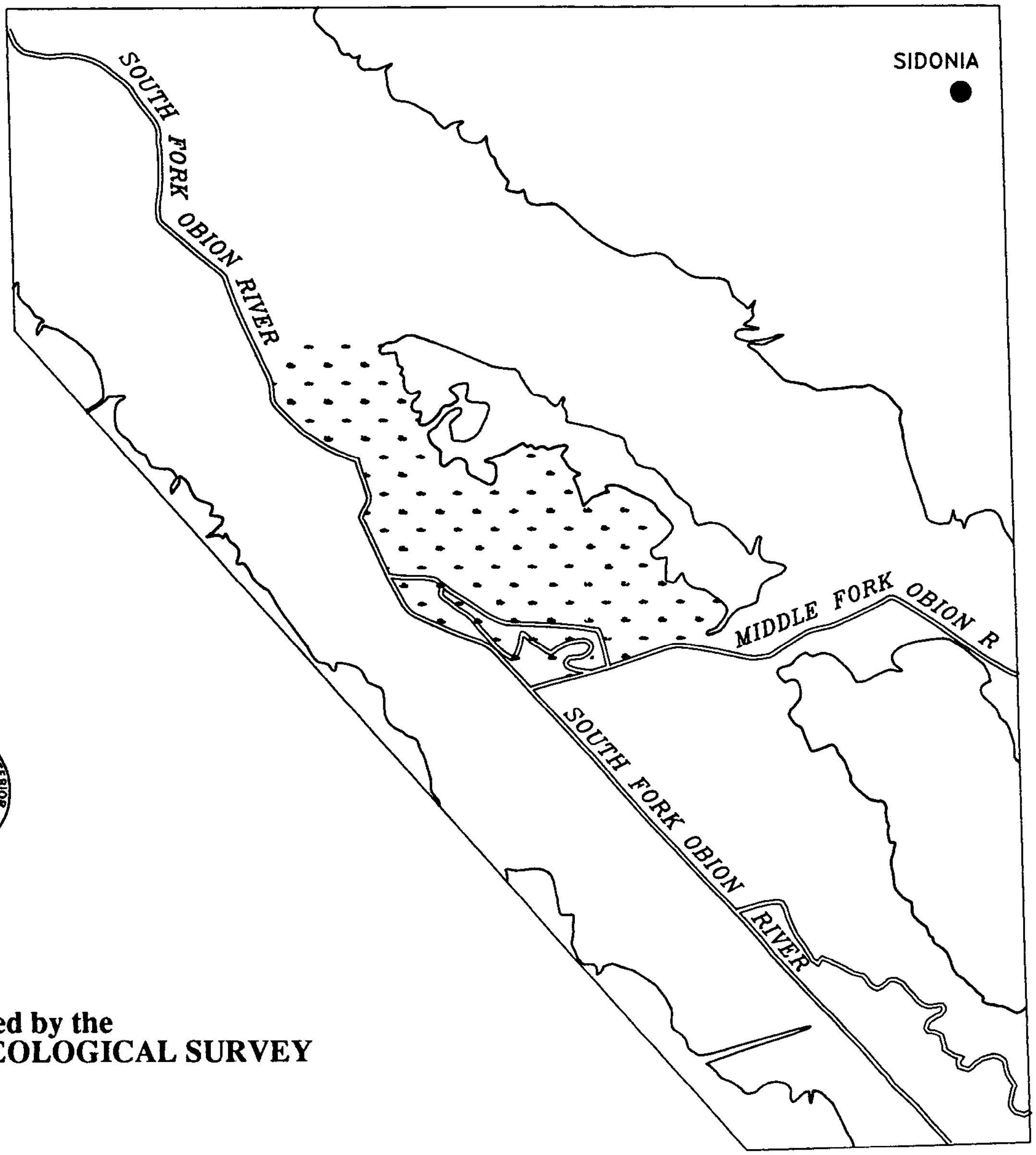
Water-Resources Investigations Report 90-4041

POTENTIAL EFFECTS OF DREDGING THE SOUTH FORK OBION RIVER ON GROUND-WATER LEVELS NEAR SIDONIA, WEAKLEY COUNTY, TENNESSEE



Prepared by the
U.S. GEOLOGICAL SURVEY

in cooperation with the
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION,
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By Patrick Tucci and Gregg E. Hileman

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	*By*	*To obtain*
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
foot squared per day (ft^2/d)	0.09290	meter square per day
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallons per minute (gal/min)	0.06308	liters per second
foot per mile (ft/mi)	0.1894	meter per kilometer

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The U.S. Army Corps of Engineers has proposed dredging an approximate 7-mile reach of the South Fork Obion River near Sidonia, Tennessee. This dredging will have an effect on ground-water levels in a wetland area near the river. The river cuts into a sandy aquifer that is confined by an overlying clay layer. Ground water in the confined aquifer flows from a ridge on the north side of the study area toward the river. Estimates of aquifer transmissivity range from 3,300 to 18,800 feet squared per day.

Assuming a 3-foot decline in stream stage due to dredging, the maximum decline in ground-water levels would be about 2.4 feet at low flow. Ground-water levels in the aquifer would decline by at least 2 feet at a distance of 0.5 mile from the river within 60 days after the change in stream stage, regardless of the assumed transmissivity value. Water-level declines in the upper clay layer probably would be much smaller. The time required for a specified change in ground-water level is dependent on the aquifer properties and distance from the river.

INTRODUCTION

The U.S. Army Corps of Engineers has proposed dredging an approximate 7-mile reach of the South Fork Obion River, about 3 miles southwest of Sidonia, Tennessee (fig. 1), to aid in flood control. In January 1988 the U.S. Geological Survey, in cooperation with the Tennessee Department of Health and Environment[1], Division of Water Pollution Control, began a 1-year study to determine the effects of the proposed dredging on the hydrology of the area. The purpose of the study was to determine the potential effects of dredging on:

1. Bankfull discharge and flow frequency,
2. Sediment erosion,
3. Channel erosion and deposition,
4. Bank stability,
5. Wetland hydroperiod (period in which a soil area is waterlogged), and
6. Ground-water levels.

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[1]Tennessee Department of Environment and Conservation as of late 1991.

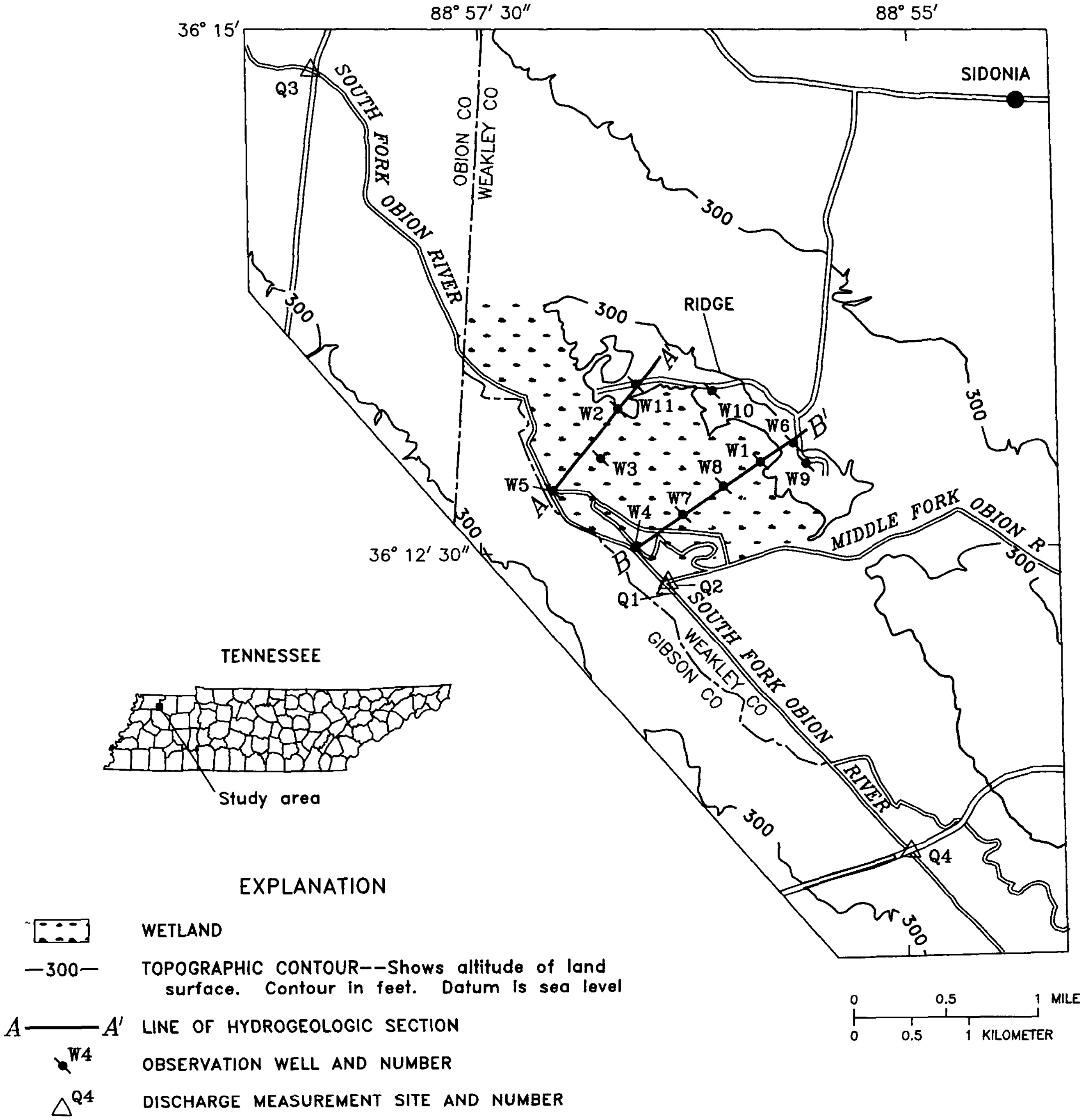


Figure 1.--Study area, observation wells, and discharge-measurement sites.

Purpose and Scope

This report assesses the potential effects of the proposed dredging on ground-water levels beneath a wetland bordered by the South Fork Obion River, the Middle Fork Obion River, and a small northwest-southeast trending ridge (fig. 1). Quantitive analysis of the effects of dredging on ponded water in the wetlands is beyond the scope of this report.

Data collected for this part of the study include lithologic information on subsurface materials, ground-water levels, and stage and discharge data for rivers adjacent to the wetland. Information on wells near the study area, and the regional geologic setting were obtained from published reports and well records.

Well Installation and Discharge Measurements

Eleven wells were installed in the wetland and on the ridge northeast of the wetland (fig. 1) to provide lithologic and water-level information for the study. The wells range in depth from 11 to 26 feet, and most wells were completed with 2-inch-diameter PVC (plastic) pipe attached to a 3-foot PVC well screen at the bottom. Most wells were installed with a hand auger; however, wells W9, W10, and W11 were installed with a conventional drill rig using hollow-stem augers. These three wells were completed with 4-inch-diameter PVC pipe and 5-foot-long PVC screen. All wells were packed with sand around the screen and casing to a level at or above the contact of a lower sand layer and an upper clay layer. About 0.5 foot of clay-rich cuttings were packed above the sand pack, and 1 to 2 feet of bentonite pellets were packed above the clay cuttings to seal the well screen near the top of the lower sand layer. The rest of the borehole annulus was packed to the surface with fine-grained cuttings.

Discharge was measured at three sites on the South Fork Obion River and at one site on the Middle Fork Obion River near its confluence with the South Fork (fig.1). The measurements were made during low-flow conditions (August 1988) to determine the base flow contribution to the South Fork Obion River. Stream stages were also measured at this time.

HYDROGEOLOGIC SETTING

The study area is within the Mississippi embayment of the Mississippi Alluvial Plain physiographic province, an area underlain by unconsolidated clastic sediments of Cretaceous to Quaternary age. Surficial deposits consist of stream alluvium in low-lying areas and loess on bluffs and ridges (Hardeman and others, 1966).

Within the study area, the deposits of interest consist of an upper clay layer (confining unit) and a lower sand layer (aquifer) (fig. 2). The upper layer consists of 7 to 21 feet of silty, sandy clay. Some organic material occurs within the clay layer in the wetlands. Locally, the upper layer is a uniform plastic clay, which may contain thin (less than 4 inches) lenses of sand. The deposits are mottled gray with local zones of red iron-staining and black organic matter.

The lower sand layer generally consists of rounded to well-rounded, fine- to medium-grained quartz sand. Silty or clayey sands are locally present in the lower layer. These deposits are light grey to yellowish brown. The thickness of the lower sand layer in the study area is not known, because the wells drilled for this study penetrated only the upper 5 feet of the layer. Records of wells near the study area indicate that the lower layer may be as much as 200 feet thick.

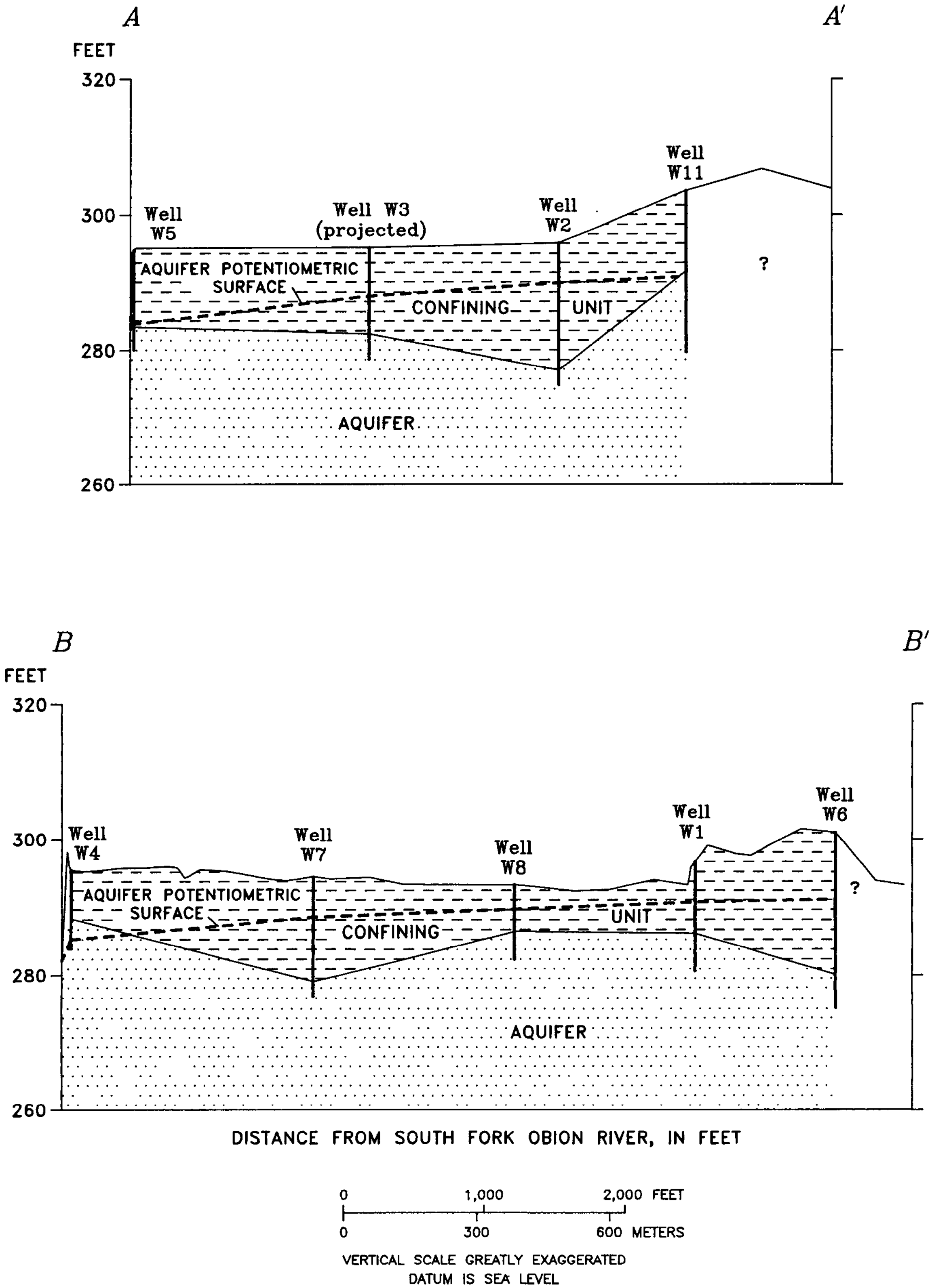


Figure 2.--Hydrogeologic sections A-A' and B-B'.

The potentiometric surface of the lower sand layer generally is above the base of the overlying fine-grained layer (fig. 2), so that this lower layer is considered a confined aquifer. The fine-grained confining layer impedes vertical ground-water movement to the lower sand aquifer. After intense rains and flooding, water is ponded and perched above the confining unit throughout the wetlands, and slowly drains and evaporates.

Ground water in the confined aquifer flows from the ridge south and west to the South Fork Obion River, and south and east to the Middle Fork Obion River (fig. 3). The South Fork Obion River is in direct contact with the upper part of the aquifer in the wetlands area. The average gradient of the potentiometric surface is about 9.8 ft/mi (1.9×10^{-3} ft/ft). Discharge measurements made on August 16, 1988, in a reach of the South Fork Obion River that includes the wetland area, indicate a net ground-water contribution to the river of 15 ft^3/s (fig.4), or 4.4 ft^3/s per river mile. Assuming that half of this contribution comes from each side of the river and given a river length of 1.1 miles adjacent to the wetland, the ground-water contribution to the river from the wetland was estimated to be about 2.4 ft^3/s on August 16, 1988. An estimate of transmissivity for the aquifer can be made using the equation

$$T = q/i \qquad (1)$$

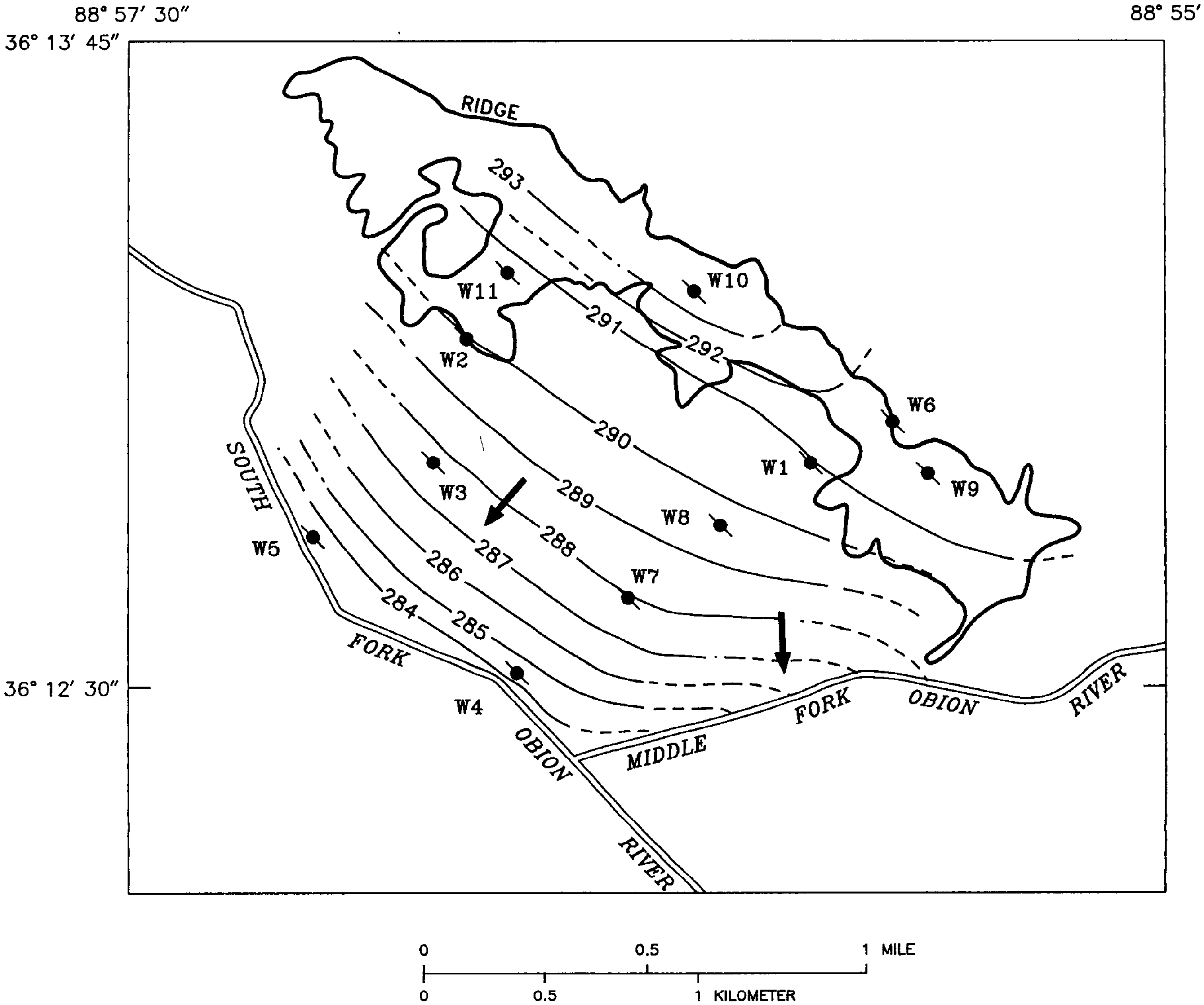
where T is transmissivity, in feet squared per day;
q is discharge, in cubic feet per day per foot of river length; and
i is the gradient of the potentiometric surface, in foot per foot;

Using $q = 35.7$ $(ft^3/d)/ft$ and $i = 0.0019$ ft/ft, transmissivity is estimated to be about 18,800 ft^2/d. This transmissivity value is probably a maximum estimate because steady-state conditions are assumed for this analysis. Water levels and streamflow may still have been recovering from rainfall 10 days prior to the data collection on August 16, 1988, so that steady-state conditions may not have been achieved by that date.

Analysis of specific-capacity tests of domestic wells surrounding the study area may also provide insights into the hydraulic characteristics of the confined aquifer. Specific capacities obtained from State records for 18 wells in the area range from 0.67 to 4.0 gal/min per foot of drawdown. Transmissivities estimated from these data using the method described by Brown (1963) range from 635 to 9,440 ft^2/d, and average 3,300 ft^2/d. These values are much lower than the maximum estimate based on streamflow and potentiometric gradients. Because the values from the specific-capacity analyses are based on well data that sample a larger vertical part of the aquifer, they are probably more representative of the entire aquifer.

Information concerning the hydraulic characteristics of the upper fine-grained layer are not available; however, hydraulic conductivity values of clays are typically 2 to 3 orders of magnitude less than those of sands (Davis and DeWiest, 1966, p. 164).

Although the South Fork Obion River gained 15 ft^3/s from the ground-water system in the reach downstream of the wetland area, the river lost 6 ft^3/s in the reach upstream of the wetland (fig. 4). This difference may be caused by slow drainage from the wetlands through the upper fine-grained layer, a lack of connection between the river and the aquifer in the reach upstream of the wetland, or measurement errors



EXPLANATION

—284— — WATER-LEVEL CONTOUR--Shows altitude of potentiometric surface. Dashed where approximately located. Contour interval 1 foot. Datum is sea level

RIDGE BOUNDARY--Topographic high where land surface altitude is 300 feet or more above sea level

W4 OBSERVATION WELL AND NUMBER

DIRECTION OF GROUND-WATER FLOW

Figure 3.--Potentiometric surface of confined aquifer and directions of ground-water flow, August 17, 1988.

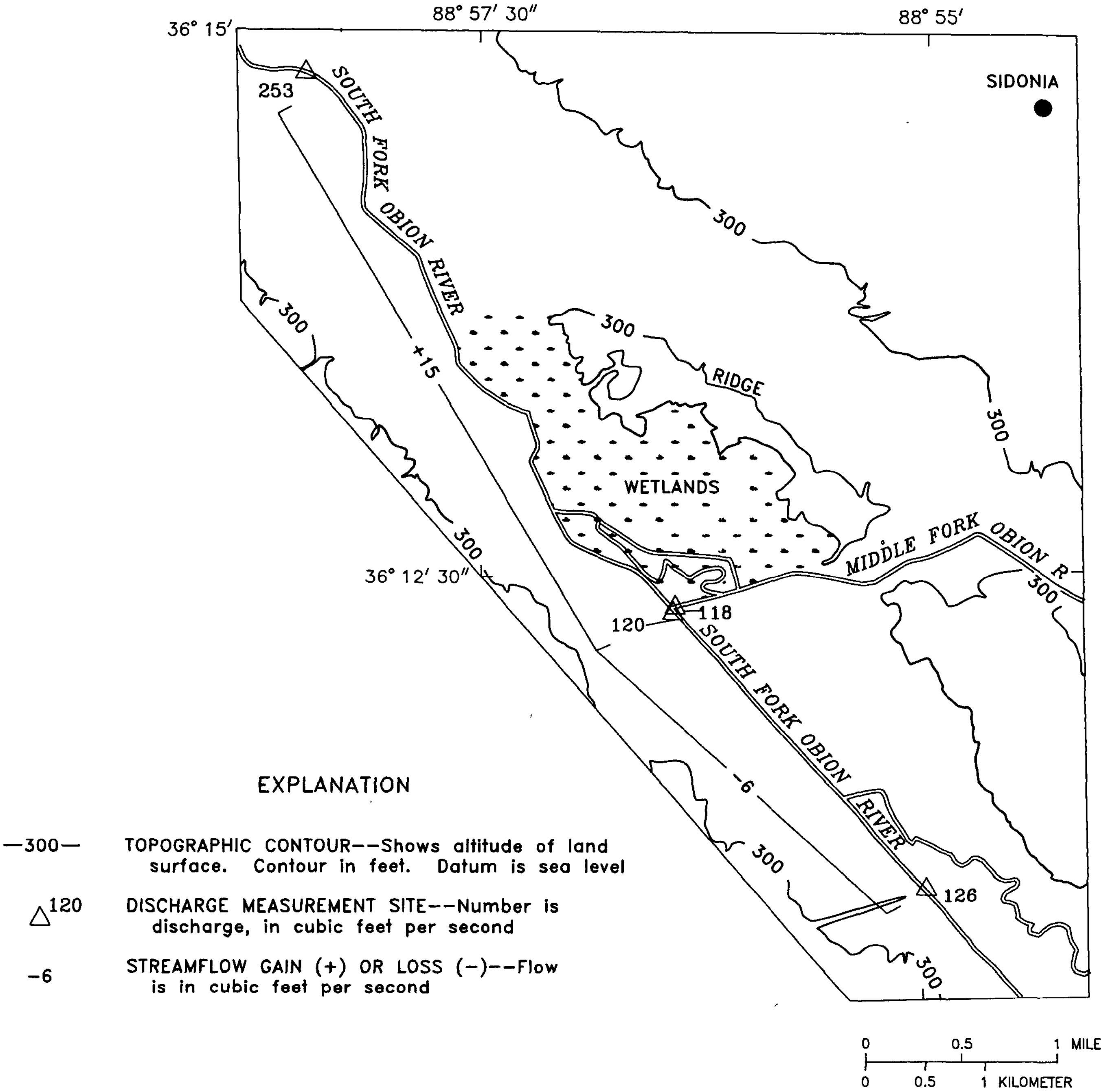


Figure 4.--Discharge measurements and streamflow gains and losses, August 16, 1988.

POTENTIAL EFFECTS OF DREDGING ON GROUND-WATER LEVELS

Plans for dredging of the South Fork Obion River included several options; however, this analysis considers only the effects of "full-channel" dredging. Full-channel dredging would lower the streambed by an average of about 3 feet in the study area, but would leave channel geometry about the same and would not realign the channel. For this analysis, average stream stage after dredging is assumed to be about 3 feet lower than the stage prior to dredging. This option and assumptions will result in the maximum lowering of ground-water levels in this analysis.

The method used to estimate the effects of dredging on ground-water levels is described by Bedinger and Reed (1964). In their analysis, a surface-water hydrograph is divided into a sequence of instantaneous changes separating steady stages of equal time duration. The effect of each unit duration of stream stage on ground-water level at a specified distance from the stream is analyzed separately. Changes in ground-water level are considered to be the algebraic sum of the effects of independent antecedent changes in stream stage.

The change in ground-water level for each segment of stream stage is calculated using a plot (fig. 5) of the ratio of change in potentiometric surface (s) to instantaneous change in stream stage (s_o) against the parameter $1/u^2$, where

$u^2 = x^2S/4Tt$;
x = distance from stream, in feet;
S = storage coefficient (unitless);
T = transmissivity, in feet squared per day; and
t = time, in days.

Changes in ground-water level are equal to about one half the change in stream stage ($s/s_o = 0.5$) when $1/u^2$ is about 5, and are about 70 percent of the change in stream stage ($s/s_o = 0.7$) when $1/u^2$ equals 16 (fig. 5). Under ideal conditions of infinitely large transmissivity and time, and infinitesimally small distance from the stream, the change in aquifer water level would be equal to the change in stream stage (3 feet). For all practical purposes, however, the maximum change in ground-water level is equal to about 80 percent of the change in stream stage ($1/u^2 = 36$, fig. 5).

In the present analysis, stream stage is assumed to decline instantaneously by 3 feet, resulting in a decline in maximum ground-water level of as much as 2.4 feet. The time over which ground-water levels decline is dependent on distance from the stream and aquifer properties. This analysis assumed uniform transmissivity values of the lower aquifer of 3,300 and 18,800 ft^2/d and a storage coefficient of 0.01, which is considered representative for the confined aquifer in the study area.

Values of $1/u^2$ were calculated for each well site for times of 1, 7, 30, 60, and 180 days from the assumed instantaneous drop in stream stage. Values of s/s_o were obtained from figure 5 for each calculated $1/u^2$ value. The change in ground-water level at each well site was then calculated by multiplying s/s_o by the change in stream stage (3 feet) and plotted on figure 6. Distances were measured from the nearest stream, assuming that a 3-foot change in stage of the South Fork Obion River will also result in a 3-foot change in stage of the Middle Fork Obion River.

In the lower aquifer, ground-water levels would decline by at least 0.5 foot after 7 days from the drop in stream stage at distances up to 3,000 feet from the streams, assuming a transmissivity value of 3,300 ft^2/d (fig. 6). Ground-water-level declines are greater (1.5 feet) at the same

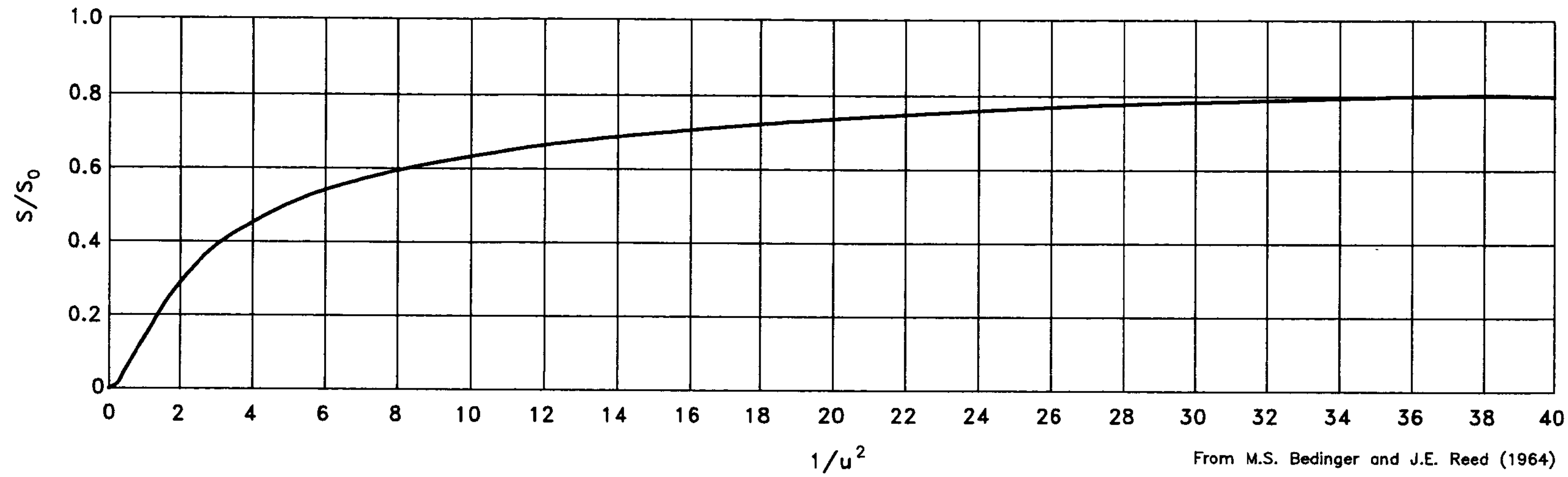


Figure 5.--Type curve of change in ground-water level to an instantaneous change in stream stage.

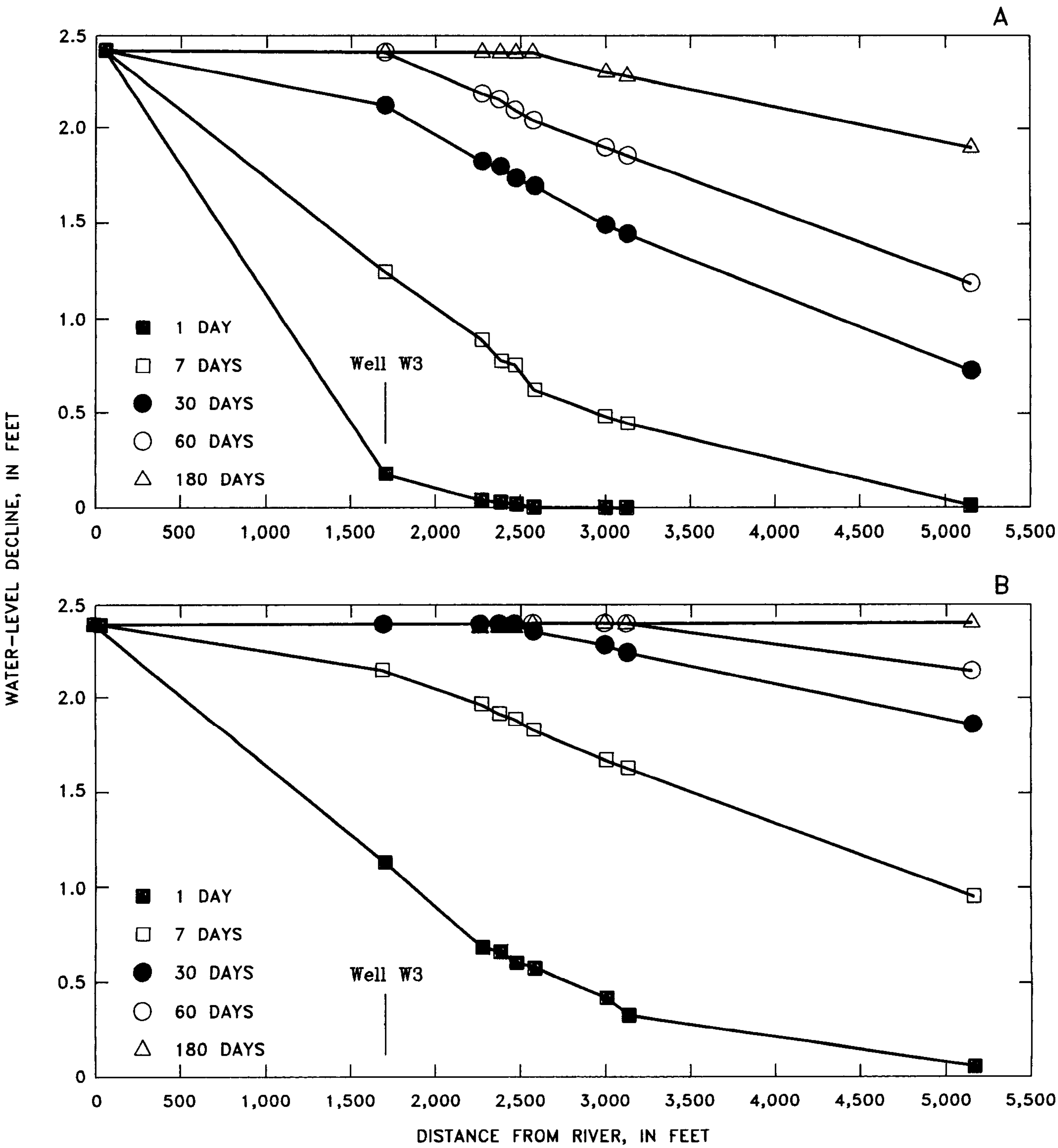


Figure 6.--Relation between calculated water-level declines and distance from the river for transmissivity values of (A) 3,300 and (B) 18,800 feet squared per day.

distance from the streams, assuming a transmissivity of 18,800 ft^2/d (fig. 6). After 30 days, ground-water levels would decline by 1.5 feet at distances of up to 3,000 feet from the streams, and by at least 2.0 feet at distances of more than 4,000 feet, assuming transmissivity values of 3,300 and 18,800 ft^2/d, respectively (fig. 6). After 60 days, ground-water levels would decline by nearly 2.0 feet within 0.5 mile of the streams for both assumed transmissivity values (fig. 6). Changes in ground-water levels at times greater than 60 days after the change in stream stage will probably be masked by natural fluctuations in hydrologic conditions, and are considered speculative after that time.

The calculated change in ground-water level is sensitive to the transmissivity and storage coefficient values used in the calculations. Calculated ground-water-level declines at any given distance from the stream are largest when the largest transmissivity value (18,800 ft^2/d) is used. Ground-water-level declines within the upper clay layer would probably be much less than those calculated for the lower sand aquifer because the transmissivity of the clay layer is probably two to three orders of magnitude less than the transmissivity of the sand. Overestimation of storage coefficient in the analysis will result in an underestimate of the water-level decline, particularly at early times. For example, calculated water-level decline at well W3 after 1 day, assuming $T = 18{,}800\ ft^2/d$ and $S = 0.01$, is about 1.2 feet (fig. 6); however, the calculated decline assuming $S = 0.001$ would be about 2.1 feet. Similarly, underestimation of storage coefficient will result in an overestimation of ground-water-level decline.

Dredging at the South Fork Obion River should reduce the frequency of overbank flooding in the wetland adjacent to the river (C.R. Gamble, U.S.Geological Survey, written commun., 1989). This reduced flood frequency will have little effect on water levels in the aquifer because most discharge from the fine-grained confining unit is by evapotranspiration rather than leakage to the underlying aquifer.

SUMMARY

The U.S. Army Corps of Engineers has proposed dredging an approximate 7-mile reach of the South Fork Obion River near Sidonia, Tennessee. This dredging will have an effect on ground-water levels in a wetland area near the river. To help evaluate the effects of dredging on ground-water levels, 11 wells were installed for lithologic and water-level information, and streamflow was measured at 4 sites.

The study area is underlain by an upper clay layer and a lower sandy aquifer. The aquifer is confined by the overlying clay layer; however, the river cuts through the clay layer and into the sand aquifer. The clay layer impedes vertical ground-water movement, so that after intense rains or flooding, water is ponded and perched throughout the wetlands. Ground-water flow in the confined aquifer is from the ridge on the north side of the study area to the rivers. Estimates of transmissivity of the lower aquifer range from 3,300 to 18,800 ft^2/d. Transmissivity values for the clay layer are not available, but are probably two to three orders of magnitude less than those in the sand. Streamflow measurements made during low-flow conditions of August 1988 indicate that the South Fork Obion River was a gaining stream downstream of the confluence with the Middle Fork Obion River, but was a losing stream upstream of the confluence.

An analytical method was used to calculate the potential effects of dredging on ground-water levels. This method was based on the assumption of an instantaneous 3-foot change in stream stage, a storage coefficient of 0.01, and transmissivity values of 3,300 and 18,800 ft^2/d for the lower aquifer. For all practical purposes, the maximum decline in ground-water levels would be about 2.4 feet. Ground-water levels in the lower aquifer would decline by at least 2 feet, regardless of the assumed transmissivity value, 60 days after the change in stream stage, within

0.5 mile of the streams. Water-level declines in the upper clay layer probably would be much smaller. The time required for a specified change in ground-water level is dependent on the aquifer properties and distance from the river.

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