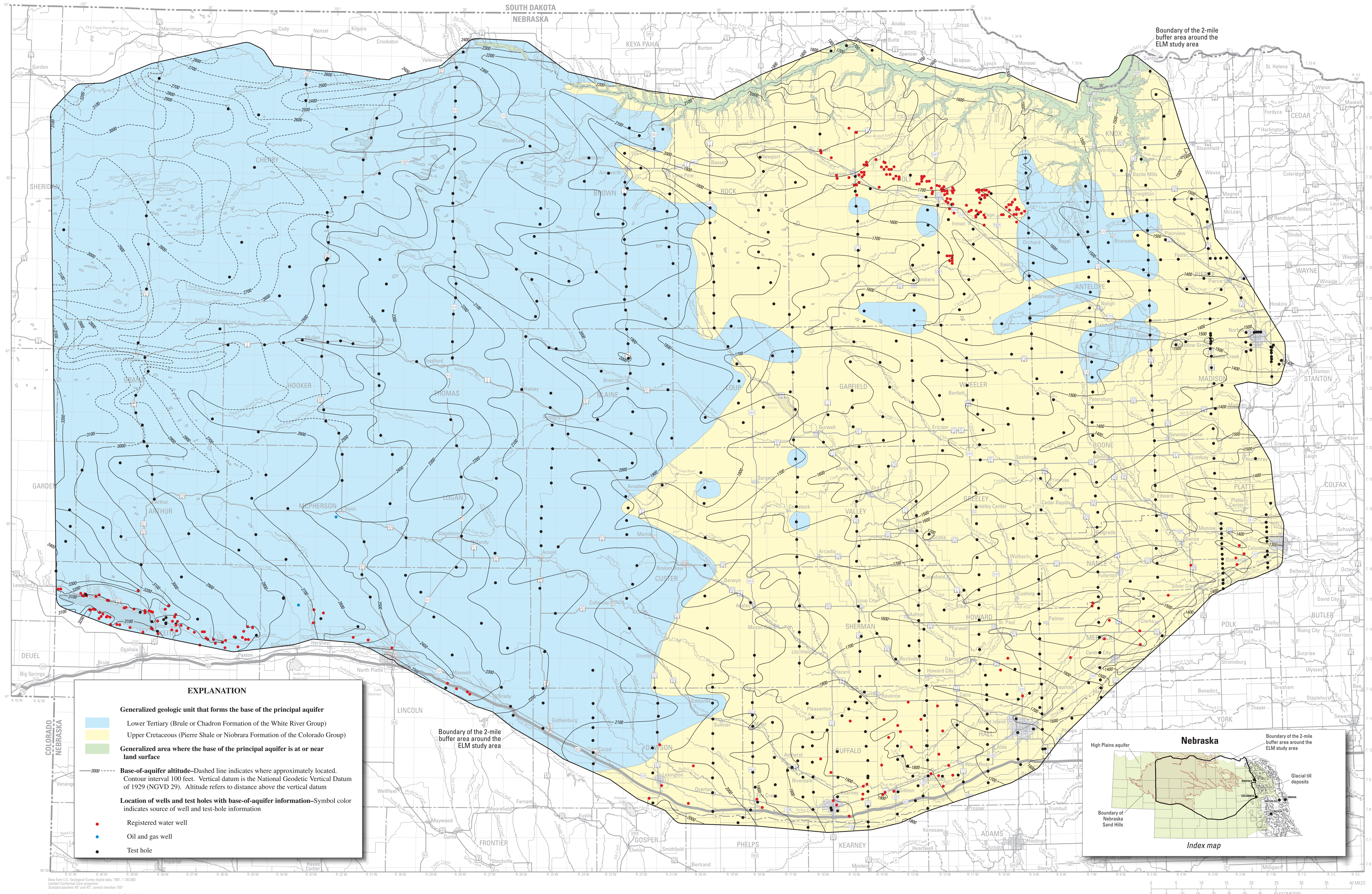
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with
LEWIS AND CLARK, LOWER ELKHORN, LOWER LOUP, LOWER NIOBRARA, LOWER PLATTE NORTH,
MIDDLE NIOBRARA, UPPER ELKHORN, UPPER LOUP NATURAL RESOURCES DISTRICTS

SCIENTIFIC INVESTIGATIONS MAP 3042
McGuire, V. L. and Peterson, S. M., 2008, Base of Principal Aquifer for the Elkhorn-Loup Model Area, North-Central Nebraska



Abstract

In Nebraska, the water managers in the Natural Resources Districts and the Nebraska Department of Natural Resources are concerned with the effect of ground-water withdrawal on the availability of surface water and the long-term effects of ground-water withdrawal on ground- and surface-water resources. In north-central Nebraska, in the Elkhorn and Loup River Basins, ground water is used for irrigation, domestic supply, and public supply; surface water is used in this area for irrigation, recreation, and hydropower production. In recognition of these sometimes competing ground- and surface-water uses in the Elkhorn and Loup River Basins, the U.S. Geological Survey, the Lewis and Clark Natural Resources District, the Lower Elkhorn Natural Resources District, the Lower Loup Natural Resources District, the Lower Niobrara Natural Resources District, the Lower Platte North Natural Resources District, the Middle Niobrara Natural Resources District, the Upper Elkhorn Natural Resources District, and the Upper Loup Natural Resources District agreed to cooperatively study water resources in the Elkhorn and Loup River Basins. The goals of the overall study were to construct and calibrate a regional ground-water flow model of the area and to use that flow model as a tool to assess current and future effects of ground-water irrigation on stream base flow and to help develop long-term water-resource management strategies for this area, hereafter referred to as the Elkhorn-Loup model area.

The Elkhorn-Loup model area covers approximately 30,800 square miles, and extends from the Niobrara River in the north to the Platte River in the south. The western boundary of the Elkhorn-Loup model area coincides with the western boundary of the Middle Niobrara, Twin Platte, and Upper Loup Natural Resources Districts; the eastern boundary coincides with the approximate location of the western extent of glacial till in eastern Nebraska. The principal aquifer in most of the Elkhorn-Loup model area is the High Plains aquifer; the principal aquifer in the remaining part of the Elkhorn-Loup model area is an unnamed alluvial aquifer. The upper surface of the geologic units that directly underlie the aquifer is called the "base of aquifer" in this report. The geologic unit that forms the base of aquifer in the Elkhorn-Loup model area varies by location. The Tertiary-age Brule Formation generally is the base of aquifer in the west; the Cretaceous-age Pierre Shale generally is the base of aquifer in the east.

The purpose of this report is to update the altitude and configuration of the base of the principal aquifer in the Elkhorn-Loup model area and a 2-mile buffer area around the Elkhorn-Loup model area, using base-of-aquifer data from test holes, registered water wells, and oil and gas wells within the Elkhorn-Loup model area and a 20-mile buffer area around the Elkhorn-Loup model area that have become available since the publication of earlier maps of the base of aquifer for this area. The base-of-aquifer map is important for the Elkhorn-Loup ground-water flow model because it defines the model's lower boundary. The accuracy of the Elkhorn-Loup ground-water flow model and the accuracy of the model's predictions about the effects of ground-water irrigation on stream base flow are directly related to the accuracy of the model's lower boundary.

Introduction

In Nebraska, the water managers in the Natural Resources Districts (NRDs) and the Nebraska Department of Natural Resources (NDNR) are concerned with the effect of ground-water withdrawal on the availability of surface water and the long-term effects of ground-water withdrawal on ground- and surface-water resources. In north-central Nebraska, in the Elkhorn and Loup River Basins, ground water is used for irrigation, domestic supply, and public supply and surface water is used for irrigation, recreation, and hydropower production. In addition, outflows of the Elkhorn and Loup Rivers merge with the Platte River near Waterloo, Nebraska, and Columbus, Nebraska, respectively, and support in-stream flow appropriations, such as Nebraska Game and Parks Commission In-Stream Appropriation, A-17331 (Nebraska Department of Natural Resources, 2008). Outflows from the Elkhorn and Loup Rivers also supply recharge to the Platte River alluvial aquifer for large downstream municipal water systems that pump ground water near and below the Platte River to supply Lincoln and Omaha, Nebraska. Further, newly adopted legislation requires a sustainable balance between long-term water supplies and uses for ground- and surface-water users (Nebraska Department of Natural Resources, 2007b). In recognition of sometimes competing ground- and surface-water uses in the Elkhorn and Loup River Basins, the U.S. Geological Survey (USGS), the Lewis and Clark NRD, the Lower Elkhorn NRD, the Lower Loup NRD, the Lower Niobrara NRD, the Lower Platte North NRD, the Middle Niobrara NRD, the Upper Elkhorn NRD, and the Upper Loup NRD agreed to cooperatively study water resources in these basins, hereafter referred to as the Elkhorn-Loup model (ELM) area. The overall goals of the ELM study were to construct and calibrate a regional ground-water flow model of the area and to use that flow model as a tool to assess current and future effects of ground-water irrigation on stream base flow and to help develop long-term water-resource management strategies for the ELM area. The ELM area covers approximately 30,800 square miles, and extends from the Niobrara River in the north to the Platte River in the south (See map at left). The western boundary coincides with the western boundary of the Middle Niobrara, Twin Platte, and Upper Loup NRDs, and the eastern boundary coincides with the approximate location of the western extent of glacial till in eastern Nebraska (University of Nebraska—Lincoln, Conservation and Survey Division, 2007a).

The purpose of this report is to update the altitude and configuration of the base of principal aquifer in the ELM area and a 2-mile buffer area around the ELM area using data that have become available in the ELM area and a 20-mile buffer area around the ELM area since earlier maps of the base of aquifer for this area were published (University of Nebraska—Lincoln, Conservation and Survey Division, 1979; Pettijohn and Chen, 1983; Gutentag and others, 1984; Cooperative Hydrology Study, 2006a). The base-of-aquifer map is important for the ELM ground-water flow model because it defines the lower boundary of the model. The accuracy of the ELM ground-water flow model and the accuracy of the model's predictions about the effects of ground-water irrigation on stream base flow are directly related to the accuracy of the model's lower boundary.

In a small area along the northeastern border of the ELM area, the principal aquifer is an unnamed alluvial aquifer, which is composed of Quaternary-age deposits of alluvium (See Index Map). Elsewhere, the principal aquifer is the High Plains aquifer, which is composed of the following geologic units:

- Quaternary-age deposits of alluvium and valley-fill deposits, eolian sand, and loess;
- Broadwater Formation of Tertiary age;
- Ogallala Group of Tertiary age;
- Arikaree Group of Tertiary age; and
- Brule Formation of Tertiary age, where the Brule Formation is fractured (Gutentag and others, 1984). Although the fractured part of the Brule Formation is considered part of the High Plains aquifer, the presence and extent of fracturing in the Brul Formation has not been compiled in most of the ELM area. Therefore, the fractured part of the Brule Formation was not included in the aquifer for this report.

The geologic units that form the base of aquifer in the ELM area vary by location and are listed below:

- Brule Formation of the White River Group of Tertiary age, where it is not fractured. But because the presence and extent of fractures in the Brule Formation have not been compiled in most of the ELM area, the top of the Brule Formation, where present, was considered the base of the aquifer for this report;
- Chadron Formation of the White River Group of Tertiary age;
- Pierre Shale of Cretaceous age; and
- Niobrara Formation of the Colorado Group of Cretaceous age.

The Brule Formation generally is the base of aquifer in the west; whereas in the east it is the Pierre Shale (Bentall and others, 1971; Dreeszen and others, 1973; Burchett and others, 1975; Pettijohn and Chen, 1983; Burchett and others, 1988; Eversoll and others, 1988; Diffendal, 1991; University of Nebraska—Lincoln, Conservation and Survey Division, 1996; and Souders, 2000).

Methods

The base-of-aquifer altitude in the ELM area and in the surrounding 2 miles was compiled by first assembling the current (1979 to 2006) maps of the base of aquifer, the base of the Ogallala Group, and the top of the uppermost Cretaceous units in the ELM area, and depth to the geologic units that form the base of aquifer from available data for test holes, NDNR registered water wells, and oil and gas wells in the ELM area and the surrounding 20 miles. Then 10-meter land-surface altitude data for the ELM area were acquired in raster form to determine land-surface altitude at each test hole and well location using a consistent method. The 10-meter land-surface altitude at the test hole and well location was used to assess the accuracy of the test hole and well location and, for most wells, to calculate the altitude of the base of aquifer. For the remaining wells and test holes, the land-surface altitude from the test-hole database or from the test-hole-paper files was used to calculate the altitude of the base of aquifer (University of Nebraska—Lincoln, Conservation and Survey Division, 2007b; data in files at University of Nebraska—Lincoln, Conservation and Survey Division, 2007).

The base-of-aquifer altitude data at locations of test holes, NDNR registered water wells, and oil and gas wells, and selected parts of previously published maps of the base of aquifer were input to a geographic information system (GIS). To construct initial contours of the base-of-aquifer altitude, a GIS function (topogrid) was applied (Environmental Systems Research Institute, 1992). The computer-generated contours were modified manually within the GIS to better reflect that the base-of-aquifer surface configuration was shaped by natural processes; the paleodrainage patterns indicated in the previously published maps were used to guide the manual modifications. The altitude of the surface represented by the base-of-aquifer contours was digitally compared within the GIS to the land-surface altitude to identify areas where the base-of-aquifer contours needed to be adjusted because the representation of the base-of-aquifer surface intersected the land surface, which likely means the principal aquifer is not present or is very thin. This occurred primarily in the eastern part of the Niobrara River valley. After the revised base- of-aquifer contours were reviewed, the contours again were modified manually within the GIS to incorporate changes suggested by peer reviewers.

The previously published maps of the base of aquifer that were considered during compilation were maps of the base of the principal aquifer in Nebraska (University of Nebraska—Lincoln, Conservation and Survey Division, 1979), the base of the High Plains aquifer (Pettijohn and Chen, 1983; Gutentag and others, 1984; Cederstrand and Becker, 1999), and the base of aquifer in the Platte River Valley upstream from Columbus, Nebraska (Cooperative Hydrology Study, 2006a, 2006b). The base of the Ogallala Group had been mapped in the Nebraska Sand Hills and in the northeastern and south-central parts of the ELM area (Swinehart and others, 1985; Swinehart and Diffendal, 1998; and Souders, 2000); these maps were used either as an indicator of the regional paleodrainage pattern for the base of aquifer in areas where the Arikaree Group is present, or as a guide for the base-of-aquifer contours, in areas where the Arikaree Group is not present. The top of the Cretaceous System was mapped in the northeastern and south-central part of the ELM area (Bentall and others, 1971; Burchett and others, 1988; Souders, 2000); these maps were used as a guide for the base-of-aquifer contours in the ELM area.

The available information for test holes from State and Federal test-drilling programs can include lithologic logs, borehole geophysical logs, mineralogical investigations, and the results of stratigraphic studies to identify the geologic units and the depth to the top and bottom of each geologic unit that was penetrated at the test-hole location. The test-hole information is filed at the University of Nebraska—Lincoln, Conservation and Survey Division (UNL-CSD) offices in Lincoln, Nebraska, and has been largely compiled in a Web-based database (University of Nebraska—Lincoln, Conservation and Survey Division, 2007b). Because the stratigraphic information (geologic units and geologic-unit depths) had not been published in reports or on the Web for 309 of the 2,032 test holes in the ELM area and the surrounding 20 miles, the available UNL-CSD files for these test holes were reviewed by the authors for this report (data in files at University of Nebraska—Lincoln, Conservation and Survey Division, 2007). For many of these unpublished test holes, there were handwritten notes in the files by UNL-CSD geologists about the geologic units and geologic-unit depths at the test-hole location. For the remaining unpublished test holes, the lithologic and borehole geophysical logs, if available, were reviewed to estimate the depth to the unit corresponding to the base of aquifer. Data from 1,219 test holes were used to map the base of aquifer in the ELM area.

The available data for NDNR registered water wells typically consists of location information, well construction information, and a lithologic log. The NDNR registered water-well data that were used in this report were the depth to the geologic unit that forms the base of aquifer for 123 wells in Holt County, and the depth to the base of aquifer for 456 wells in the Platte River Valley (Cooperative Hydrology Study, 2006a, 2006b; Nebraska Department of Natural Resources, 2007a; S.O. Lackey, University of Nebraska—Lincoln, Conservation and Survey Division, written commun., June 2007).

The available data for oil and gas wells include identified stratigraphic data at each well location (Nebraska Oil and Gas Commission, 2007); however, because the purpose for installing these wells is primarily interest in pre-Cretaceous geologic units, data about the depth to the top of the geologic units that form the base of aquifer in the ELM area generally is not documented (Marvin Carlson, University of Nebraska—Lincoln, Conservation and Survey Division, oral commun., 2007). In the ELM area, only two of the oil and gas wells provided base-of-aquifer data used in this report.

The land-surface altitude at each published and unpublished test hole in the ELM area and at selected NDNR registered water wells in Holt County was estimated using a digital 10-meter land-surface altitude raster data set (U.S. Geological Survey and Nebraska Department of Natural Resources, 1998). The land-surface altitudes of the test holes in the ELM area, which were published on the Web or written in the test-hole documentation (University of Nebraska—Lincoln, Conservation and Survey Division, 2007b; data in files at University of Nebraska—Lincoln, Conservation and Survey Division, 2007), were compared to the digitally interpolated land-surface altitudes from the 10-meter land-surface altitude raster data set to partially assess the accuracy of the test-hole locations. If the published land-surface altitude of a test hole did not differ by more than 20 feet (ft) from the digitally interpolated land-surface altitude, the digitally interpolated land-surface altitude was used to calculate the base-of-aquifer altitude. For the five test holes with published land-surface altitudes that differed by more than 20 ft from the digitally interpolated land-surface altitudes, the land-surface altitudes, which were published on the Web or written in the test-hole documentation, were used to calculate the base-of-aquifer altitude. This approach was used because these five test holes were in parts of the ELM area with few test holes with base-of-aquifer information, therefore any reasonably accurate information about the base of aquifer in the area was useful for deriving the base-of-aquifer altitude contours.

Base-of-Aquifer Altitude and Configuration

The altitude and configuration of the base of aquifer and the geologic units that form the base of the principal aquifer in the ELM area are shown on the map to the left. The base of aquifer ranged from less than 1,300 ft above the National Geodetic Vertical Datum of 1929 (NGVD 29) in Platte County to more than 3,300 ft above NGVD 29 in Garden and Keith Counties. The altitude and configuration of the base of aquifer can be used to locate ancestral valleys and associated ridges and, together with the water-table surface, to compute the aquifer's saturated thickness. The base of aquifer is being used as the lower boundary layer in the ELM ground-water flow model; an accurate base of aquifer is essential for improving the accuracy of the ground-water flow model and its usefulness as a tool for analyzing water-resources management alternatives.

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Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Datums

Vertical Coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983.

Altitude, as used in this report, refers to distance above the vertical datum.

U.S. DEPARTMENT OF THE INTERIOR
DIRK KEMPTHORNE, Secretary

U.S. GEOLOGICAL SURVEY
Mark D. Myers, Director

Base of Principal Aquifer for the Elkhorn-Loup Model Area, North-Central Nebraska

By
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2008

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This map was produced on request, directly from digital files, on an electronic plotter

A PDF of this map is available at http://pubs.usgs.gov/sim/3042

Related metadata and digital files are available at http://water.usgs.gov/lookup/getgislist

Information regarding water resources in Nebraska is available at: http://ne.water.usgs.gov/

Suggested citation:
McGuire, V.L., and Peterson, S.M., 2008, Base of principal aquifer for the Elkhorn-Loup model area, north-central Nebraska: U.S. Geological Survey, Scientific Investigations Map, 3042, 1 sheet, available on the Web at http://pubs.usgs.gov/sim/3042