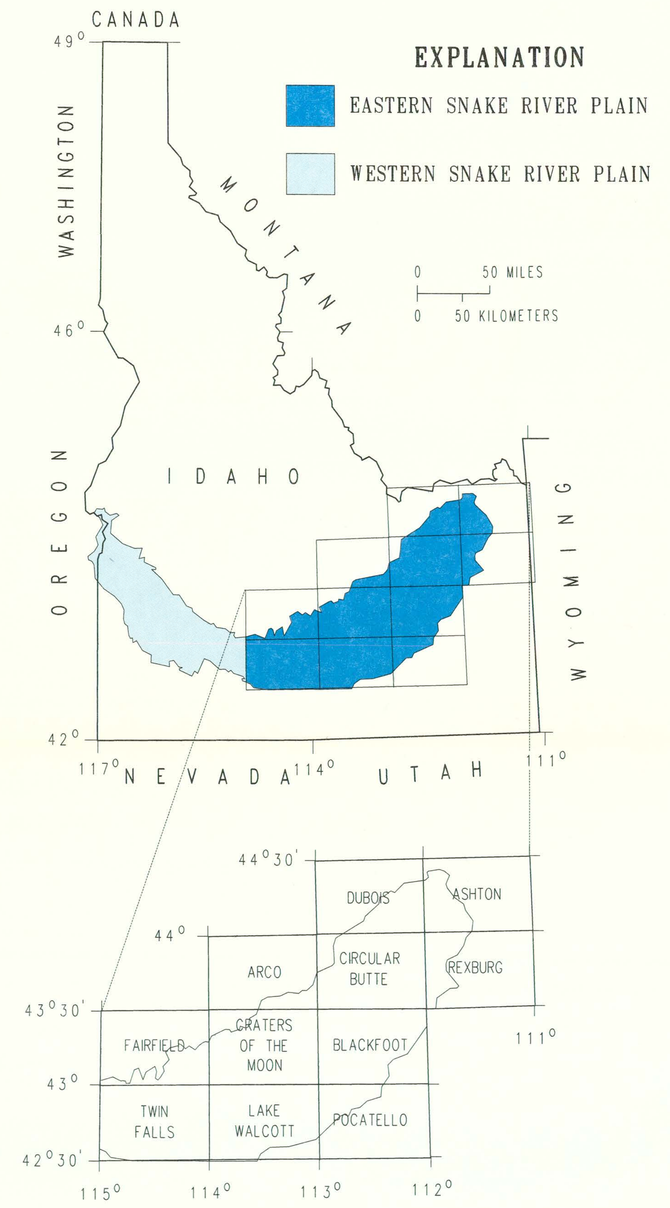

Figure 1.—Location of study area and index to 1:100,000-scale quadrangles.

CONVERSION FACTORS

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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

INTRODUCTION

The vulnerability of ground water to contamination in Idaho is being assessed by the IDHW/DEQ (Idaho Department of Health and Welfare, Division of Environmental Quality), using a modified version of the Environmental Protection Agency DRASTIC methods (Allers and others, 1985). The project was designed as a technique to: (1) Assign priorities for development of ground-water management and monitoring programs; (2) build support for, and public awareness of, vulnerability of ground water to contamination; (3) assist in the development of regulatory programs; and (4) provide access to technical data through the use of a GIS (geographic information system) (C. Grantham, Idaho Department of Health and Welfare, written commun., 1989).

A digital representation of first-encountered water below land surface is an important element in evaluating vulnerability of ground water to contamination. Depth-to-water values were developed using existing data and computer software to construct a GIS data set to be combined with a soils data set developed by the SCS (Soil Conservation Service) and the IDHW/WQB (Idaho Department of Health and Welfare/Water Quality Bureau), and a recharge data set developed by the IDWR/RSF (Idaho Department of Water Resources/Remote Sensing Facility). The USGS (U.S. Geological Survey) developed digital depth-to-water values for eleven 1:100,000-scale quadrangles on the eastern Snake River Plain and surrounding tributary valleys.

PURPOSE AND SCOPE

This report illustrates the digitally generated depth-to-water zones for eleven 1:100,000-scale quadrangles on the eastern Snake River Plain in southeastern Idaho. The values that make up the zones were generated using water-level altitudes, land-surface altitudes, and selected computer software. The 11 quadrangles cover about 19,800 mi^2 and include the Arco, Ashton, Blackfoot, Circular Butte, Craters of the Moon, Dubois, Fairfield, Lake Walcott, Pocatello, Rexburg, and Twin Falls quadrangles (fig. 1).

AREA OF STUDY

The eastern Snake River Plain, encompassing nearly 10,800 mi^2 in southern Idaho, is a structural downwarp composed of several thousand feet of Quaternary basalt flows with interflow zones and interbedded layers of gravel, sand, silt, and clay (fig. 1). The plain is underlain by the Snake River Plain aquifer, which is a major source of water for agricultural, industrial, municipal, and domestic uses. The eastern Snake River Plain is bordered by mountains to the north and south that range in altitude from about 7,000 to 12,000 ft above sea level. The Snake River flows along the southern border of the plain and drains the entire area (Lindholm, 1986, p. 88). Ground-water movement in the eastern Snake River Plain is from northeast to southwest except near the Snake River and along the edges of the plain (Lindholm and others, 1988).

Tributary valleys within the study area cover almost 2,200 mi^2. The valleys are underlain by alluvial sediments with some basalt flows, predominantly where the valleys meet the eastern Snake River Plain. Ground water is mostly unconfined; some confining conditions exist where local clay lenses are present. Most water use is for domestic, stock, and irrigation purposes. Ground water in the tributary valleys generally flows down the valleys toward the eastern Snake River Plain. Mountainous areas, for which no depth-to-water data were available, cover nearly 6,800 mi^2.

Mud Lake is a shallow topographic depression in the northern part of the eastern Snake River Plain. The Mud Lake area is agricultural and many shallow (less than 200 ft deep) wells are used for irrigation. Several streams that originate in the Beaverhead and Centennial Mountains supply water to the area. The Mud Lake area is underlain by alluvium and lake deposits that overlie basalt of the Snake River Group. North and northeast of Mud Lake, basalt is at or near land surface and is the chief aquifer. South of Mud Lake, saturated gravel, sand, and clay grade to silt and clay (Stearns and others, 1939, p. 50-52; Crosthwaite, 1973, p. 6; Johnson and others, 1984, p. 8-11). A north-, northwest-trending band of sediments transects the Mud Lake area and impedes ground-water flow, which is generally in a southwesterly direction.

ACKNOWLEDGMENTS

The IDHW/DEQ coordinated and supported the cooperative efforts between the USGS, the SCS, the IDHW/WQB, and the IDWR/RSF in the development of data sets for assessment of areas where ground water is potentially vulnerable to contamination.

DEVELOPMENT OF MAP

Data from 1-degree DEM's (Digital Elevation Models) and the GWSI (Ground-Water Site Inventory) data base maintained by the USGS were used to construct a grid and a data set for each quadrangle. DEM's provided the land-surface-altitude data and GWSI provided well data from which wells were chosen to best represent ground-water conditions from 1980 to 1988. Universal kriging software was used to estimate water-table altitudes for first-encountered water at grid intersections for the eastern Snake River Plain. ARC/INFO[1] was used to estimate water-table altitudes for first-encountered water at grid intersections for the surrounding tributary valleys. Depth to water was calculated by subtracting water-table altitudes from land-surface altitudes at the grid intersections. All depth-to-water values and corresponding locational attributes then were loaded into ARC/INFO and contoured to depict the depth-to-water zones.

[1]Use of trade names in this publication is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

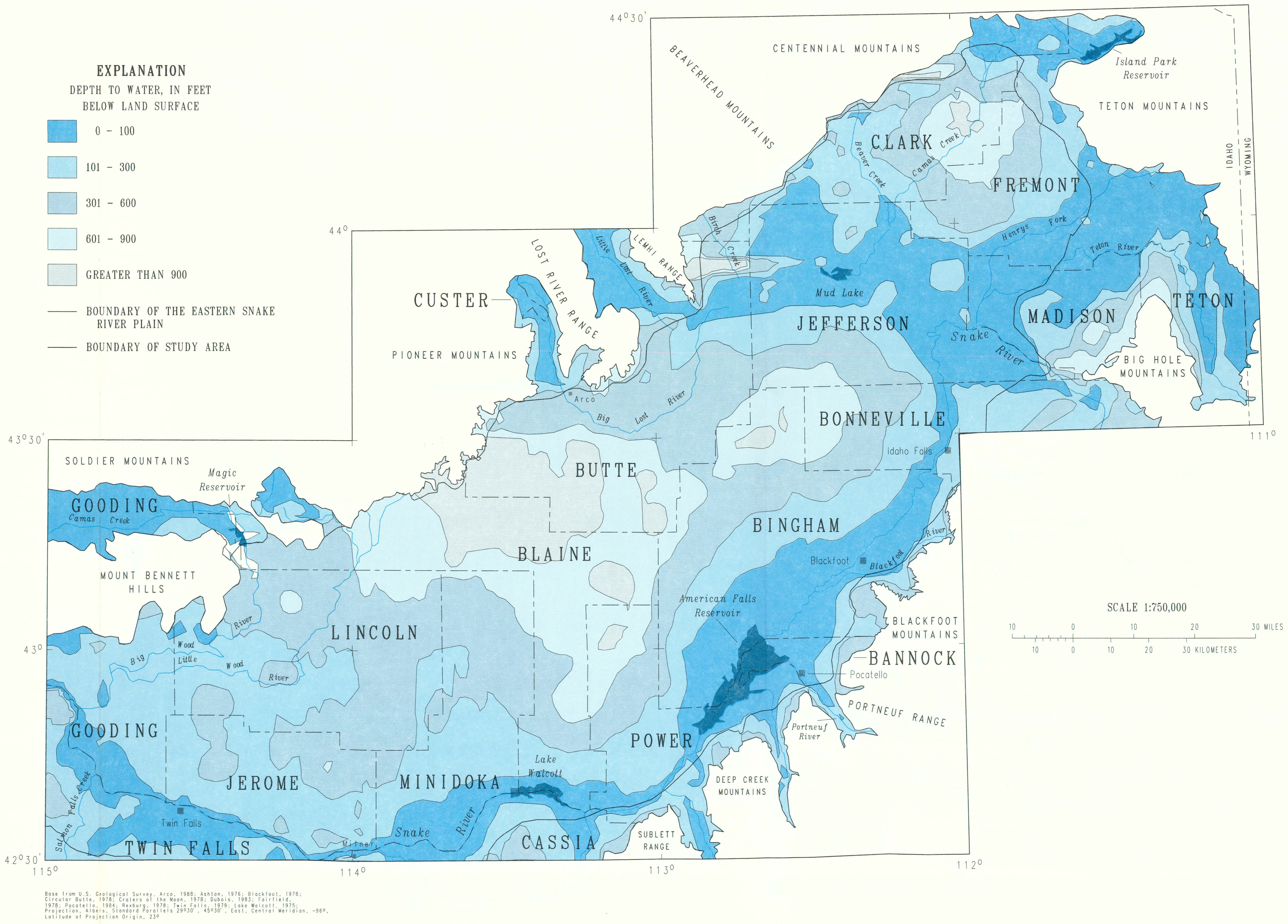

Figure 3.—Depth-to-water zones.

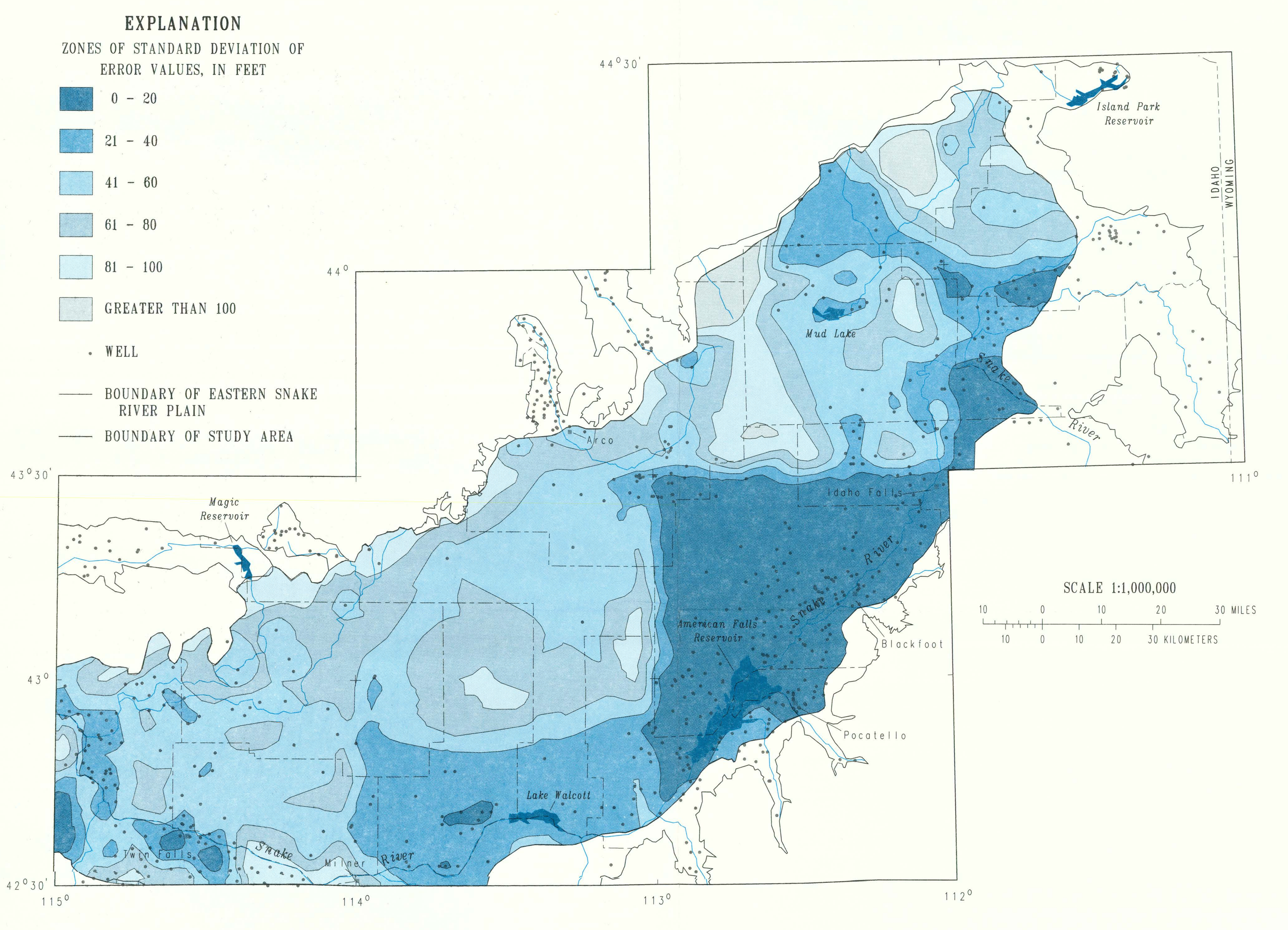

Figure 2.—Zones of standard deviation of error values and locations of wells used for analysis.

SOURCE AND DEVELOPMENT OF DATA

A DEM is an array of altitude values representing ground positions at regularly spaced intervals. DEM's are created by the Defense Mapping Agency and are reformatted and distributed by the USGS. One-degree DEM's are referenced horizontally on the geographic coordinate system (latitude/longitude) of the World Geodetic System of 1972 Datum (U.S. Geological Survey, 1987, p. 1, 5).

The DEM's were used to construct a grid of land-surface altitudes; water-table altitudes were estimated at grid intersections. Grids were constructed by splitting 1-degree DEM's into eleven 1:100,000-scale quadrangles and reducing the number of altitude points to one per square mile.

Well data were acquired from the GWSI data base, which is maintained on the USGS Idaho District Prime computer in Boise, Idaho. Data in GWSI include location, depth, altitude, and water levels of wells. All wells in the study area for which total depth of well, land-surface altitude, and water levels for the period 1980 to 1988 were available were identified from the GWSI data base. Only wells with water-level data for this period were used for analysis.

The data were refined additionally to develop a data set that best represented water-table conditions. Artesian wells were excluded from the data set to avoid false representation of the water table. An artesian well is one that penetrates an artesian, or confined, aquifer, and in which the water level stands above the top of the aquifer it taps. If these wells had not been eliminated from the data set, their high water levels would have erroneously increased the estimated water-table altitudes and created a more shallow depth-to-water value than was actually present. Wells with known total depths were selected so that water levels from wells of unknown depths were not integrated with water levels from wells of known depths. This process was necessary to accurately map first-encountered water. No attempt was made to exclude wells completed in perched-water zones. Therefore, the well-selection process excluded the ability to distinguish a shallow ground-water system from a deep ground-water system.

March water levels were selected because at that time the water table is relatively stable and less affected by water use than at other times of the year. March water levels also represent most of the available data because mass water-level measurements on the Snake River Plain are made in early spring. If more than one March water-level measurement in the last 8 years was available for a well, the shallowest water-level measurement was selected. Where few data were available, a water level from January through April was selected. Water-level measurements were converted to water-level altitudes in feet above sea level to relate measurements to a standard datum.

To develop a depth-to-water map representing first-encountered water, the shallowest representative wells were selected. Wells 100 ft deep or less were selected first from the data set, and deeper wells within 1 mi or less of a selected well were deleted. If there was more than one well 100 ft deep or less within 1 mi, all wells within that area were retained and water-table altitudes were examined and deleted as necessary. Where there were no wells 100 ft deep or less, wells 101 to 300 ft deep were selected from the data set and deeper wells were deleted. This process was repeated until no wells remained to select from. The total number of wells selected within each depth range is shown in table 1.

Table 1.—*Ranges of well depths and number of wells used for analysis*

Total depth of well, in feet below land surface	Total number of wells used for analysis
1 to 100	358
101 to 300	284
301 to 600	87
601 to 900	62
901 and greater	6

SELECTION AND APPLICATION OF SOFTWARE

Universal kriging was the statistical technique used to estimate water-table altitudes at grid intersections from measured water levels for irregularly spaced selected wells. Kriging is a two-step process in which data measurements are used to determine a mathematical definition for a semi-variogram. The semi-variogram was used to generate estimated water-table altitudes at the supplied grid intersections (Skrivan and Karlinger, 1980, p. 2-3). The semi-variogram is a diagram of the irregularity of the difference of the data measurements compared to the distance between the data points (Dunlap and Spinazola, 1984). Unlike other interpolation methods, kriging provides an SDE (standard deviation of error), or a square root of the variance, for each estimated water-table altitude (fig. 2). Low SDE values signify a greater confidence than high SDE values. If SDE values are low, estimated water-table altitudes are closer to actual water-table altitudes than if SDE values are high.

The ARC/INFO GIS software consists of a spatial data base and the associated tabular data. Each data set developed has directories of files that define the data set and the associated tabular data. Associated tabular data consist of attributes such as locational information, well depth, water levels, and SDE values. ARC/INFO contains software capable of editing, plotting, estimating, and contouring.

The methods of combining software and data to estimate the water-table altitudes for the eastern Snake River Plain were different from the methods used for the surrounding tributary valleys. The universal kriging method could not be used to estimate the water-table altitudes for the surrounding tributary valleys in an acceptable manner because of the shallow ground-water conditions and the elongate nature of the valleys. The estimating and contouring capabilities of ARC/INFO were used because they were capable of supplying more reasonable values over a larger area.

Well data from adjoining quadrangles were incorporated into each kriging operation to improve estimates along quadrangle boundaries. Depth-to-water values were calculated as the difference between land-surface altitudes and kriged water-table altitudes. If negative depth-to-water values were calculated at grid intersections that did not intersect with water bodies, the SDE values were used to recalculate the depth-to-water values below land surface. If depth-to-water values still remained negative, the kriging program was rerun and a new semi-variogram was developed.

Selected wells for the tributary valleys were organized into an ARC/INFO data set with three-dimensional and spatial qualities. Water-table altitudes represented the z axis; latitudes and longitudes represented the x and y axes. Estimations of water-table altitudes at supplied 1-mi^2 grid intersections were facilitated by an inverse weighted distance nine-neighbor algorithm. This was the preferred ARC/INFO method for estimating regularly spaced water-table altitudes for a surface with irregular hydrologic characteristics. Depth-to-water values were calculated by subtracting water-table altitudes from land-surface altitudes for all grid intersections within the tributary valleys.

ARC/INFO-estimated water-table altitudes within tributary valleys were reasonable and acceptable. Estimations of water-table altitudes where tributary valleys join the eastern Snake River Plain were compatible with kriged water-table altitudes. One difference between the two methods is that ARC/INFO does not generate SDE values. Another difference is that universal kriging is an exact interpolator of well data at grid intersections, whereas ARC/INFO is not.

After depth-to-water values for all the study area were calculated, they were combined into a single ARC/INFO data set and contoured. Corresponding attributes such as SDE values were added to the data set and contoured. Depth-to-water zones were generated from the contours and shaded in figure 3.

DEPTH-TO-WATER ZONES

In the eastern Snake River Plain, water is less than 100 ft below land surface along the Snake River, near Mud Lake, and in the central parts of tributary valleys along streams or rivers. Continuous agricultural activity along the Snake River has created an elevated water table near the river where sediments are thick. In the Mud Lake area, depth to water is least toward the northeast and greatest toward the southwest. The band of sediments that forms a barrier to ground-water flow south of Mud Lake causes a flattening of water-table gradients toward the northeast. Depth to water increases sharply over the barrier as ground water cascades to a deeper hydrologic system (Mundorff and others, 1964, p. 133; Johnson and others, 1984, p. 13, 15). Many wells in the central parts of tributary valleys are shallow and are completed in alluvial sediments.

Depth to water increases from 101 to 300 ft below land surface with increasing distance from the Snake River and with increasing distance from the streams or rivers in tributary valleys. Land use in the 101-to-300-ft zone is irrigated agriculture. In that zone, wells 100 ft deep or less did not meet selection criteria; therefore, wells 101 to 300 ft deep were used.

Along the margins of the plain and surrounding mountainous areas, depth to water generally ranges from 301 to 600 ft below land surface. In these zones, water-table altitudes are poorly defined because of the lack of data and factors that were not considered in the kriging process, such as recharge, land-surface altitudes, and depth to bedrock. Therefore, indicated depth to water may be the result of changes in water-table altitude, land-surface altitude, or both.

In the central part of the plain, such as in the areas included in the Craters of the Moon quadrangle and in the southern part of the Circular Butte quadrangle, water is generally greater than 600 ft below land surface. These areas are covered mostly by thick basalt flows and are not cultivated or densely populated. Wells in these areas are few and deep and are completed in the Snake River Plain regional aquifer system.

Because many water-level measurements were available for the Pocatello and Blackfoot quadrangles, SDE values for these quadrangles were low (less than or equal to 20 ft). SDE values in the Circular Butte and Craters of the Moon quadrangles were greater (fig. 2) because there were considerably fewer data points in these quadrangles.

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DEPTH TO WATER IN THE EASTERN SNAKE RIVER PLAIN AND SURROUNDING TRIBUTARY VALLEYS, SOUTHEASTERN IDAHO, CALCULATED USING WATER LEVELS FROM 1980 TO 1988

By
Molly A. Maupin
1991