STATSGO (State Soil Geographic Database) and SOILS-5 databases developed by the Soil Conservation Service. The Recharge layer varied significantly from DRASTIC because it incorporated irrigation practices as the largest contributor to recharge because of the typically low precipitation in the Snake River Plain. It too was developed at a much more detailed level than that used by DRASTIC. The depth-to-water layer is different from that used in DRASTIC because this project used water level information from over 1200 wells, and generated the layer using a statistical KRIGING package and computer contouring techniques. All three layers used different point rating systems, and were rated relative to each other differently than DRASTIC. This project also varied from DRASTIC in its use of a GIS, which allowed spacial analysis and advanced computer-aided mapping techniques during development of the vulnerability maps. DRASTIC was generated through standard cartographic techniques.

The Vulnerability Project did not develop layers for the vadose zone, aquifer media, hydraulic conductivity, and topography. The vadose zone was not developed because it was not cost effective to build that data layer using existing data sources. However, the vadose zone layer is believed to be a crucial layer in susceptibility assessment, and much emphasis will be focused on developing this layer in the future. The aquifer media and hydraulic conductivity layers were not developed because it was not cost effective to build the layers, and it was believed that available sources of information were not of high enough quality. The topography layer was not developed because data were not readily available to develop this layer in a cost effective manner, and because it was believed this layer is not as important in ground water susceptibility determination and hence received a lower priority for development. Depending on funding levels and available resources, all of these layers may be developed in the future.

DESCRIPTION OF DATA LAYERS

The following is an in-depth description of the depth-to-water, recharge, and soils data layers used by the Idaho Ground Water Vulnerability Project for the Snake River Plain study area.

1) Depth-to-water

a) Introduction

Evaluation of the depth to first-encountered water below land surface is a significant element in evaluating susceptibility of ground water to contamination, because areas where the ground water is close to the surface typically have a higher

probability for ground water contamination. The Project took the most conservative approach and mapped first-encountered water because these are the first resources to be potentially impacted. The Project made no distinction as to whether the first-encountered water was in small, perched aquifers or deeper regional aquifers. Many of the domestic drinking water wells in the Snake River Plain are constructed in the shallowest aquifers, which adds to the importance of mapping first-encountered water. Depth-to-water values were developed by the USGS (Maupin, in press-a; Maupin, in press-b) using existing data and software to construct a GIS data set (Figure 2). The values that make up the zones were generated using water-level altitudes, land-surface altitudes, and selected computer software. This section on depth-to-water was extracted from Maupin (in press-a; in press-b).

b) Overview of Methods

Data from 1-degree DEM's (Digital Elevation Models) and the U.S. Geological Survey's GWSI (Ground Water Site Inventory) data base 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 Snake River Plain and western tributary valleys. ARC/INFO computer programs were used to estimate water-table altitudes for first-encountered water at grid intersections for the eastern Snake River Plain and some associated tributary valleys. Depth-to-water was calculated by subtracting estimated water-table altitudes from land-surface altitudes at the grid intersections. All depth-to-water values and locational attributes were then loaded into ARC/INFO and contoured to depict the depth-to-water and standard deviation of error zones.

c) 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 U.S. Geological Survey. 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 twenty 1:100,000-scale quadrangles and reducing

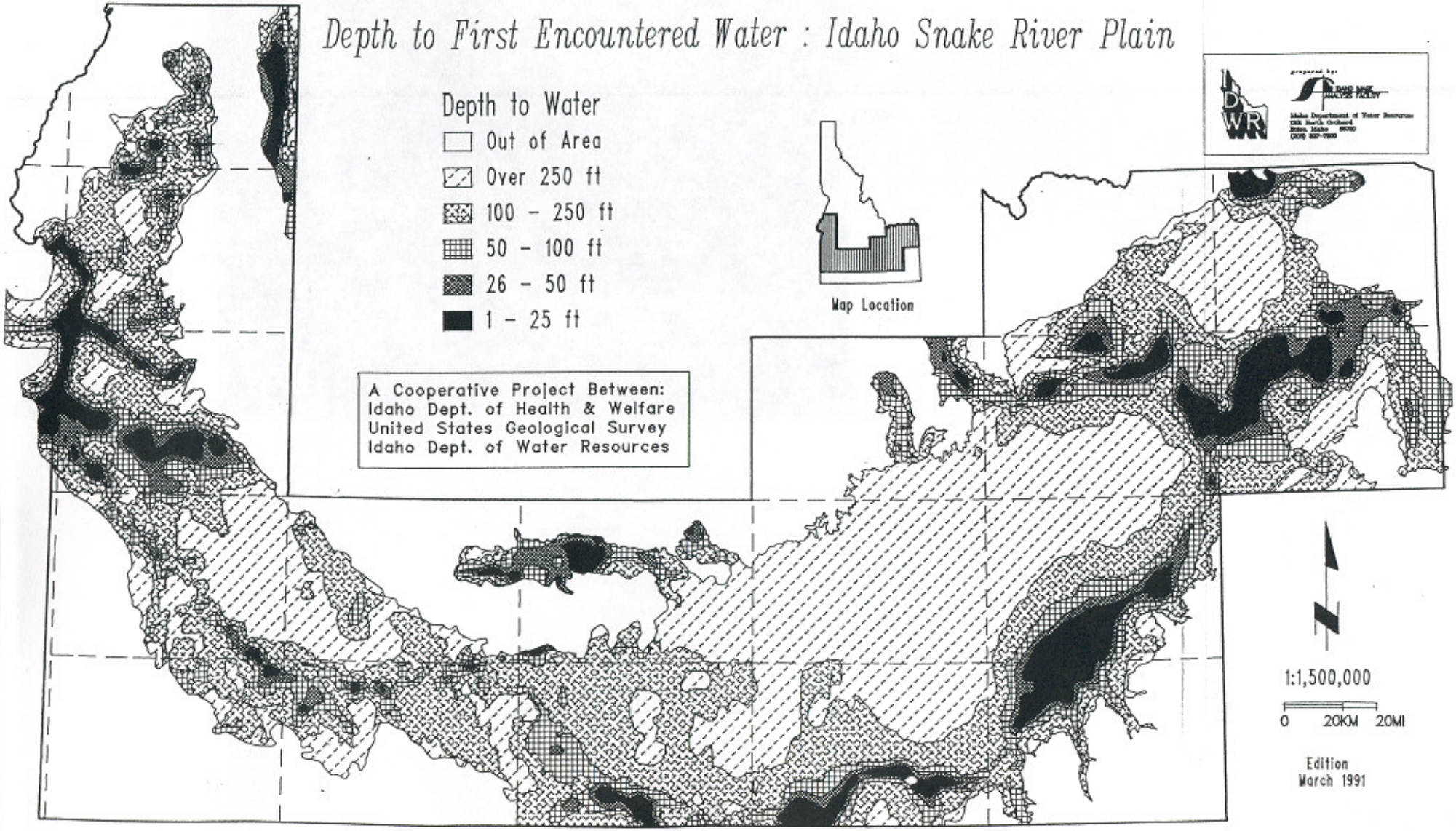

Figure 2: Depth-to-water first encountered map, Snake River Plain, Idaho.

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 a well that penetrates the upper confining layer of an artesian aquifer. In this case the water level will rise above the level of the confining layer, but not necessarily reach the land surface. 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.

March water levels were selected for the eastern Snake River Plain 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 conducted 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 on the eastern Snake River Plain, a water level obtained between January and April was selected. Where few data were available for the western Snake River Plain and in tributary valleys, June and July measurements were selected because they represent the shallowest water levels and the majority of data available. 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 were retained and water-table

altitudes were examined. 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.

d) 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 with the distance between the data points (Dunlap and Spinazola, 1984). Unlike other interpolation methods, kriging provides a Standard Deviation of Error (SDE), or a square root of the variance, for each estimated water-table altitude. 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. Figure 3 is a map of SDE values for the depth-to-water map in the Snake River Plain.

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.

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.

Selected wells for the eastern Snake River Plain tributary valleys were organized into an ARC/INFO data set with three-dimensional and spatial qualities. Water-table altitudes

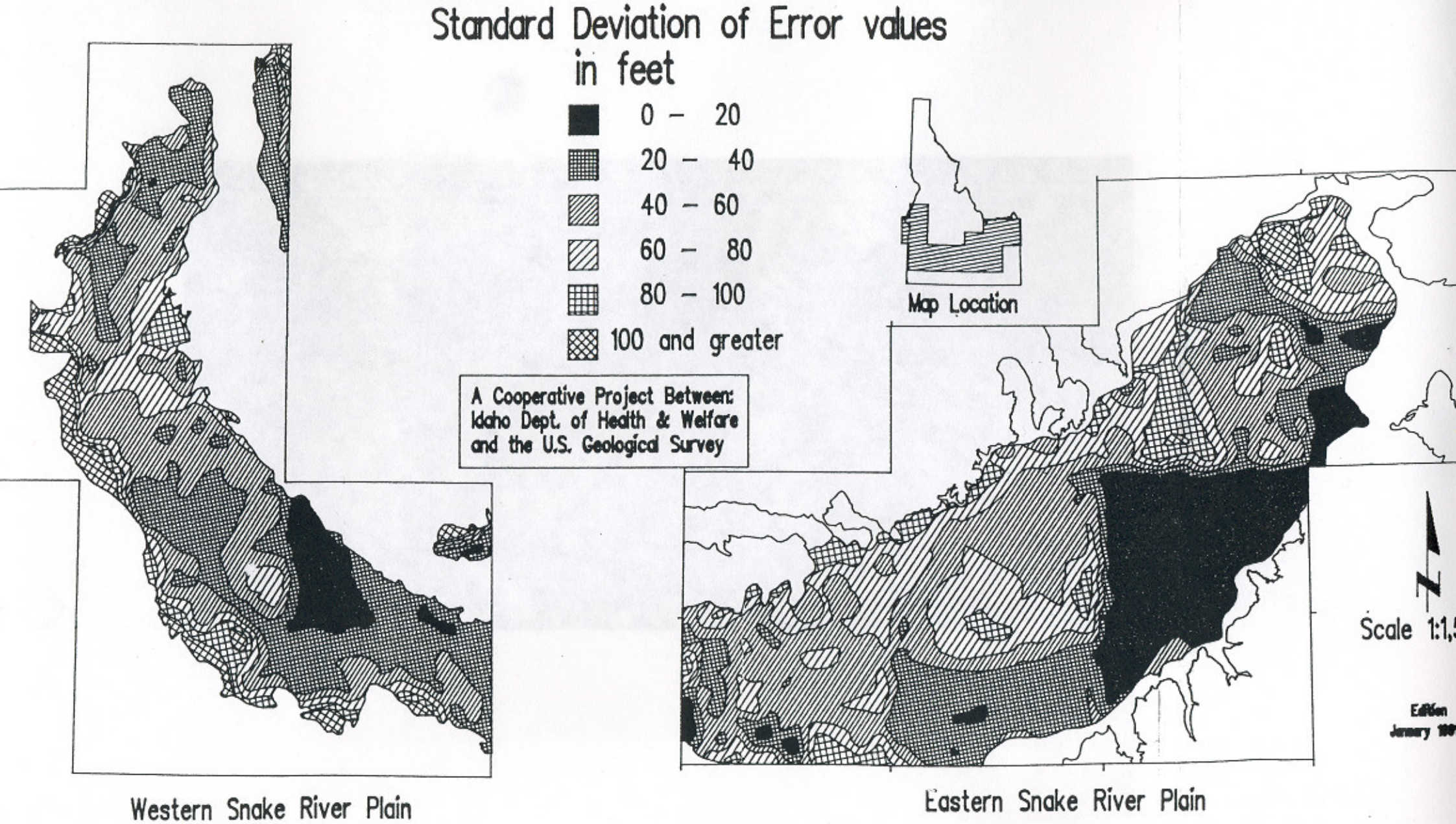

Figure 3. Zones of standard deviation of error values. Standard deviation of error values for eastern and western halves do not correspond exactly because each was kriged separately.

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 eastern Snake River Plain tributary valleys.

ARC/INFO-estimated water-table altitudes within the eastern Snake River Plain 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 honors exact well data at locations where wells fall on grid intersections, whereas ARC/INFO does not.

After depth-to-water values for the eastern and western Snake River Plain 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 created from the contours and shaded in Figure 2.

e) Rating System of Depth-to-Water Layer

The depth-to-water maps were rated on a point basis to obtain values relative to ground water susceptibility to contamination (Figure 2). Areas with smallest depth-to-water values are considered to represent the greatest danger to ground water contamination, and hence were given the greatest point rating. Areas with large depth-to-water values were believed to represent the smallest risk to ground water contamination, and therefore received the smallest point rating. The following ratings were used by the Idaho Ground Water Vulnerability Project for the depth-to-water maps. This point rating scheme may be changed in the future after a comparison to ground water monitoring data.

Depth-to-Water Ranges (feet)	Rating (points)
1 to 25	50
26 to 50	35
51 to 100	20
101 to 250	10
> 250	1