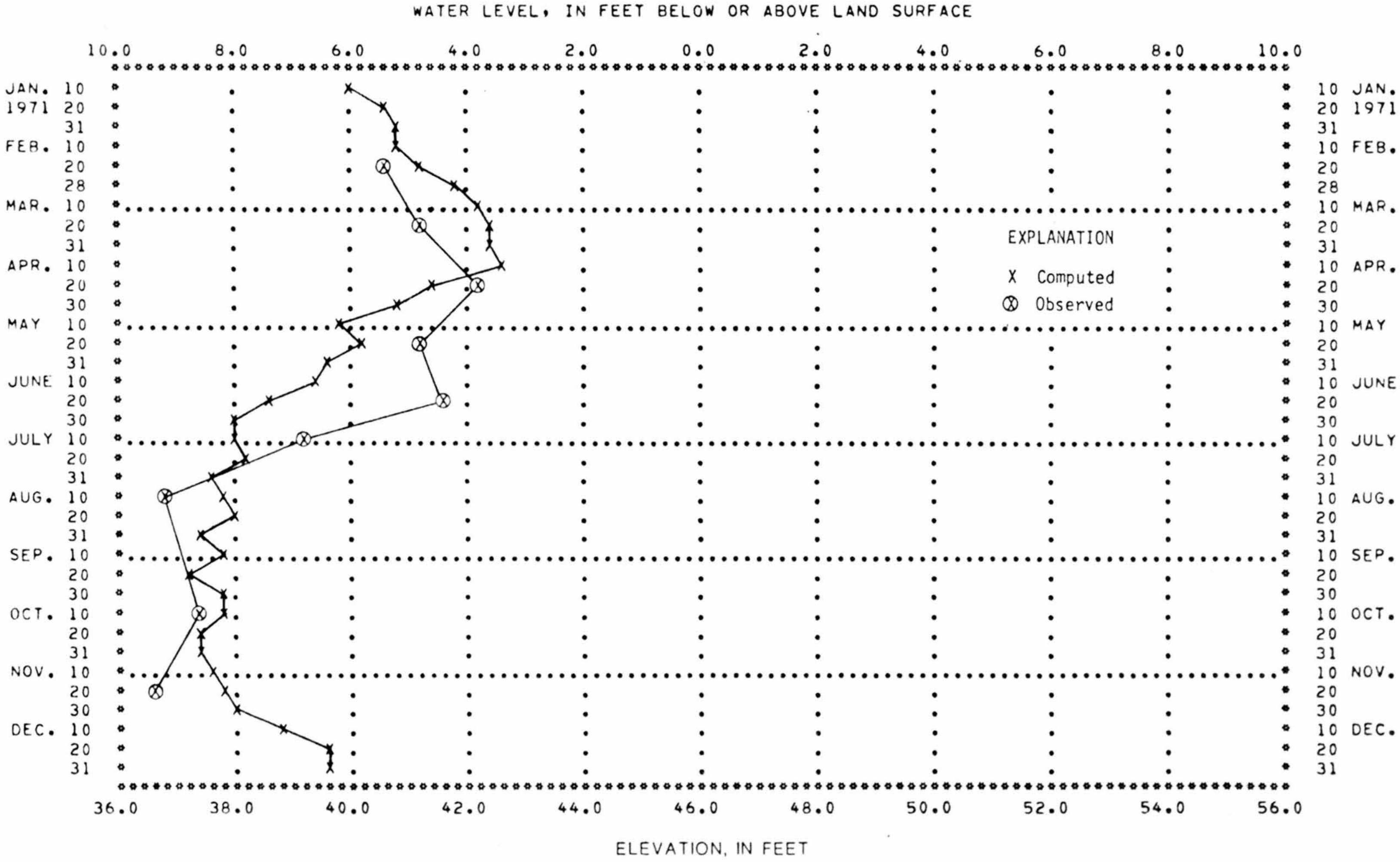

Figure 6.—Computed and observed preconstruction water-table hydrographs, well Av-337.

examples to show the characteristic cyclic pattern of annual water-table fluctuations. Observed water levels have also been plotted on the hydrographs to show the comparison between the water-level values computed in the model and those obtained from shallow piezometers at the respective well sites. The computed water level at the site of well Av-326, which is about 0.5 mi (0.8 km) from the river (pl. 1), fluctuates as much as 11.8 ft (3.6 m) annually. The computed water level at the site of well Av-337, about 4 mi (6.4 km) from the river (pl. 1), fluctuates about 5.2 ft (1.6 m) annually.

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 Av-326 and Av-337 (figs. 7 and 8) show, respectively, a representation of postconstruction conditions near and at a distance from the river. The hydrograph for the site of well Av-326 shows a water-table fluctuation of approximately 5.4 ft (1.6 m), ranging from 7.8 to 13.2 ft (2.4 to 4.0 m) below the land surface. By comparison, the observed hydrograph for preconstruction conditions at that site (fig. 5) shows a fluctuation of 10.8 ft (3 m) ranging from 11.0 to 21.8 ft (3 to 7 m) below the land surface. The computed postconstruction water table at the site of well Av-337 ranges from 2.6 to 8.2 ft (0.8 to 2.5 m) below the land surface. The observed preconstruction water table for the same location (fig. 6) ranges from 3.8 to 9.5 ft (1.2 to 2.9 m) below the land surface. The computed postconstruction water table at the site of well Av-337 is only slightly higher than the corresponding observed preconstruction values, an indication that the influence of the change in river stage has diminished to almost zero at that location.

SUMMARY

Lock and Dam 1 is to be located at mile 44 (kilometer 71), 1967 mileage, on the Red River; and the pool stage upstream from the dam will be at an elevation of 40 ft (12 m) above mean sea level. Construction of Lock and Dam 1 will cause a permanent average increase in the river stage of 9.0 ft (2.7 m) at the dam. As a result of the increased river stage, ground-water levels would be raised 1 ft (0.3 m) or more within a distance of 4 mi (6.4 km) from the river. The potentiometric surface may be near land surface in low-lying areas, and above land surface along the course of drainage features in the vicinity of the proposed damsite. Because of the attenuation in river stage caused by the formation of a pool upstream from Lock and Dam 1, the magnitude of ground-water-level fluctuations in wells near the river would be reduced to approximately half that of existing fluctuations. However, the water levels would be closer to the land surface.

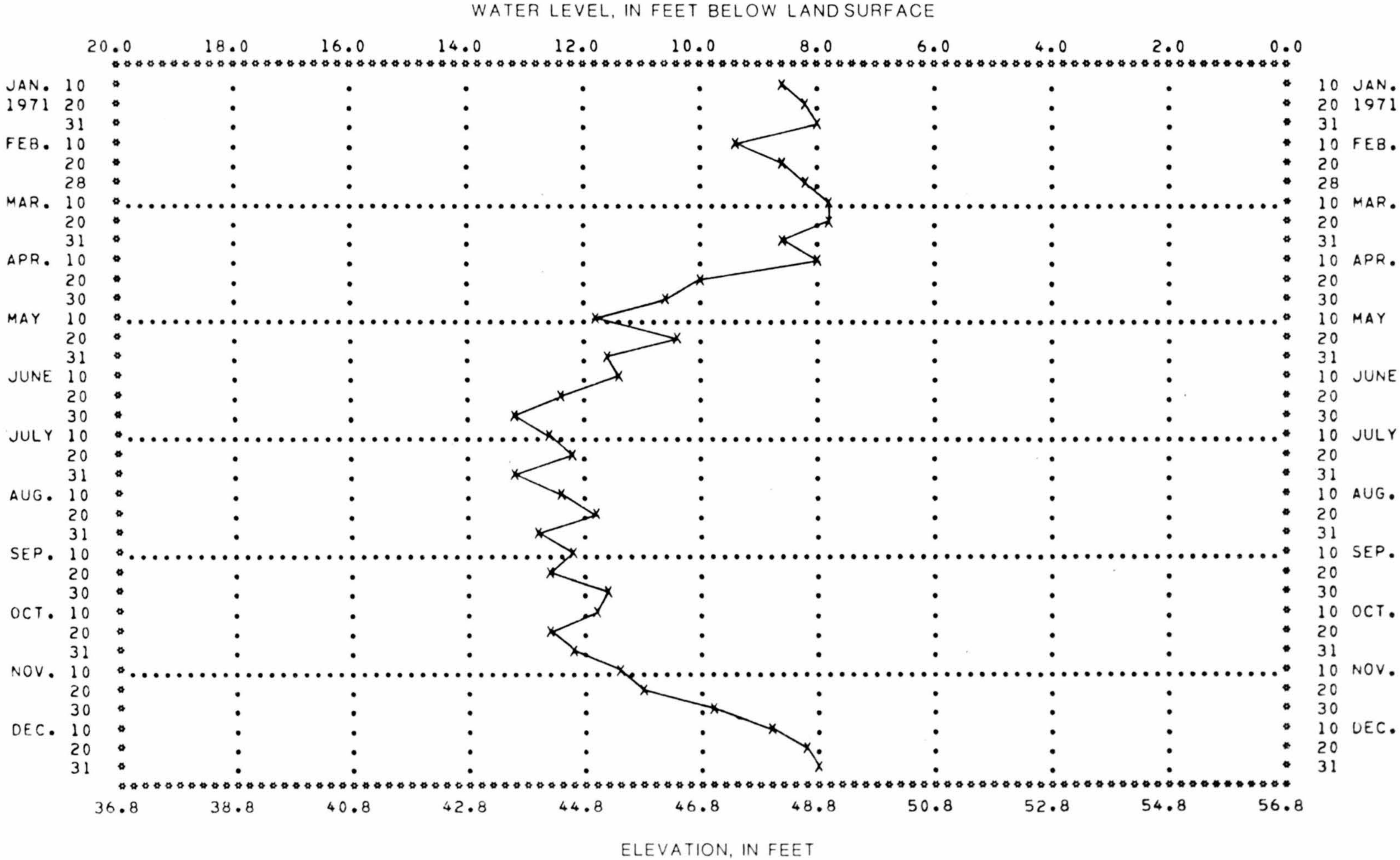

Figure 7.—Computed postconstruction water-table hydrograph, well Av-326.

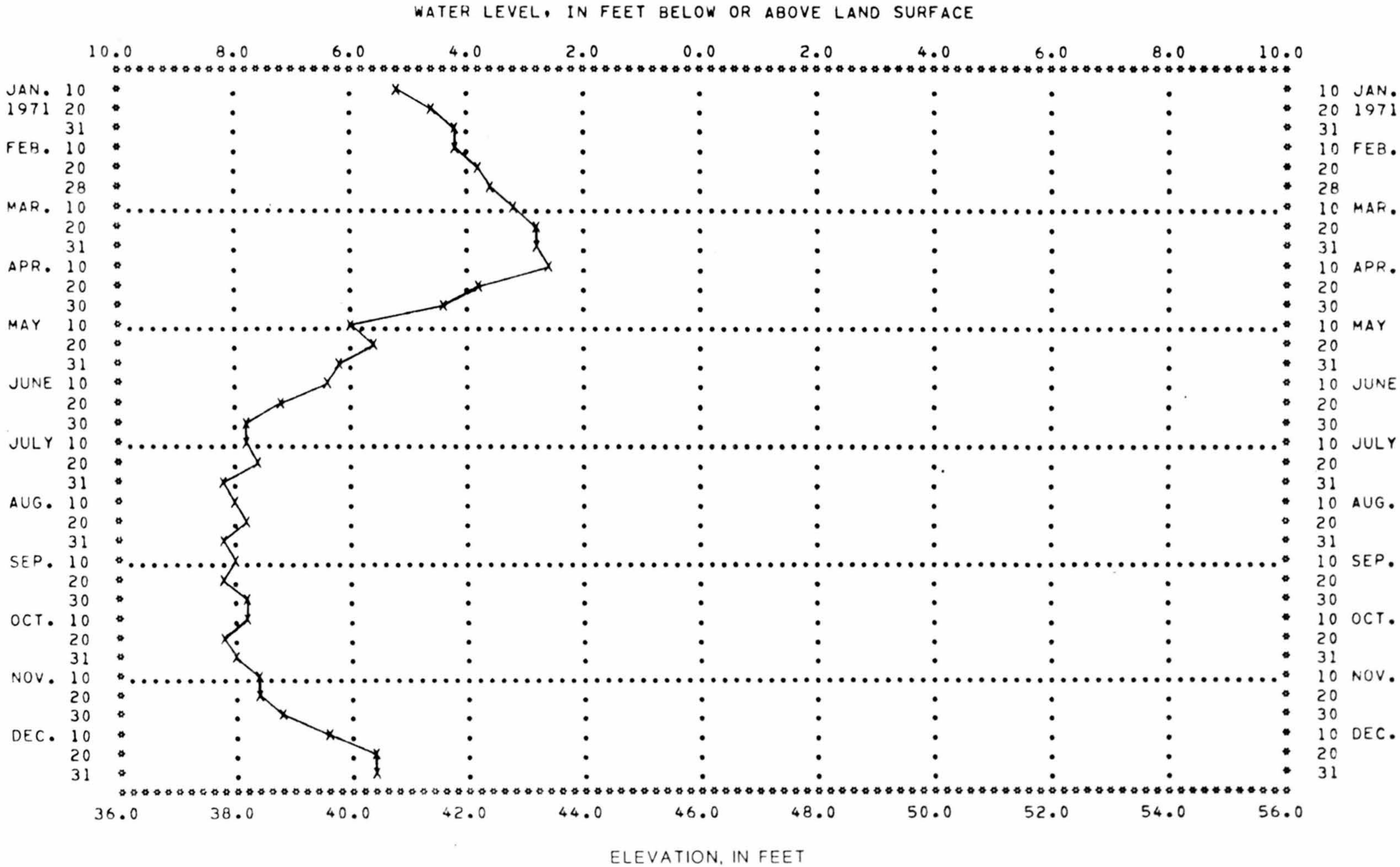

Figure 8.—Computed postconstruction water-table hydrograph, well Av-337.

SELECTED REFERENCES

Bedinger, M. S., Reed, J. E., and Griffin, J. D., 1973, Digital-computer programs for analysis of ground-water flow: U.S. Geological Survey open-file report, 85 p.

Bedinger, M. S., Reed, J. E., Wells, C. J., and Swafford, B. F., 1970, Methods and applications of electrical simulation in ground-water studies in the lower Arkansas and Verdigris River valleys, Arkansaw and Oklahoma: U.S. Geological Survey Water-Supply Paper 1971, 71 p.

Ludwig, A. H., 1974, Quality of water in the Red River alluvial aquifer, Shreveport, to the mouth of the Black River, Louisiana: U.S. Geological Survey open-file report, 7 p.

______1979, Preconstruction and postconstruction ground-water levels, Lock and Dam 2, Red River Valley, Louisiana: U.S. Geological Survey Open-File Report 79-919, 18 p.

Marie, J. R., 1971, Ground-water resources of Avoyelles Parish, Louisiana: Louisiana Department of Conservation and Louisiana Department of Public Works Water Resources Bulletin 15, 70 p.

Newcome, Roy, Jr., 1960, Ground-water resources of the Red River Valley alluvium in Louisiana: Louisiana Department of Conservation and Louisiana Department of Public Works Water Resources Pamphlet 7, 21 p.

Reed, J. E., Bedinger, M. S., and Terry, J. E., 1976, Simulation procedure for modeling transient water-table and artesian stress and response: U.S. Geological Survey Open-File Report 76-792, 173 p.

Stallman, R. W., 1956, Numerical analysis of regional water levels to define aquifer hydrology: American Geophysical Union Transactions, v. 37, no. 4, p. 451-460.

Stephens, J. W., 1976, Records of wells, water-level measurements, and drillers' logs, Red River Valley, Louisiana: U.S. Geological Survey Open-File Report 76-759, 335 p.