METHODS (cont.)

After initial processing by SkyTEM, the data were inverted using the Aarhus Geophysics Aps, (Aarhus, Denmark) program Workbench (Auken and others, 2009). To make the AEM data useful for geologic interpretation, numerical inversion converted measured data into a depth-dependent subsurface resistivity model, which was displayed as a resistivity profile. The inverted resistivity model (referred to hereafter as inverted AEM profiles), along with sensitivity analyses and test-hole information, were used to identify hydrogeologic features such as bedrock highs and paleochannels. A depth of investigation (DOI) calculation using the method given in Christiansen and Auken (2010) for each sounding is included in appendix 2 of U.S. Geological Survey Crustal Geophysics and Geochemistry Science Center (2014). The DOI can be defined as a critical depth below which the resistivity value is no longer constrained and interpretations of layer boundaries applied below DOI should be used with caution. Details on the data processing and inversion modeling can be located in Smith and others (2009, 2010).

An interpretation of the location of the BOA was completed using a GIS that output *x, y,* and *z* coordinates. Before interpreting the inverted AEM profiles, several complementary datasets were included and graphically displayed in two- and three-dimensional GIS environments. Complementary data included test-hole lithology, test-hole geophysical logs (including natural-gamma and normal resistivity; University of Nebraska-Lincoln, Conservation and Survey Division, 2014; J.C. Cannia, U.S. Geological Survey, written commun., 2012; Hobza and Sibray, 2014; T.A. Kuntz, Adaptive Resources Inc., written commun., 2012), TDEM resistivity models (Abraham and others, 2012; M.A. Kass, U.S. Geological Survey, written commun., 2014), airborne measurements of the intensity of 60-hertz power-line interference, airborne measurements of the magnetic total-field intensity, aerial photographs (Esri, 2014), unpublished bedrock outcrop maps (R.F. Diffendal, Jr., University of Nebraska-Lincoln, Conservation and Survey Division, unpub. data, 2013; J.B. Swinehart, University of Nebraska-Lincoln, Conservation and Survey Division, unpub. data, 2013), and the 10-m digital elevation model (DEM; Nebraska Department of Natural Resources, 1998). The inverted AEM profiles were displayed as colored resistivity profiles within the GIS environment. To assist interpretation, the inverted AEM profiles were plotted using a consistent color scale, and all of the datasets for each NRD were placed in the same projected coordinate system. This allowed the data to be examined at varying spatial scales, and for data to be iteratively displayed or hidden to fully examine how the geophysical data correlated with complementary datasets.

The overview of the process of creating BOA maps from inverted AEM profiles is described below with a more detailed discussion included in the subsequent subsections. Geologic interpretation involved manually picking locations (BOA elevations) on the displayed AEM profile by the project geophysicist, hydrologist, and geologist. These locations, or picks, of the BOA (herein referred to as BOA picks; typically the top of the Brule) were then stored in a georeferenced database. The BOA picks were made by comparing the inverted AEM profile along a flight line to the known lithology of the area based on lithologic descriptions and borehole geophysical logs from test holes. Using a GIS to view all available data at one time in a spatially georeferenced manner provides a high degree of confidence in the elevation values for the picks. The point dataset of the BOA picks' elevation was the input to a surface-interpolation algorithm of the GIS. A contouring algorithm subsequently was used to construct contours of the BOA elevation. The generated contours then were manually adjusted based on the interpreted location of paleovalleys eroded into the BOA surface and associated bedrock highs. The interpreted BOA surface is the result of erosion and subsequent valley-filling fluvial deposition from eastward draining streams (Cannia and others, 2006), and therefore is not expected to contain enclosed depressions. These newly revised contours were compared with land-surface elevation as a consistency check. Where the interpolated BOA intersected land surface, the contours were reshaped manually to follow the 10-m DEM. This was done to correct areas in the final dataset where the BOA elevation exceeded the land surface. As another consistency check, the DOI information (appendix 2, U.S. Geological Survey Crustal Geophysics and Geochemistry Science Center, 2014) was compared to the BOA-pick depth. In nearly every case, the BOA picks were above the DOI depth. In cases where the BOA picks exceeded the DOI, the supported BOA contours are dashed to indicate the contour locations are inferred (fig. 2); however, the inferred BOA contours and BOA picks are included in the final GIS dataset because they are supported by test-hole and other complementary geophysical data.

NORTH PLATTE AND SOUTH PLATTE NATURAL RESOURCES DISTRICTS BASE-OF-AQUIFER INTERPRETATION

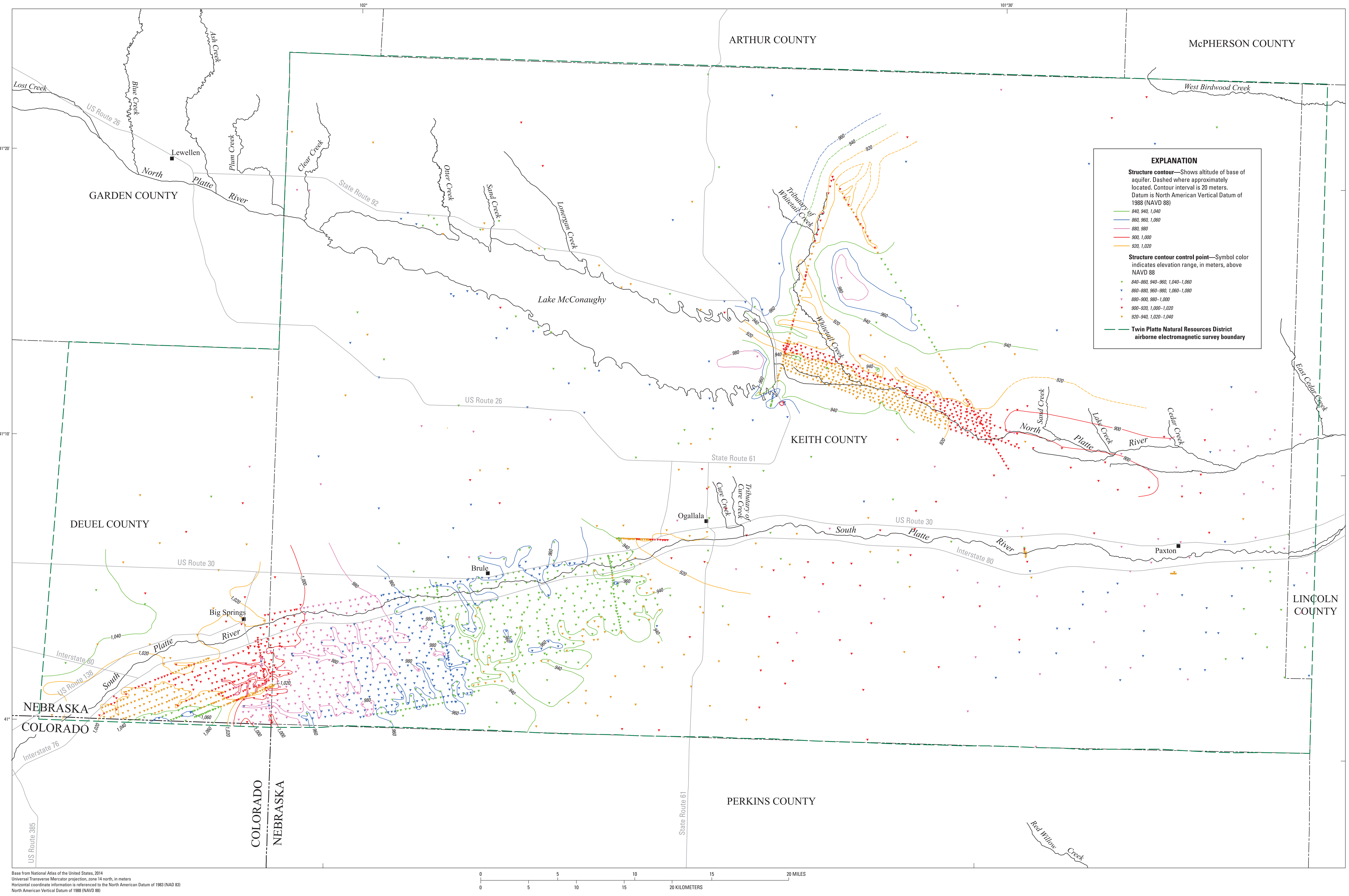
The BOA picks derived from the inverted AEM profiles acquired in 2010 were added to the georeferenced database used by Abraham and others (2012). All BOA-pick elevations were referenced as feet above the National Geodetic Vertical Datum of 1929 (NGVD 29; fig. 2). This was done by first sampling the elevation at each BOA-pick location from a 10-m DEM (Nebraska Department of Natural Resources, 1998) and subtracting the BOA-pick depth from the corresponding inverted AEM profile. Point locations of BOA elevations were picked from inverted AEM profiles and correlated to borehole geophysical logs confirming the base geologic unit. These locations were exported to Esri shapefile format to provide more detailed elevation control in redefining the BOA contours from Abraham and others (2012). Point locations with BOA elevation from existing wells and test holes (Cannia and others, 2006) used in the original interpolation of the BOA (Abraham and others, 2012) were used again as elevation control in the contours presented in this report. Additional point locations for BOA elevation were provided from interpreted resistivity models of the TDEM surveys (M.A. Kass, U.S. Geological Survey, written commun., 2014) and test hole drilling (Hobza and Sibray, 2014; T.A. Kuntz, Adaptive Resources Inc., written commun., 2012).

The georeferenced database of BOA picks from the interpretation of the new inverted AEM profiles was used to create the new BOA contours (fig. 2). Preliminarily, 50-ft (15.2-m) contours were generated using the ArcGIS application, Topo to Raster (Esri, 2014; Hutchinson, 1988, 1989, and 1996; Hutchinson and Gallant, 2000; Hutchinson and others, 2011). The Topo to Raster tool interpolated the bedrock-topographic surface described by the previous version of BOA contours (Abraham and others, 2012) to produce a raster version of the interpolated BOA-elevation surface. The interpolated surface was refined manually to have no cells above land surface elevation (as represented by the 10-m DEM). The GIS tool, contour, generated a set of hypsometric contours from the gridded surface with the specified interval of 50 ft (15.2 m; Esri, 2012a). The generated contours then were manually adjusted based on the interpreted location of paleovalleys eroded into the BOA surface and associated bedrock highs. The new BOA contours for this report (fig. 2) are a modification of the previously mapped tops of the Brule or Cretaceous units, which collectively are known as a confining unit where they are in contact with the primary aquifer presented by Abraham and others (2012). All GIS datasets for the new BOA surface are included at the following link (*http://pubs.usgs.gov/sim/3310/GIS_files*).

TWIN PLATTE NATURAL RESOURCES DISTRICT BASE-OF-AQUIFER INTERPRETATION

For the TPNRD, the most recent BOA map published was completed by Cannia and others (2006), and was used in recently published COHYST groundwater models (Carney, 2008; Luckey and Cannia, 2006). This dataset included 100-ft (30.5-m) contours referenced to the NGVD 29 datum. Since 2008, changes have been made to the primary groundwater model used by the TPNRD, which is now referenced to the North American Vertical Datum of 1988 (NAVD 88) with all elevations given in meters. The depth to the BOA at available test holes (J.C. Cannia, U.S. Geological Survey, written commun., 2012; University of Nebraska-Lincoln, Conservation and Survey Division, 2014) were converted to reference the NAVD 88 datum before being included in the TPNRD georeferenced database. Near Western Canal, the TPNRD AEM area extends west of the TPNRD boundary to partially overlap the SPNRD AEM area (fig. 1). The area of overlap includes a 2008 and 2009 AEM block flight (fig. 1). For continuity across the TPNRD-SPNRD boundary, the BOA picks derived from the 2010 AEM block flight near Western Canal were converted to meters above NAVD 88 and included in the TPNRD georeferenced database.

Before the inclusion of BOA picks from the 2010 inverted AEM profiles, conversion of the existing BOA contours was necessary. The conversion process is described in the following paragraph.



Base from National Atlas of the United States, 2014
Universal Transverse Mercator projection, zone 14 north, in meters
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)
North American Vertical Datum of 1988 (NAVD 88)

Figure 3. Elevation of the base-of-aquifer surface for parts of the Twin Platte Natural Resources District, 2014.

Preliminary, 20-m (66-ft) contours were generated using the ArcGIS tool, Topo to Raster (Esri, 2014), to interpolate the original contour surface (Cannia and others, 2006) and produce a raster version of that surface. Next, the ArcGIS tool, contour, was used to recontour the data using 20-m (66-ft) intervals (Esri, 2012a). The BOA contour data also were converted to reference the NAVD 88 datum by using CORPSCON, version 6 (U.S. Army Corps of Engineers, 2014). To accomplish the datum conversion, a 100-m grid was created using the ArcGIS tool, Create Constant Raster (Esri, 2012b). A set of evenly-distributed points (Esri, 2012c) were extracted from the 100-m grid and assigned the CORPSCON-calculated datum-conversion offset value between vertical datums (U.S. Army Corps of Engineers, 2014). The offset values were interpolated to produce an elevation-offset surface, which then was used to adjust the initial surface generated from the previously contoured BOA surface in feet above NGVD 29, (Cannia and others, 2006) to produce a raster dataset with elevations stored in meters above NAVD 88.

Once the vertical datum conversion was completed, the process of creating new BOA contours (fig. 3) was similar to that done with the NPNRD and SPNRD areas. The adjusted (NAVD 88) BOA was contoured using a 20-m (66-ft) interval, and this modified version of Cannia and others (2006) BOA surface was used as one input for the new, refined BOA dataset. The georeferenced dataset of BOA picks that included the 2010 inverted AEM profiles was the second input. The Topo to Raster tool was used to interpolate the new, updated BOA-elevation surface from these two inputs. The new BOA surface was refined to ensure that no grid cells had BOA elevations above land surface elevation (10-m DEM). The GIS tool, contour, was used to generate a set of preliminary hypsometric contours from the refined gridded surface using a contour interval of 20 m (66 ft). The generated contours then were manually adjusted based on the interpreted location of paleovalleys eroded into the BOA surface and associated bedrock highs, many of which were unmapped before this study (fig. 3). All GIS datasets for the new BOA surface are included at the following link (*http://pubs.usgs.gov/sim/3310/GIS_files*).

BASE-OF-AQUIFER ELEVATION AND CONFIGURATION

The contours of the elevation and configuration of the BOA presented in this report (figs. 2 and 3) can be used to identify paleovalleys and associated bedrock highs. When overlain by the water-table surface, the aquifer's saturated thickness can be computed (but is not provided herein), which allows an estimate of total water in storage. The maps of the BOA surface presented in this report can be used as the lower boundary layer in existing and future groundwater-flow models. Accurate elevation and configuration of the BOA are essential for improving the accuracy of groundwater-flow models and the usefulness of models as tools for understanding groundwater and surface-water interaction, and for analyzing water-resources-management alternatives. The integration of geophysical data into the contouring process facilitated a more continuous and spatially comprehensive view of the hydrogeologic framework compared to test-hole data alone.

CONVERSION FACTORS

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F=(1.8×°C)+32

Vertical coordinate information varies and is specific to the Natural Resources District being studied. Vertical coordinate information for the North Platte Natural Resources District and South Platte Natural Resources District is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Vertical coordinate information for the Twin Platte Natural Resources District is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Altitude, as used in this report, refers to distance above the vertical datum.

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Base of Principal Aquifer for Parts of the North Platte, South Platte, and Twin Platte Natural Resources District, Western Nebraska

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