

# **Nebraska Statewide Groundwater-Level Monitoring Report**

# **2012**

**Aaron R. Young  
Mark E. Burbach  
Jesse T. Korus  
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Conservation and Survey Division  
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**Nebraska Water Survey Paper Number 80**

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# University of Nebraska-Lincoln

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March 2013

ISBN 1-56161-025-9

ISBN-13 978-1-56161-025-9

## ACKNOWLEDGMENTS

The cooperation and assistance of the following agencies and associations in collecting and providing water-level data during 2012 are gratefully acknowledged: U.S. Bureau of Reclamation; Central Nebraska Public Power and Irrigation District; U.S. Geological Survey; and the following Natural Resources Districts; Lower Republican, Middle Republican, Upper Republican, Upper Big Blue, Little Blue, Lower Big Blue, Lower Platte South, Lower Platte North, Central Platte, Twin Platte, North Platte,

South Platte, Lower Niobrara, Middle Niobrara, Upper Niobrara-White, Lower Loup, Upper Loup, Lower Elkhorn, Upper Elkhorn, Papio-Missouri River, Lewis and Clark, Nemaha, and Tri-Basin. We also thank the many hundreds of land-owners who graciously allowed these agencies to collect water-level information from their wells and install observation wells on their land. Thanks to Dee Ebbeka for assisting with the preparation of this report.

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## FORWARD

Nebraska's proud tradition of natural-resources stewardship is particularly apparent in the case of groundwater. Groundwater is inextricably linked to the State's rich heritage; it also maintains our agricultural economy and provides steady flows to some of the Nation's most admired natural streams. The groundwater resources that lie beneath Nebraska are indeed vast, but they are also vulnerable: even small changes in groundwater levels can have profound impacts.

We are proud to present this report, which is a continuation of the series of water resources reports and maps published by the Conservation and Survey Division (CSD) of the School of Natural Resources. The information provided herein can be used to inform, educate, and guide the citizens of Nebraska as we enter new and challenging times regarding water resources.

## INTRODUCTION

*Groundwater-level information is valuable to citizens and stakeholders for understanding water resource availability and making informed management decisions.*

This report is a statewide synthesis of groundwater-level monitoring programs in Nebraska. It is a continuation of the series of annual reports and maps produced by the CSD of the University of Nebraska in cooperation with the U.S. Geological Survey (USGS) since the 1950's. Groundwater-level monitoring began in Nebraska in 1930 in an effort to survey the State's groundwater resources and observe changes in its availability on a continuing basis. The CSD and USGS cooperatively developed, maintained, and operated an observation well network throughout the State. These two agencies were responsible for collecting, storing, and making this information available to the citizens.

Although CSD and USGS still occupy a central role in the statewide groundwater-level monitoring program, other agencies have assumed the responsibilities of building and maintaining observation networks and measuring water levels. The CSD and USGS continue to operate some of the original observation wells, but today the majority of measurements are made by agencies such as the Natural Resources Districts, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Public Power and Irrigation Districts, and municipalities. Because these agencies are located throughout the State, they are able to implement groundwater-level monitoring programs using local field staff, landowner contacts, taxing and regulatory authority, and first-hand knowledge of local conditions. Collectively, these agencies have developed an extensive network of observation wells throughout the State.

The CSD plays a vital role in providing technical expertise to these agencies as they develop and implement groundwater-level monitoring plans. The CSD evaluates the adequacy and accuracy of the water-level data and provides

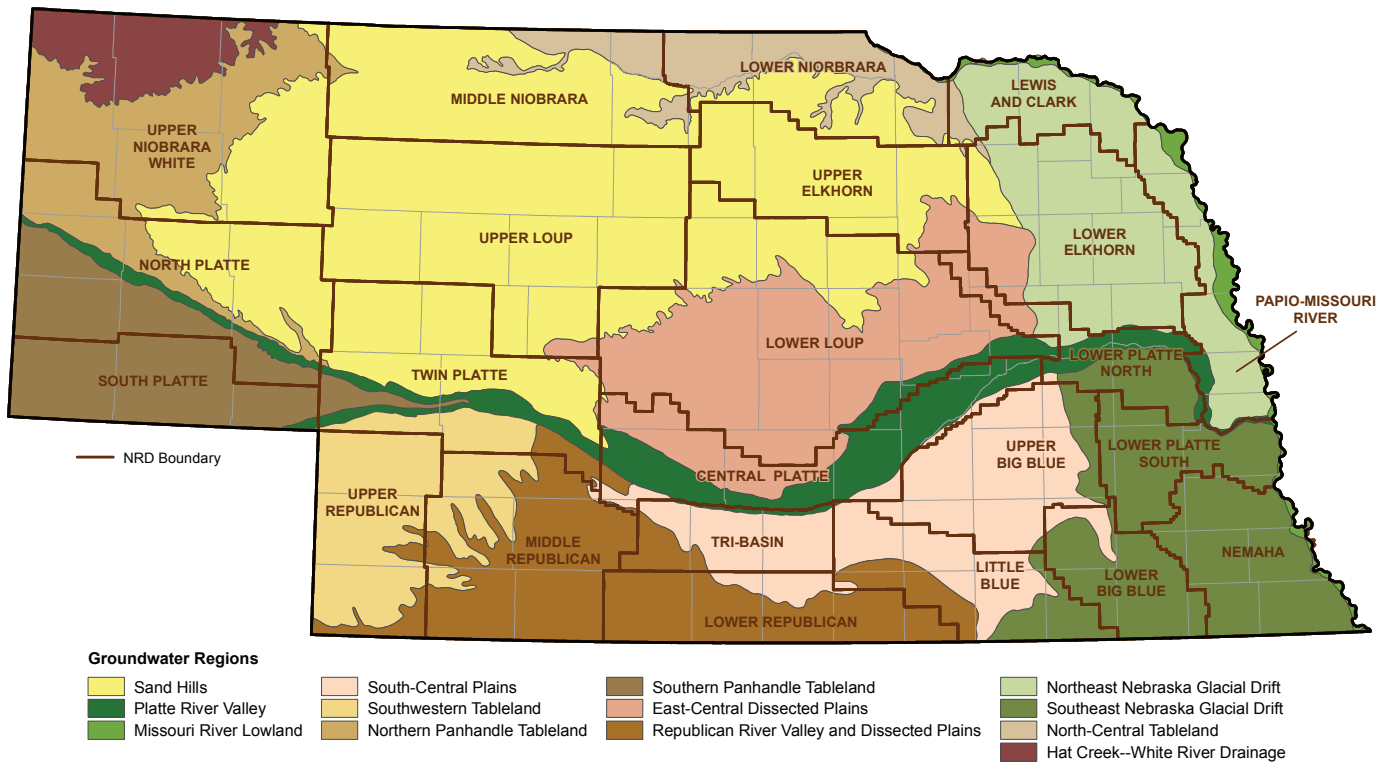
the statewide assessment of groundwater-level changes across all groundwater regions (Fig. 1) and in many of the State's aquifers (Fig. 2,3).

The CSD has long provided technical services to stakeholders by integrating groundwater-level change data with multiple data sets in order to:

- 1) Determine the amount of groundwater in storage and its availability for use.
- 2) Assess the water-supply outlook by determining changes in the volume of groundwater in storage.
- 3) Identify areas in which changes in groundwater levels may have an economic impact.
- 4) Assist state and local agencies in the formulation and administration of resource-management programs.
- 5) Determine or estimate the rate and direction of groundwater movement, specific yield of aquifers, base flow of streams, sources and amounts of groundwater recharge, and locations and amounts of groundwater discharge.
- 6) Assess the validity of hydrogeologic interpretations and the assumptions used in developing models of groundwater systems.

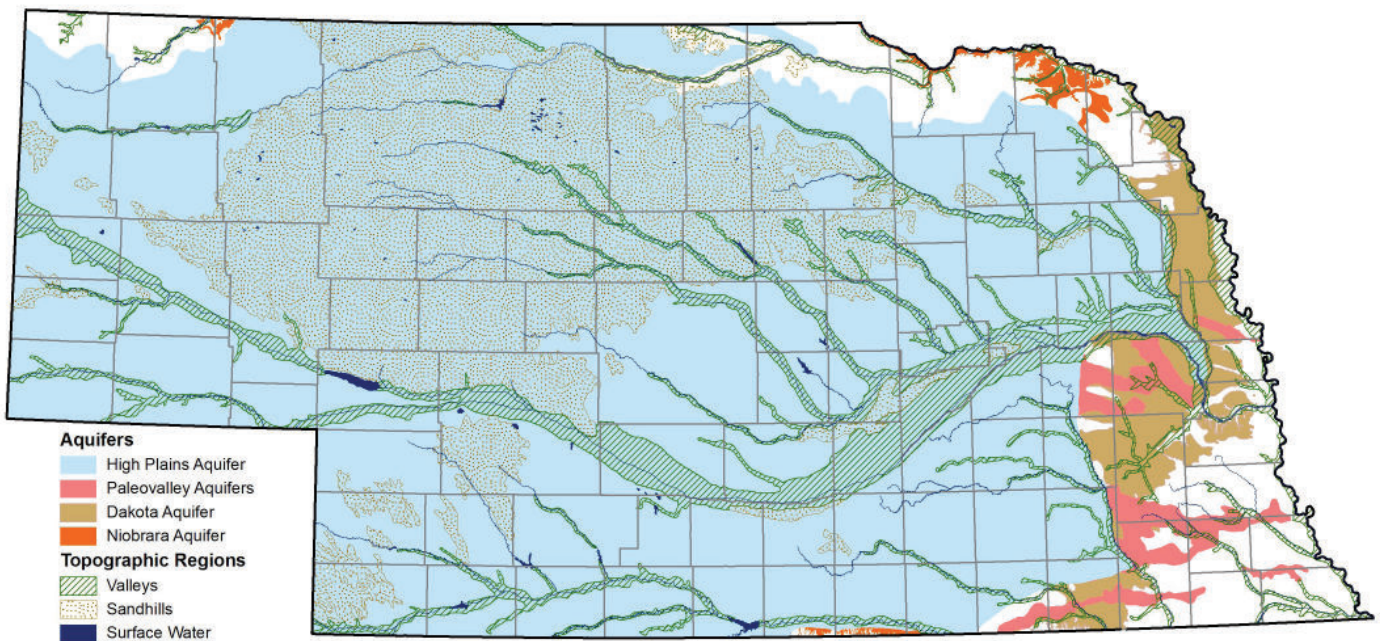
The need for this information has increased tremendously over the past few years, yet the resources available for fulfilling this need have decreased. The CSD strives to meet this challenge by focusing on fundamental data, building collaborative relationships with the agencies that depend on the information, and providing scientifically accurate information in a timely manner.

**Figure 1. National Resources Districts and Groundwater Regions of Nebraska**



*Groundwater regions from Flowerday et al. (1998)*

**Figure 2. Important Aquifers and Topographic Regions of Nebraska**



*Note: In some areas, the aquifer units shown here may contain little or no saturated thickness.*



## INTRODUCTION (continued)

### *Purpose and Methods*

This report summarizes changes in Nebraska's groundwater levels over periods of 1, 5, and 10, years prior to 2012, as well as from 1981 to 2012, predevelopment to 1981, and predevelopment to 2012. 1981 was selected as a fixed year, as groundwater level declines in many parts of the state reached a maximum in 1981. These changes are depicted in maps that delineate regional trends on a statewide basis. Although localized conditions may vary considerably, the maps presented in this report provide an overview of the general locations, magnitudes, and extents of rises and declines. The reader should use figures 1 – 4 to locate groundwater regions, aquifers, and counties mentioned in the text.

The 1-, 5-, and 10-, year changes are presented in the spring 2011 to spring 2012, spring 2007 to spring 2012, and spring 2002 to spring 2012, respectively. Groundwater levels measured from thousands of wells throughout the State in spring 2012 (Fig. 5) were compared to levels measured in the same wells in the spring of the earlier year. For the 1-, 5-, and 10-year change maps, contours were generated using computer interpolation. These contours were incorporated into the final maps in areas where the principal aquifer is continuous, is in relatively good hydraulic connection over large areas, and where data density is relatively high. In areas not meeting the above conditions, the computer-generated contours were manually edited on maps at a scale of 1:500,000 in order to conform to hydrogeologic boundaries that prevent the flow of groundwater. Such boundaries include 1) areas where relatively impermeable bedrock units outcrop or exist in the shallow subsurface, such as southeastern Nebraska and in areas of Scotts Bluff County, 2) valley boundaries in eastern Nebraska where alluvial aquifers are a major source of groundwater but upland areas between them lack a primary aquifer, and 3) areas where the High Plains Aquifer is separated by deeply entrenched parts of the Niobrara, Republican, and Platte River valleys. For the spring 1981 to spring 2012 map, computer interpolation was impractical because data was sparse in many areas. Contours were therefore drawn manually with knowledge of the major hydrogeologic boundaries listed above.

For the predevelopment to spring 2012 and predevelopment to spring 1981 maps, water levels from wells measured in 2012 and 1981 were compared to estimated predevelopment water levels in the same wells. An estimated predevelopment water level is the approximate average water level at a well site prior to any development that significantly affects water levels. Predevelopment water levels for most of the State are the estimated water levels that generally occurred before the 1930s, 1940s, or early to mid-1950s. These dates, which vary throughout

Nebraska, generally depend on the beginning dates of intensive use of groundwater for irrigation. Typically all available water-level data collected prior to or during the early stages of groundwater development are used to estimate predevelopment water levels. Contours were drawn manually with the aid of previously existing maps for similar time periods and with knowledge of major hydrogeologic boundaries.

Areas of sparse data are shown with a hatched pattern on all maps. A computer point density interpolation was used to determine the number of observation points within a 6 mile (10 kilometer) search radius. Areas of sparse data were defined as areas with zero observation points within the search radius.

Precipitation maps were prepared by comparing total precipitation over the time period of interest to the 30-year normal provided by the National Climate Data Center. The 30-year normal currently in use is based on average annual precipitation from 1970 to 2000. Computer interpolation was used to generate contours for these maps.

The average daily streamflows were computed by taking the average of all daily mean values for the water year, which was from October 1, 2010 to September 30, 2011. The long-term average is calculated from all available annual data from the 30 year period previous to the current water year. The 2011 stream flows were compared to the average annual flows from 1981 to 2011. For a few sites, less than 30 years of data is available for computing the long term average.

### *Factors Causing Groundwater-Level Changes*

Long-term groundwater-level changes are a reflection of the changing balance between recharge to, discharge from, and storage in an aquifer. If recharge and discharge are in balance, such as they were before widespread irrigation development, groundwater levels are generally steady because the amount of water stored in the aquifer does not change. Minor changes in groundwater levels may occur due to natural variations in precipitation and streamflow, but generally the system is in equilibrium. If, however, the rate of recharge exceeds the rate of discharge over a long period, the amount of water stored in the aquifer increases and groundwater levels rise. Conversely, if the rate of discharge exceeds the rate of recharge for a long period, the amount of water in storage is depleted and groundwater levels decline. The magnitudes, locations, and rates of groundwater level changes are controlled by many factors, including: the aquifer's storage properties, permeability, and saturated thickness; the locations, rates, and pumping schedules of wells; the locations and rates of artificial recharge areas; and

**Figure 3. Generalized Geologic and Hydrostratigraphic Framework of Nebraska**

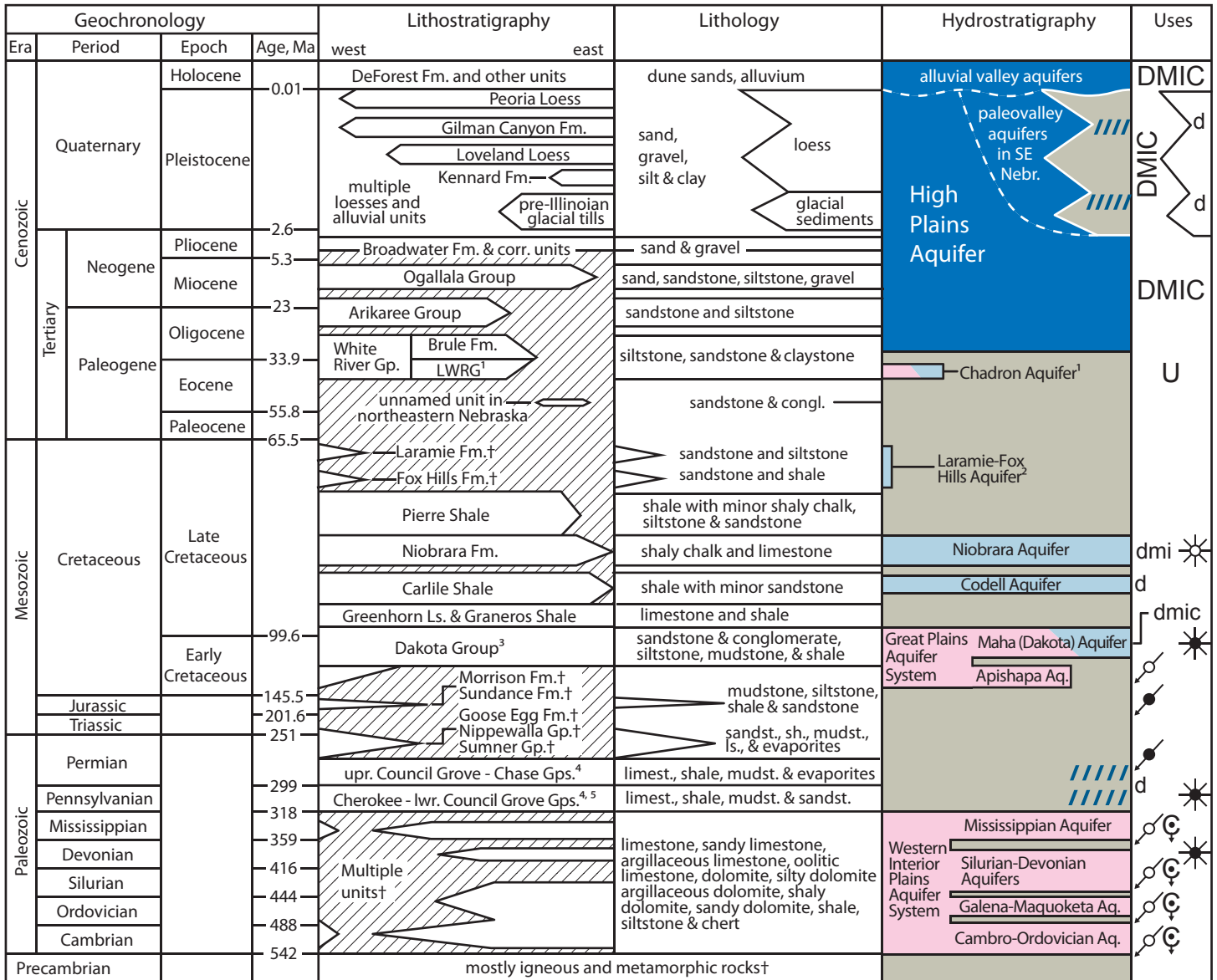


Diagram is not to scale relative to geologic time and stratigraphic thicknesses.

#### Hydrostratigraphic characteristics and water quality

	primary aquifers with good quality water
	secondary aquifers with good quality water
	secondary aquifers with generally poor quality water
	aquitards with local low-yield aquifers
	aquitards

<sup>1</sup> lower White River Group - includes Chamberlain Pass and Chadron Formations according to some authors; "Chadron Aquifer" historically refers to aquifer in lower White River Group

<sup>2</sup> important aquifer in Colorado, but present in Nebraska only in extreme southwestern Panhandle

<sup>3</sup> Dakota Formation in adjacent states

<sup>4</sup> includes correlative units with different names in northwest Nebraska

<sup>5</sup> Cherokee, Marmaton & Pleasanton Groups are not exposed in Nebraska

<sup>†</sup>present only in subsurface

#### Groundwater uses and related aspects

D	major domestic use	I	major irrigation use
d	minor domestic use	i	minor irrigation use
M	major municipal use	C	major commercial/industrial use
m	minor municipal use	c	minor commercial/industrial use
	units used for wastewater injection		
	units with potential use for wastewater injection		
U	unit mined for uranium by in-situ leaching (Dawes Co.)		
	unit with potential use for carbon sequestration		
	unit producing petroleum or natural gas		
	unit with natural gas potential		

From Korus and Joeckel, 2011



the degree of hydraulic connection between the aquifer and surface water bodies.

It is a common misconception that the rate of recharge from precipitation can be used as a “safe yield” or “sustainable limit” on the rate of groundwater extraction from an aquifer (Bredehoeft, 1997). This idea is too simplistic. The aquifer properties and all sources of recharge and discharge must be taken into consideration. Recharge is provided primarily by precipitation, but also by irrigation return flow and seepage from canals, reservoirs, and streams. Discharge occurs as baseflow to streams and lakes, evapotranspiration, and groundwater pumping. Groundwater levels, therefore, respond to a variety of natural and anthropogenic factors affecting recharge and discharge and are controlled largely by the physical properties of the aquifer. Limiting groundwater extraction to a rate equal to or less than the rate of recharge from precipitation will not prevent depletion of the aquifer. In fact, groundwater “mining” is prone to occur to one degree or another in any heavily pumped aquifer. A holistic, adaptive approach to groundwater management based on hydrologic mass balance is more appropriate. These strategies are discussed by several authors (e.g. Sophocleous, 1997, 2000; Alley and Leake, 2004; Maimone, 2004; Korus and Burbach, 2009a).

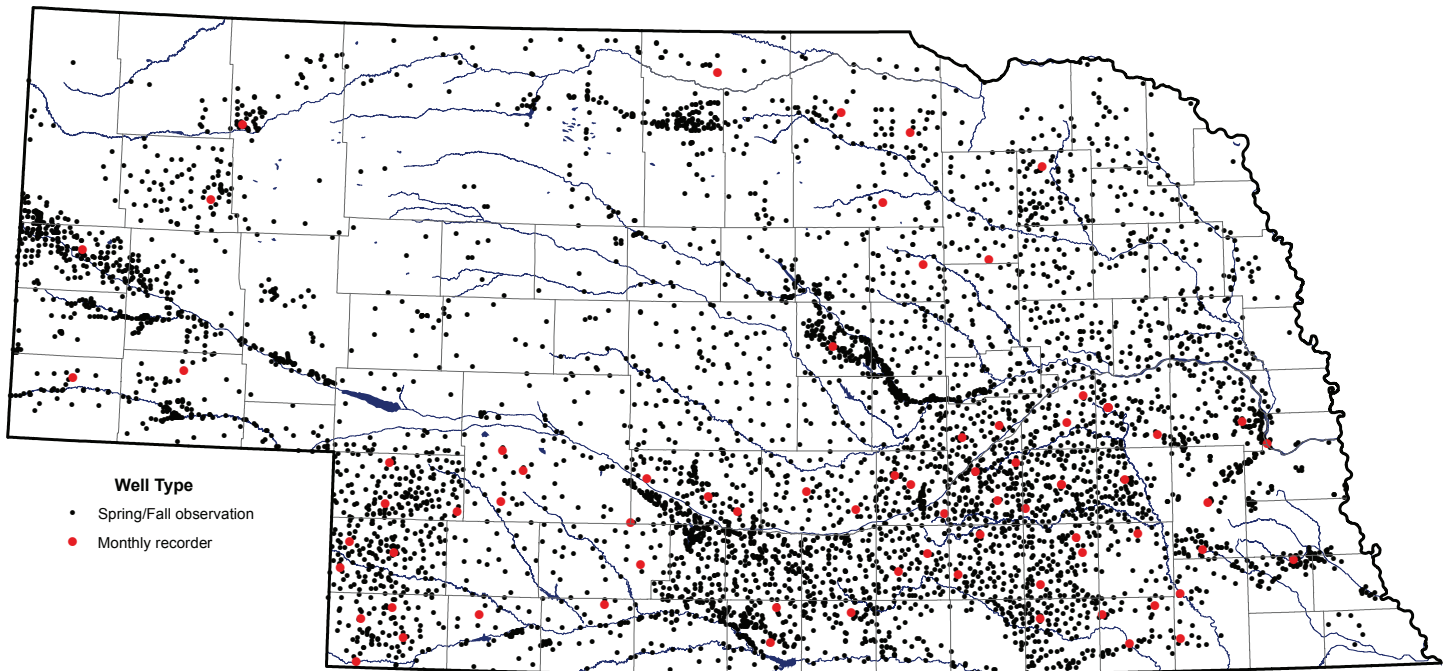
Groundwater-level changes can be observed at many different temporal scales (Fig. 6). Changes may occur over several minutes or hours in response to pumping, floods, or earthquakes. Long-term changes may occur due to the cumulative effects of pumping over many irrigation seasons, prolonged droughts or periods of high rainfall, or seepage from man-made water bodies. Similarly, groundwater levels can be observed at multiple spatial scales. For example, groundwater levels decline around the immediate vicinity of an individual well during pumping, but also from the cumulative effects of many irrigation wells pumped over many irrigation seasons at the scale of an entire regional aquifer. Groundwater levels rise along the banks of a stream during a flood, but may also rise significantly over an entire drainage basin during a prolonged wet period. The temporal and spatial scales of observation must be taken into account when using the maps presented in this report.

The maps presented in this report were generally created at a scale of 1:500,000. They are intended to identify regional trends at medium and long-term time scales throughout the entire state of Nebraska. As such, these changes chiefly reflect the interplay between precipitation, groundwater pumping, and artificial recharge from reservoirs and canals.

**Figure 4. Counties, Major Cities, and Streams of Nebraska**

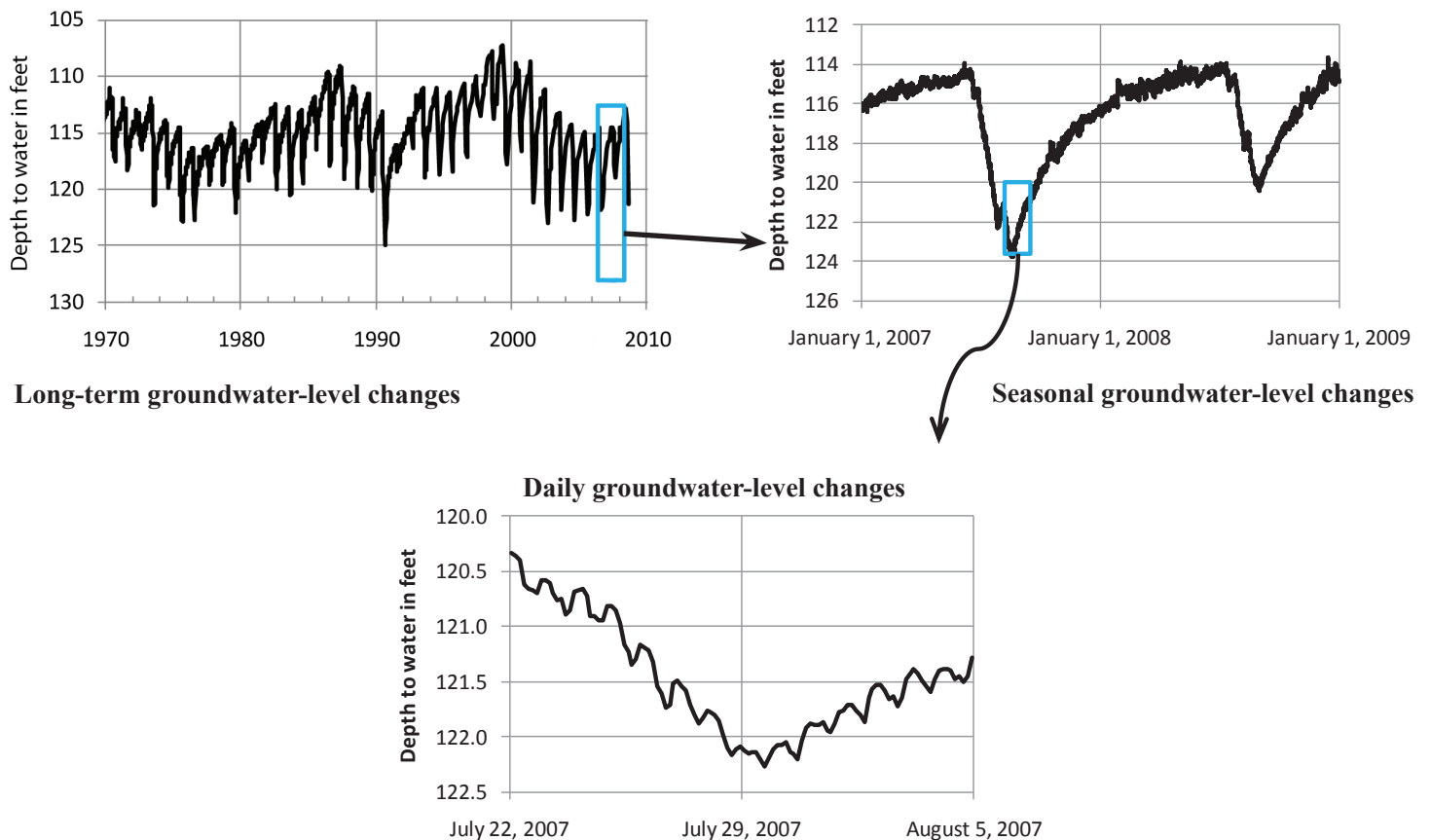


**Figure 5. Locations of Spring/Fall and Monthly Observation Wells**



*Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District; Conservation and Survey Division, School of Natural Resources, University of Nebraska–Lincoln*

**Figure 6. Example of Groundwater-Level Changes at Different Temporal Scales**



*Based on data from Plymouth Recorder well, Jefferson County*

## CHANGES IN GROUNDWATER LEVELS, SPRING 2011 TO SPRING 2012

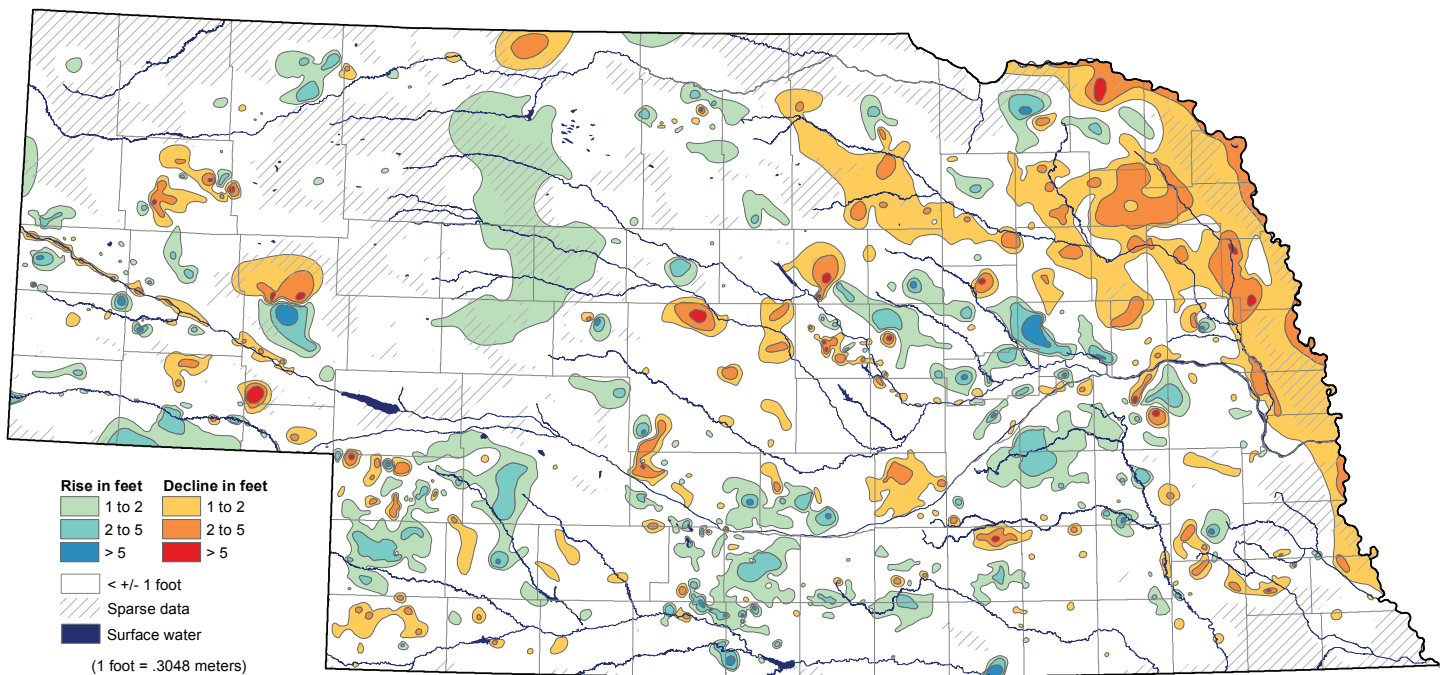
*From the spring of 2011 to the spring of 2012 about an equal number of groundwater rises and declines were recorded in wells throughout the state.*

From the spring of 2011 to the spring of 2012 about an equal number of groundwater rises and declines were recorded in wells throughout the state. Rises were recorded in 54% of wells, with rises of greater than one foot measured in 18% of all wells. The largest contiguous area of the state with a groundwater level increase greater than one foot occurred in the central Sand Hills where precipitation was 120-160% of the 30 year average. A rise of greater than five feet was recorded in central Garden County, where groundwater is moving slowly downslope through the aquifer as a result of a particularly wet 2009 and 2010. Groundwater-level rises in Chase, Cheyenne, Hayes and Lincoln Counties were the result of reduced pumping stress on aquifers due to above normal precipitation during the growing season. Many other localized parts of the state also experienced groundwater-level rises, particularly in east-central and south-central parts of the state. Higher precipitation in many of these areas reduced the demand for water pumped from irrigation wells. Additionally, increased stream flow and increased aquifer recharge from above normal precipitation resulted in localized areas of groundwater-level rises.

Groundwater-level declines were recorded in 46% of measured wells, with declines of greater than one foot occurring in 15% of all wells. Most areas of groundwater level declines occurred along the Missouri River, and in the northeast portion of the state. Extremely high water levels on the Missouri River in 2009 and 2010 caused groundwater level increases in wells immediately adjacent to the river. With reduced flows during 2011, wells in the Missouri River Valley dropped on average two to five feet. During 2012, precipitation was 70-100% of the 30 average for much of eastern Nebraska. Greater demands for irrigation water combined with at or below normal precipitation resulted in water-level declines for much of northeastern Nebraska. Many other isolated areas experienced groundwater-level declines on a local level. Some of these areas were the result of reduced stream flows from 2010 to 2011, such as along the North Platte River, with other areas the result of small pockets of less than average precipitation or continued use of significant quantities of groundwater for irrigation.

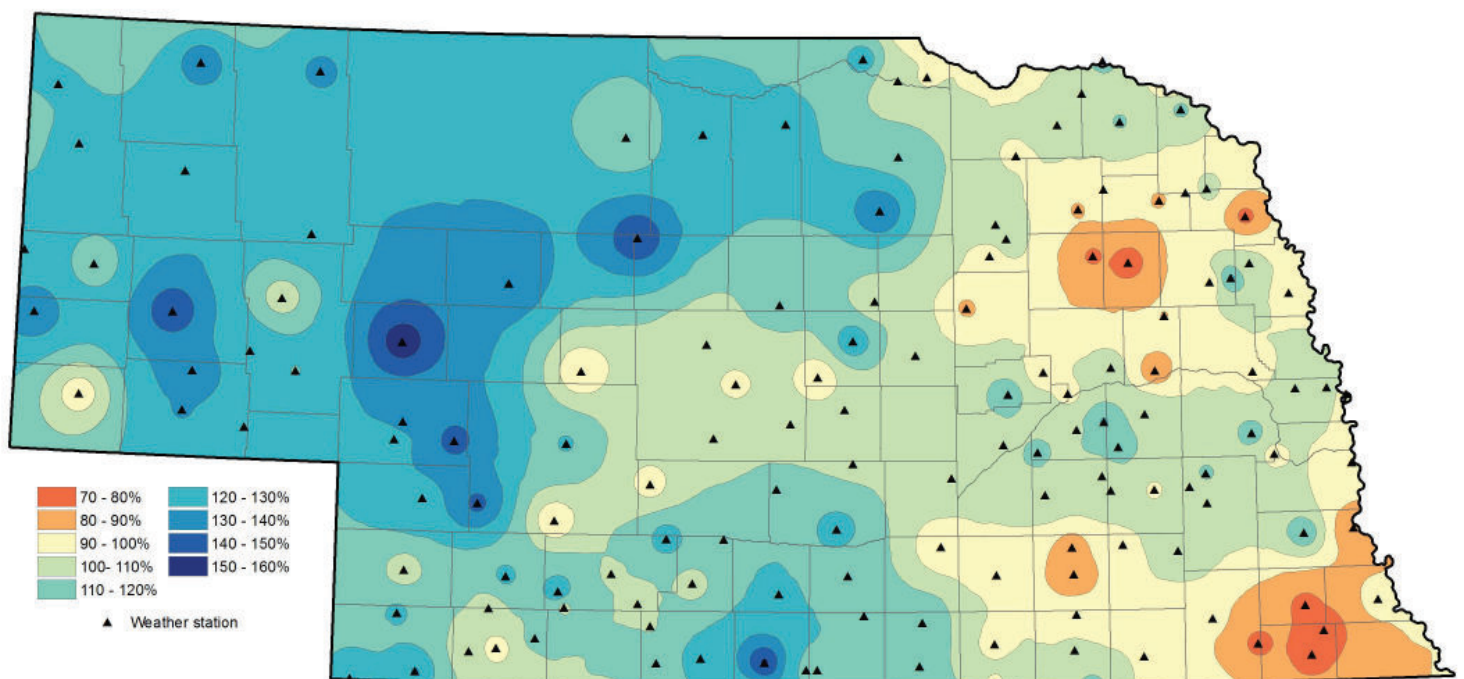


**Figure 7. Groundwater-Level Changes in Nebraska - Spring 2011 to Spring 2012**



*Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District; Conservation and Survey Division, School of Natural Resources, University of Nebraska–Lincoln*

**Figure 8. Percent of Normal Precipitation - January 2011 to January 2012**



*Sources: National Climate Data Center, Asheville, North Carolina; High Plains Regional Climate Center, University of Nebraska–Lincoln*

## CHANGES IN GROUNDWATER LEVELS, SPRING 2007 TO SPRING 2012

*During the five year period between 2007 and 2012, significant groundwater level increases were recorded for almost all of Nebraska.*

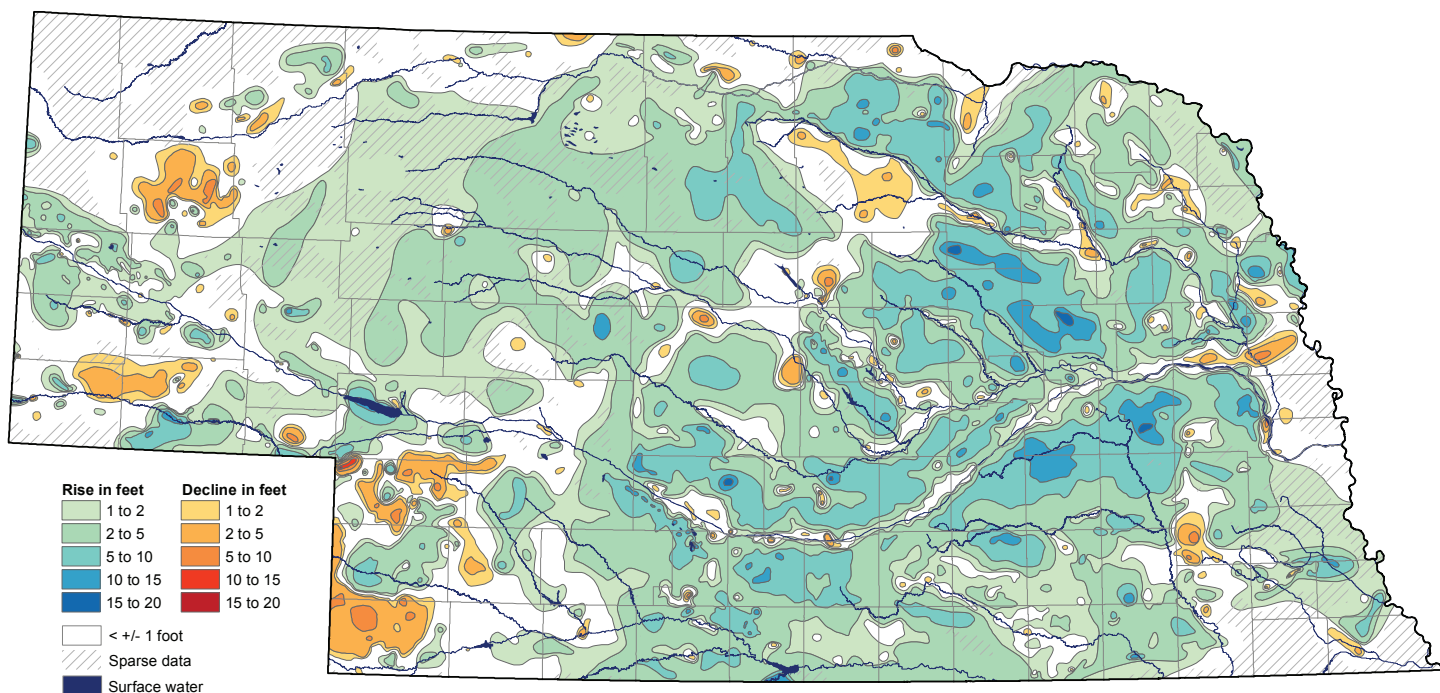
During the five year period between 2007 and 2012, significant groundwater level increases were recorded for almost all of Nebraska. Groundwater-level rises were recorded in 80% of all wells, with rises of greater than one foot recorded in 67% of wells. Precipitation was above normal for all of the state, with the exception of parts of Fillmore, Kimball and Scotts Bluff Counties. Significant areas with rises of greater than ten feet occurred in large portions of Butler, Polk, York, Platte, and Antelope Counties. Other smaller areas of rises of greater than ten feet occurred in northern Holt County, and other localized areas in central Nebraska. Groundwater-level rises from 2007 to 2012 resulted from a combination of factors, including increased flows in streams and canals, decreased irrigation withdrawals, and increased recharge to aquifers, compared to the several dry years prior to 2006 (c.f. Burbach, 2006). The relative importance of each factor in contributing to

the rises depends on the depth of the water table, density of irrigation wells, and degree of connection between groundwater and surface water. Rises in the Platte River Valley and the Sand Hills were largely driven by increased recharge to aquifers and higher flows in streams and canals, whereas decreased irrigation withdrawals probably account for most of the rises in other areas.

Groundwater-level declines between 2007 and 2012 were recorded in 19% of wells, with 12% of measured wells having declines of greater than one foot. Areas in the southern Panhandle and Box Butte, Perkins, and Dundey Counties experienced the most significant declines despite near normal to above normal precipitation for these areas. Declines persist in these areas because large amounts of irrigation water are still required for growing crops in dryer western portion of the state, even during years of normal precipitation.

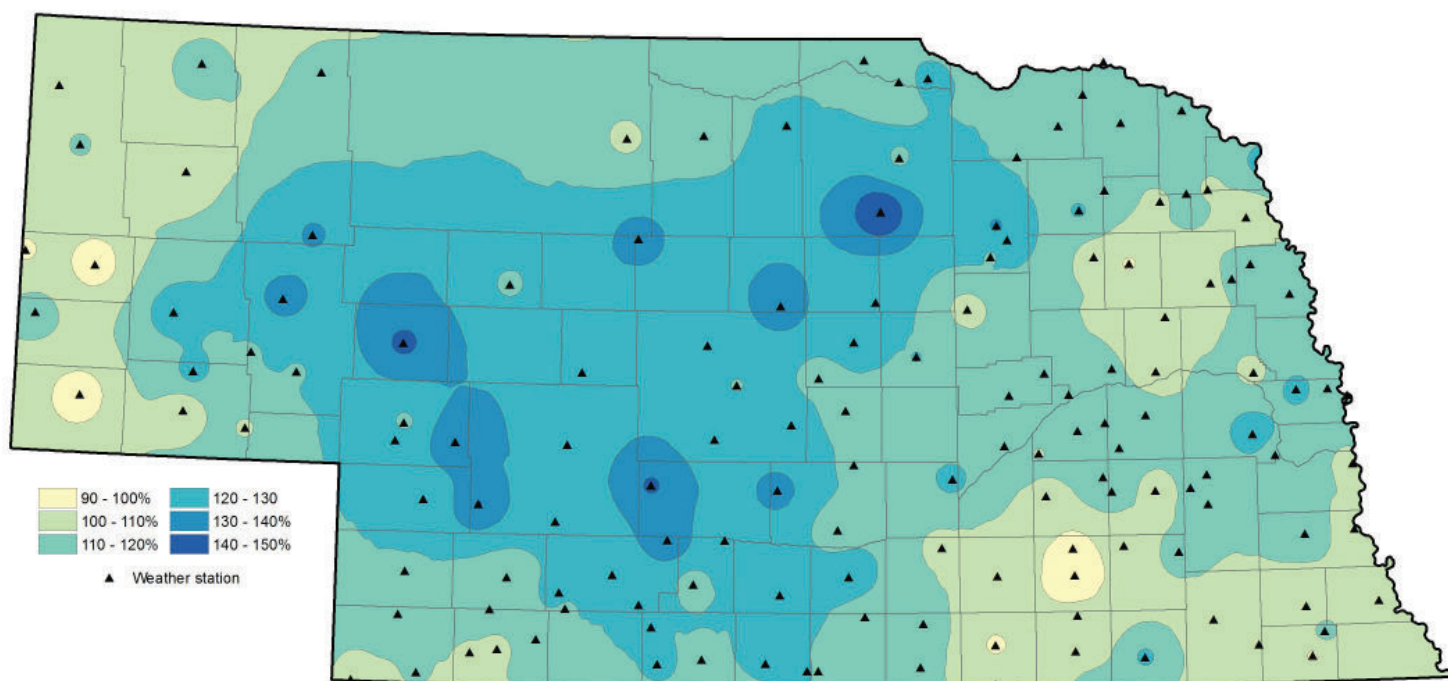


**Figure 9. Groundwater-Level Changes in Nebraska - Spring 2007 to Spring 2012**



*Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District*

**Figure 10. Percent of Normal Precipitation - January 2007 to January 2012**



*Sources: National Climate Data Center, Asheville, North Carolina; High Plains Regional Climate Center, University of Nebraska–Lincoln*

## CHANGES IN GROUNDWATER LEVELS, SPRING 2002 TO SPRING 2012

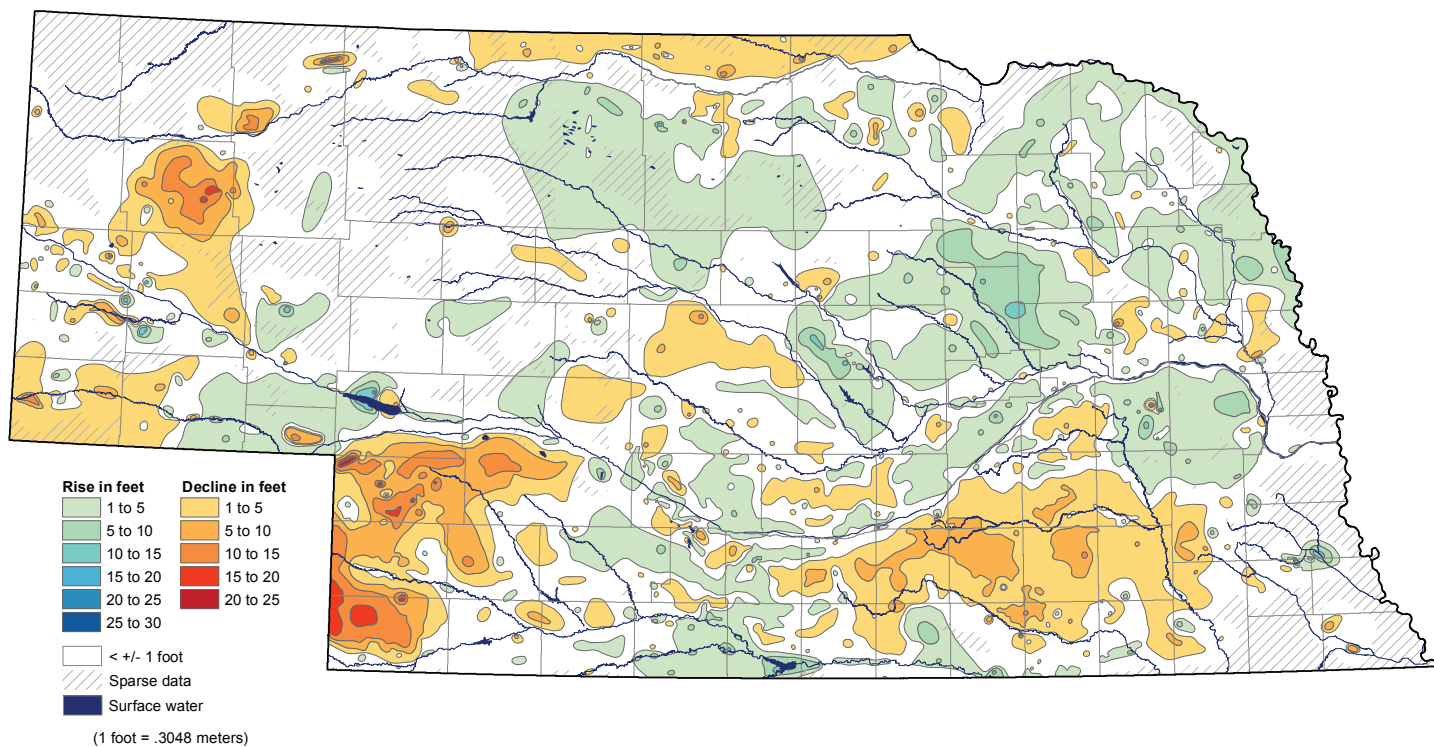
*Contrasting patterns of groundwater level changes over the past ten years reflect variations in the timing and locations of precipitation and irrigation withdrawals.*

Groundwater-level changes from 2002 to 2012 were dominated by two contrasting periods of change. Much of the Midwest and all of Nebraska except for the northeast part of the state were in a period of drought from 2000 to about 2007. During this time, Groundwater-level declines were recorded throughout the state of Nebraska (Burbach, 2007). Precipitation returned to above normal levels for the years between 2007 and 2012, causing groundwater levels to return to pre-drought levels in much of eastern and central Nebraska. Groundwater-level rises of one to five feet were recorded in many areas scattered throughout the state. Rises of greater than 10 feet were recorded in parts of Butler, Boone, Platte, Valley, Otoe, Garden and Scotts Bluff Counties. Increased flow in the North Platte River returned levels in Lake McConaughy to near full levels, causing rises in groundwater of more than 20 feet in the area surrounding the reservoir.

Despite four years of above average precipitation for the state, groundwater levels in some parts of the state

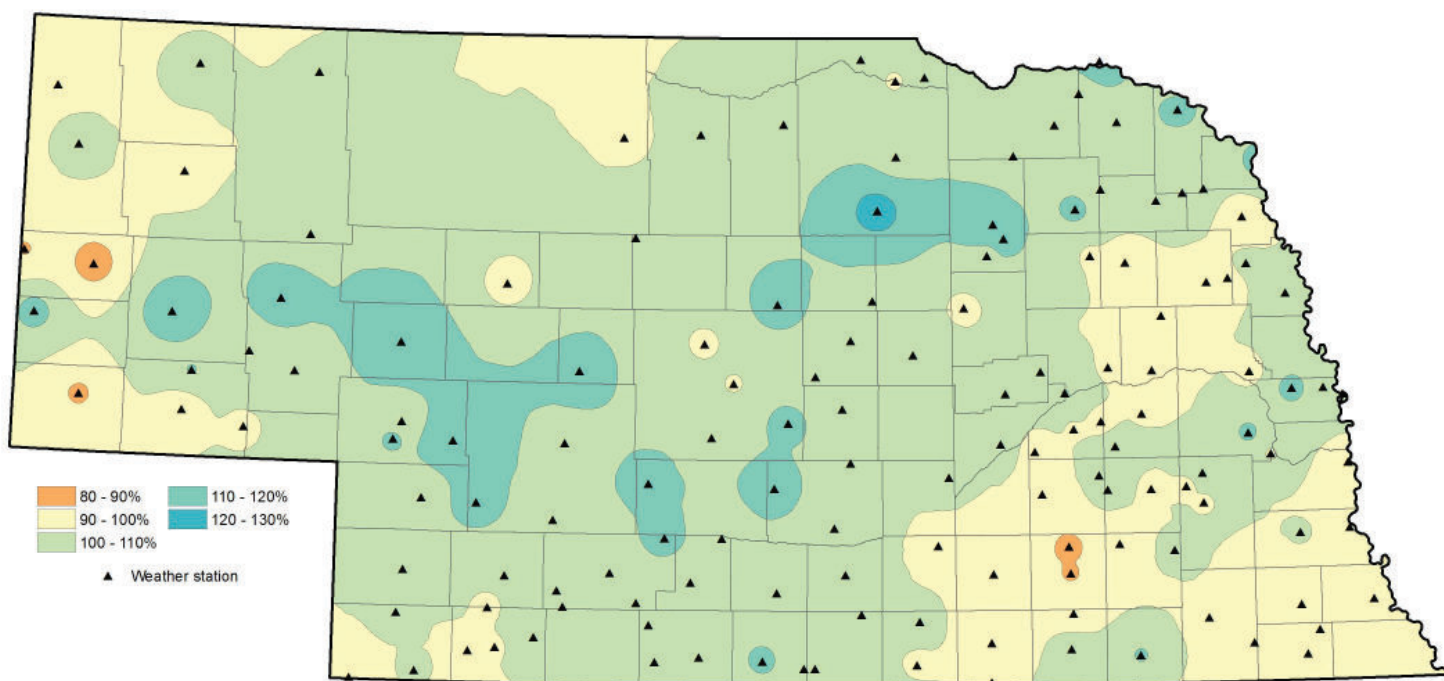
continue to decline. Major areas of groundwater-level decline include the South-Central Plains, Southwestern Tablelands and the Central Panhandle. Declines of more than five feet occurred over much of these regions, with declines of more than 20 feet occurring in parts of Box Butte, Perkins, Chase, and Dundy Counties. Water-level declines in these counties are largely the result of drawing large quantities of irrigation water from deep aquifers with little or no connection to surface water. At or below normal precipitation in the South-Central Plains, combined with a high density of irrigation wells per acre have resulted in declines of one to ten feet for much of the region. Other localized areas of groundwater level declines occurred throughout the state, which may result from a combination of factors including irrigation water withdrawals or reduced recharge from near normal to slightly below normal precipitation on a regional scale.

**Figure 11. Groundwater-Level Changes in Nebraska - Spring 2002 to Spring 2012**



*Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District*

**Figure 12. Percent of Normal Precipitation - January 2002 to January 2012**



*Sources: National Climate Data Center, Asheville, North Carolina; High Plains Regional Climate Center, University of Nebraska–Lincoln*



## CHANGES IN GROUNDWATER LEVELS, PREDEVELOPMENT TO SPRING 2012

*Long-term groundwater-level changes in Nebraska primarily reflect aquifer depletion in areas of dense irrigation development and increases in storage due to seepage from canals and reservoirs.*

Spring 2012 groundwater levels continue to indicate long-term declines and rises in certain areas of Nebraska (Fig. 13). With a few exceptions, areas of significant groundwater level declines generally correspond to areas where irrigation well density is high and aquifers are deep and have little or no connection to surface water (Fig. 14). The largest groundwater-level declines from predevelopment to spring 2012 occurred in the Southwestern Tablelands and the Panhandle Tablelands. Some smaller areas of declines occurred in the extreme southern East-Central Dissected Plains and the South-Central Plains. The largest rises occurred in Gosper, Phelps, and Kearney Counties in the South-Central Plains and in the East-Central Dissected Plains; both are areas where canals and surface irrigation systems exist.

The predevelopment groundwater levels used in the Southwestern Tablelands are representative of the approximate average water levels prior to 1953. Available data indicate that, as a result of intensive use of groundwater for irrigation, a general trend of declining water levels began in about 1966. Predevelopment water levels used to develop the groundwater-level change map in Box Butte County are the approximate average water levels prior to 1946. Intensive groundwater development for irrigation since 1950 has caused water-levels to decline 5 to more than 70 feet from predevelopment levels (Fig. 13). Records from recorder wells in both areas indicate that rates of decline have been more or less steady despite changes in groundwater management practices, water use allocations, and fluctuations in the amount of annual precipitation (see Korus and Burbach, 2009b and forthcoming section).

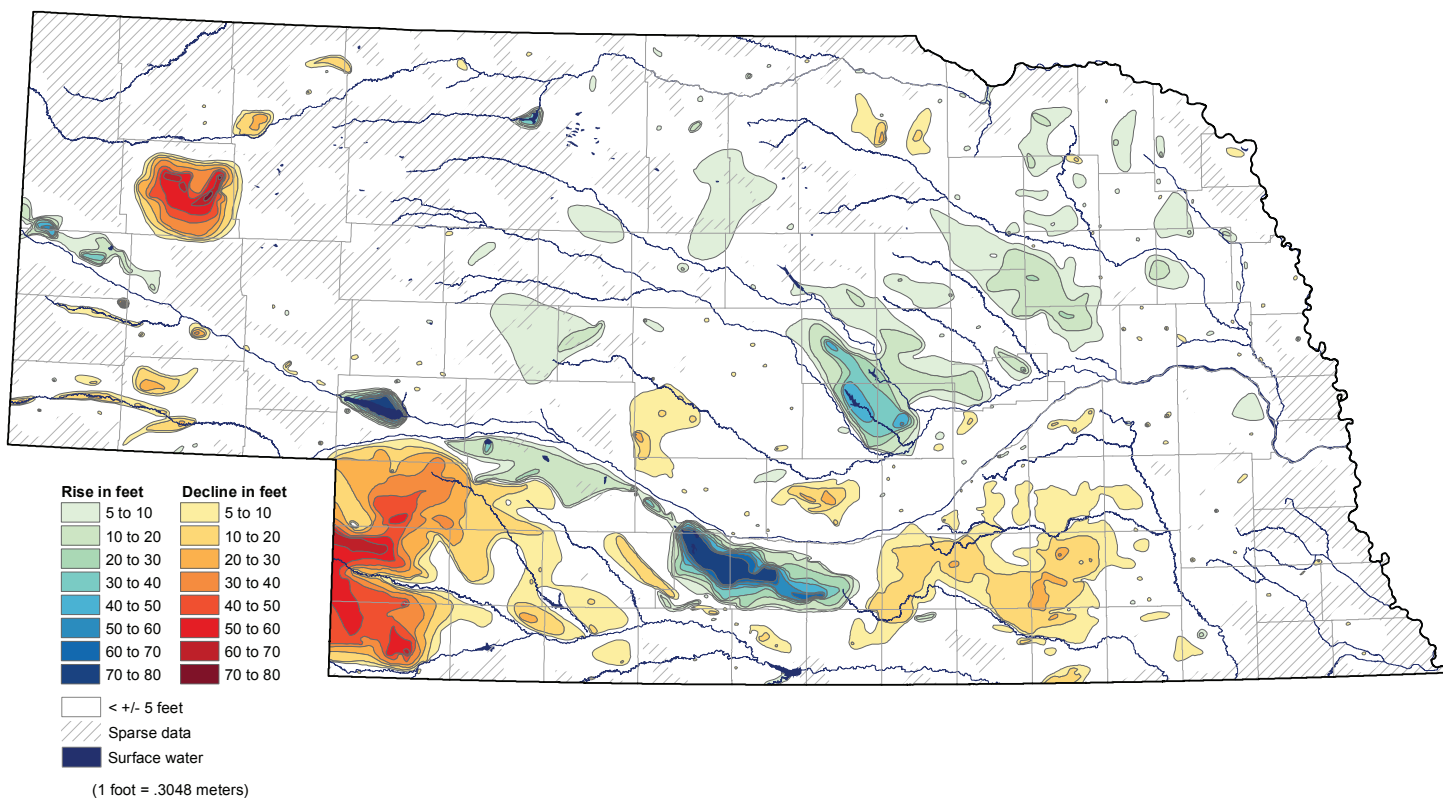
A large portion of the South-Central Plains has experienced long-term groundwater-level declines since predevelopment (Fig. 13). Predevelopment water levels in this area are generally representative of the approximate average water levels prior to 1950. Groundwater levels in large parts of this region have declined more than 10 feet, and in some areas more than 20 feet, from predevelopment. Declines in other areas of the South-Central Plains are at least 5 feet from predevelopment. The declines in this region, however, are much less severe than in recent years (cf. Burbach, 2007).

Parts of other regions that experienced relatively large areas of decline include the East-Central Dissected Plains; Republican River Valley and Dissected Plains; Southern Panhandle Tableland; Northern Panhandle Tableland; and northeastern Sand Hills (Fig. 13). Irrigation well density is high in some, but not all, of these areas. Other factors such as aquifer characteristics, rates of recharge, and irrigation scheduling could be contributing to the declines.

Groundwater-level rises from predevelopment generally occurred in areas of surface irrigation systems. Storage of water in Lake McConaughy began in 1941, and seepage losses caused water-level rises of as much as 70 feet in nearby observation wells (Ellis and Dreeszen, 1987). Water levels generally stabilized by about 1950 and since then have fluctuated in response to changes in reservoir levels and precipitation (Johnson and Pederson, 1984). Water is released from storage in Lake McConaughy, is subsequently diverted from the Platte River near North Platte, and then flows through the Tri-County Canal and a series of reservoirs toward Dawson, Gosper, Phelps, and Kearney Counties, where it has been used for irrigation since 1941. Deep percolation of water from these irrigation-distribution systems and from excess water applied to crops has raised groundwater levels as much as 70 feet (Fig. 13). Groundwater levels have also risen in association with seepage from Sutherland Reservoir, Lake Maloney, and their associated canals in eastern Keith and central Lincoln Counties. Rises of as much as 60 feet in the Northern Panhandle Tableland region are also associated with irrigation canal systems.

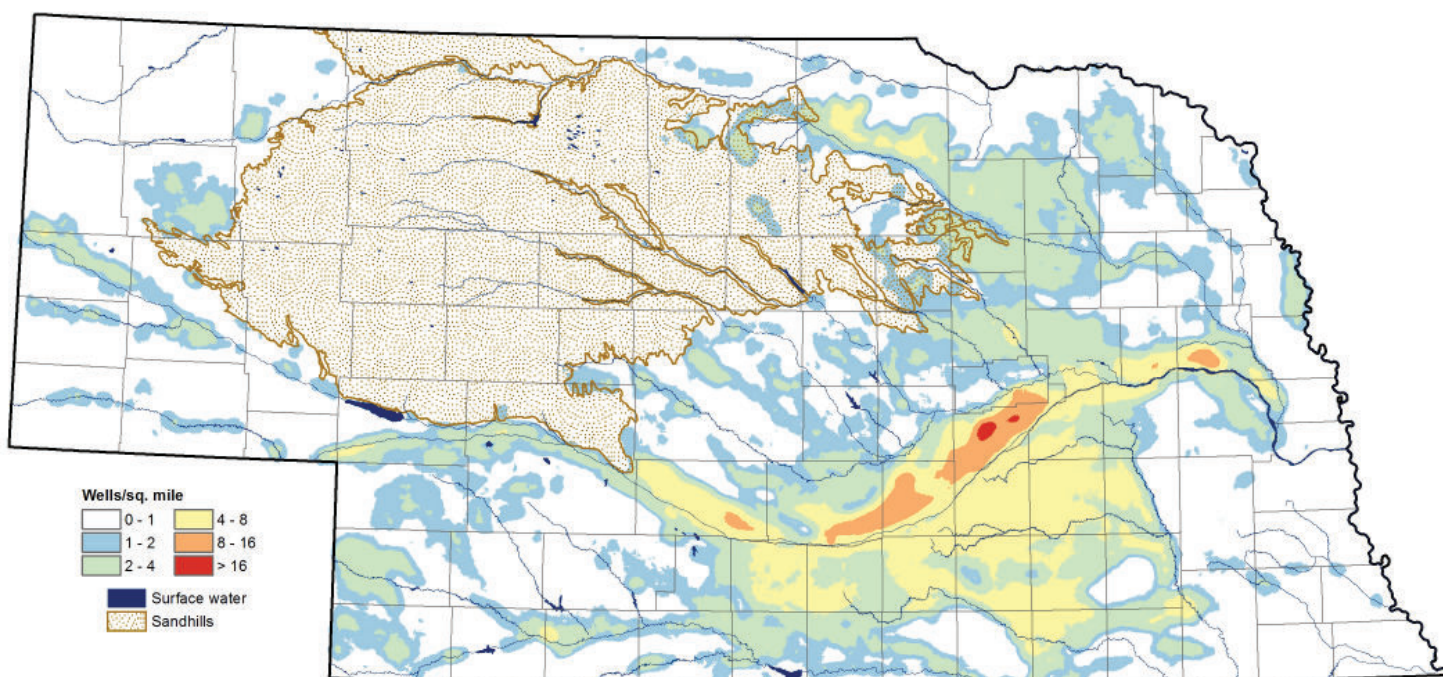
Groundwater-level rises of 10 to more than 60 feet occurred in portions of the East-Central Dissected Plains and Northeast Glacial Drift region (Fig. 13). The highest water-level rises occurred in Valley, Sherman, and Howard Counties as the result of seepage from irrigation canals, Sherman and Davis Creek Reservoirs, and deep percolation of irrigation water applied to crops. Eastward of that area, rises occurred in aquifers that are relatively deep, have little connection to surface water, and have high densities of irrigation wells. In other areas of Nebraska, this combination of factors has resulted in groundwater-level declines, so the rises in northeast Nebraska are most likely the result of higher than average precipitation spanning several decades.

**Figure 13. Groundwater-Level Changes in Nebraska - Predevelopment to Spring 2012**



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

**Figure 14. Density of Active Registered Irrigation Wells - December 2012**



Source: Nebraska Department of Natural Resources



## CHANGES IN GROUNDWATER LEVELS, PREDEVELOPMENT TO SPRING 1981 AND SPRING 1981 TO SPRING 2012

*Prior to 1981, groundwater levels were declining in nearly all areas of the State.  
After 1981, however, markedly different changes occurred in the east compared to the west.*

Groundwater-level changes from predevelopment to Spring 1981 reflect the responses of aquifers to the development of groundwater and surface water irrigation systems in Nebraska. Areas of significant groundwater-level declines generally corresponded to areas of dense irrigation well development (cf. Johnson and Pederson, 1981). Declines were generally equal in magnitude in eastern and western areas (Fig. 15). The largest areas in which declines occurred were in the Panhandle Tablelands, Southwestern Tablelands, South-Central Plains, Platte River Valley, East-Central Dissected Plains, and northeast portion of the Sand Hills. Declines exceeded 30 feet in Box Butte County in the Panhandle, Chase County in the Southwestern Tablelands, and Clay and Fillmore Counties in the South-Central Plains. Declines occurred in smaller areas of the Republican River Valley and Dissected Plains as well as the Northeast Glacial Drift region. Almost all groundwater-irrigated areas of Nebraska experienced declines associated with groundwater withdrawals. Such declines are a necessary response of the aquifer to development according to laws of hydrologic mass balance (see Korus and Burbach, 2009a).

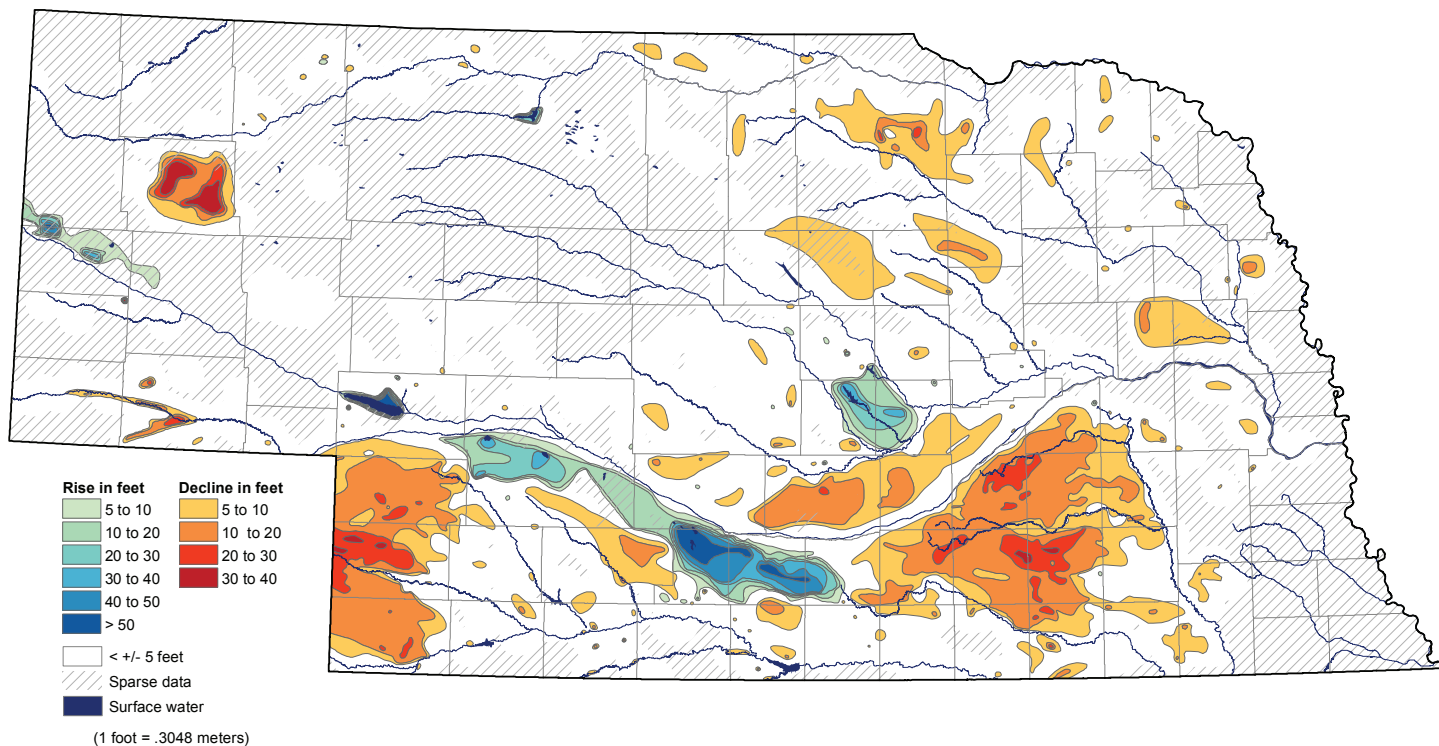
Groundwater-level rises from predevelopment to Spring 1981 were associated with irrigation canal systems and reservoirs (Fig. 15). The rise in southern Sioux and northern Scotts Bluff Counties was associated with seepage from the Interstate canal system, among numerous smaller systems, and excess water applied to crops beginning in the early 20th century. The rise in these counties exceeded 60 feet in some areas. The rise in Cherry County was associated with seepage from Merritt Reservoir beginning in the mid-1960s and exceeded 20 feet immediately adjacent to the reservoir. Seepage from Lake McConaughy beginning in 1941 caused groundwater levels to rise as much as 70 feet by 1981. Reservoirs and canals south of the Platte River, which are used for hydroelectric power production and irrigation, provided seepage that caused groundwater-levels to rise from eastern Keith County to western Kearney County (see discussion in previous section). Water levels began rising in this area after 1941 and had nearly reached their maximum by 1981. In the East-Central Dissected Plains, groundwater levels began rising in 1963 due to seepage from Sherman Reservoir, its irrigation-distribution system, and deep percolation of irrigation water applied to crops. Rises of 10 to more than 30 feet occurred in this area by 1981.

Compared to the changes discussed above, a much different pattern of groundwater-level changes has

emerged in Nebraska since 1981 (Fig. 16). In central and eastern Nebraska, areas in which declines had occurred from predevelopment to 1981 experienced rises of five to more than 20 feet from 1981 to 2012. This pattern of pre-1981 decline and post-1981 recovery is observed in many wells, including the Hastings Recorder well, which has a continuous record dating to the mid-1930's, and the Aurora Recorder well, which dates to the mid-1950's (Fig. 17). In areas such as the East-Central Dissected Plains, Northeast Glacial Drift region, and extreme eastern Sand Hills, a net rise in groundwater levels has occurred from predevelopment to 2012 (Fig. 13). Rises in areas such as Hall County in the Platte River Valley and Colfax and Dodge Counties in the northern Glacial Drift region erased earlier declines that were similar in magnitude, resulting in little or no observable change today.

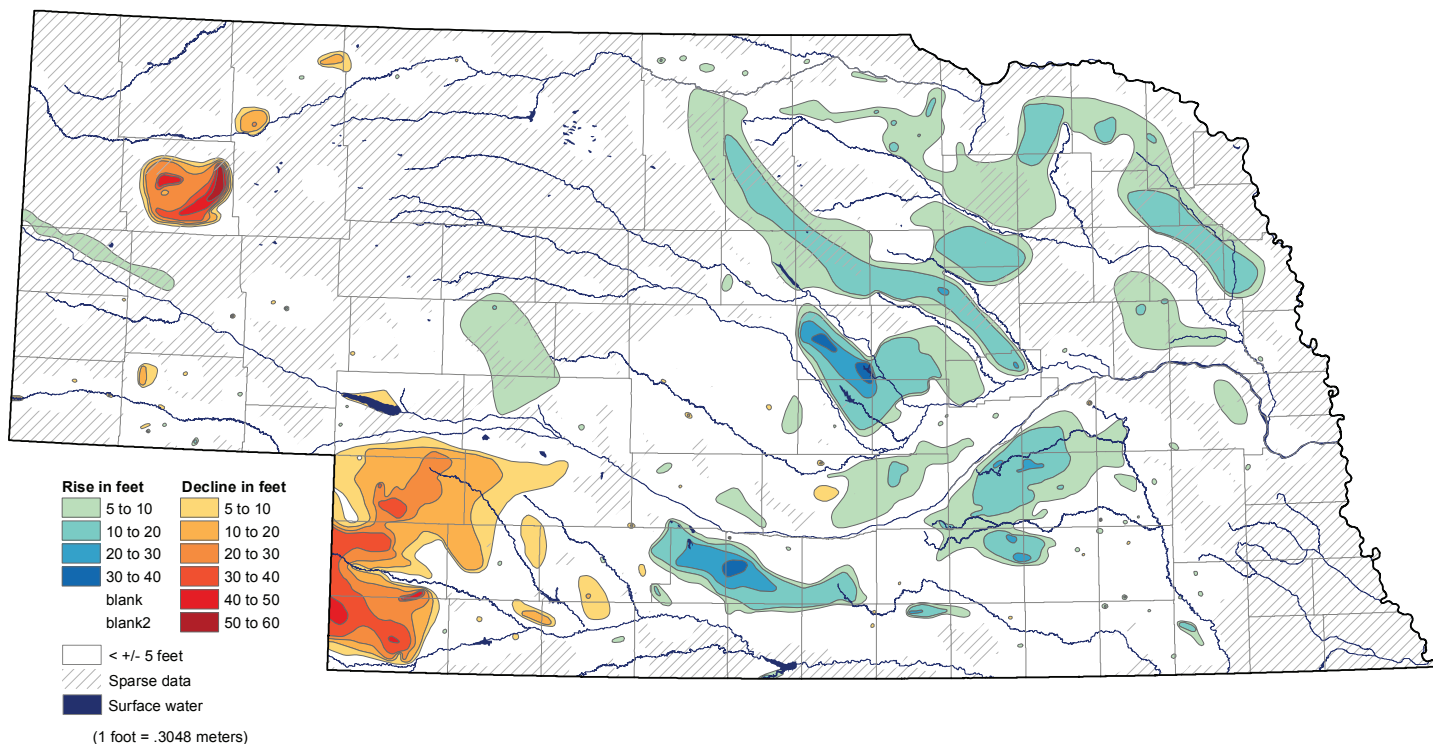
Declines in the South-Central Plains reached a maximum in 1981 and have since recovered such that changes in some areas are now less than five feet compared to predevelopment levels (Figs 13, 15, 16). Groundwater levels in most of this area, however, remain below predevelopment levels. It is hypothesized that the post-1981 recovery of groundwater levels in central and eastern Nebraska resulted from a combination of factors, including (1) reduced groundwater withdrawals during several long periods of above-average precipitation, (2) increased irrigation efficiencies that resulted in reduced pumping rates and volumes, and (3) stabilization of groundwater-levels as the aquifer equilibrated to the new hydrological conditions imposed on it by irrigation development decades earlier (see Korus and Burbach, 2009a). Another possible explanation for these rises may be related to increasing rates of recharge. In some areas, a shallow water table aquifer is separated from the primary aquifer by a confining layer. Irrigation during the first several decades after development was primarily by means of flooding along rows of crops. This method resulted in over-application and deep percolation, which thereby recharged the shallow aquifer. Evidence for this phenomenon is shown in the hydrograph for the Exeter Recorder Well, which is screened in the shallow aquifer (Fig. 17). The steady rise from 1956 to 1981 in this well corresponds to the steady decline observed in nearby wells that are screened in the deep aquifer. This excess water may have served as a source of new recharge to the primary aquifer in areas where the confining layer is sufficiently permeable.

**Figure 15. Groundwater-Level Changes in Nebraska - Predevelopment to Spring 1981**



Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

**Figure 16. Groundwater-Level Changes in Nebraska - Spring 1981 to Spring 2012**

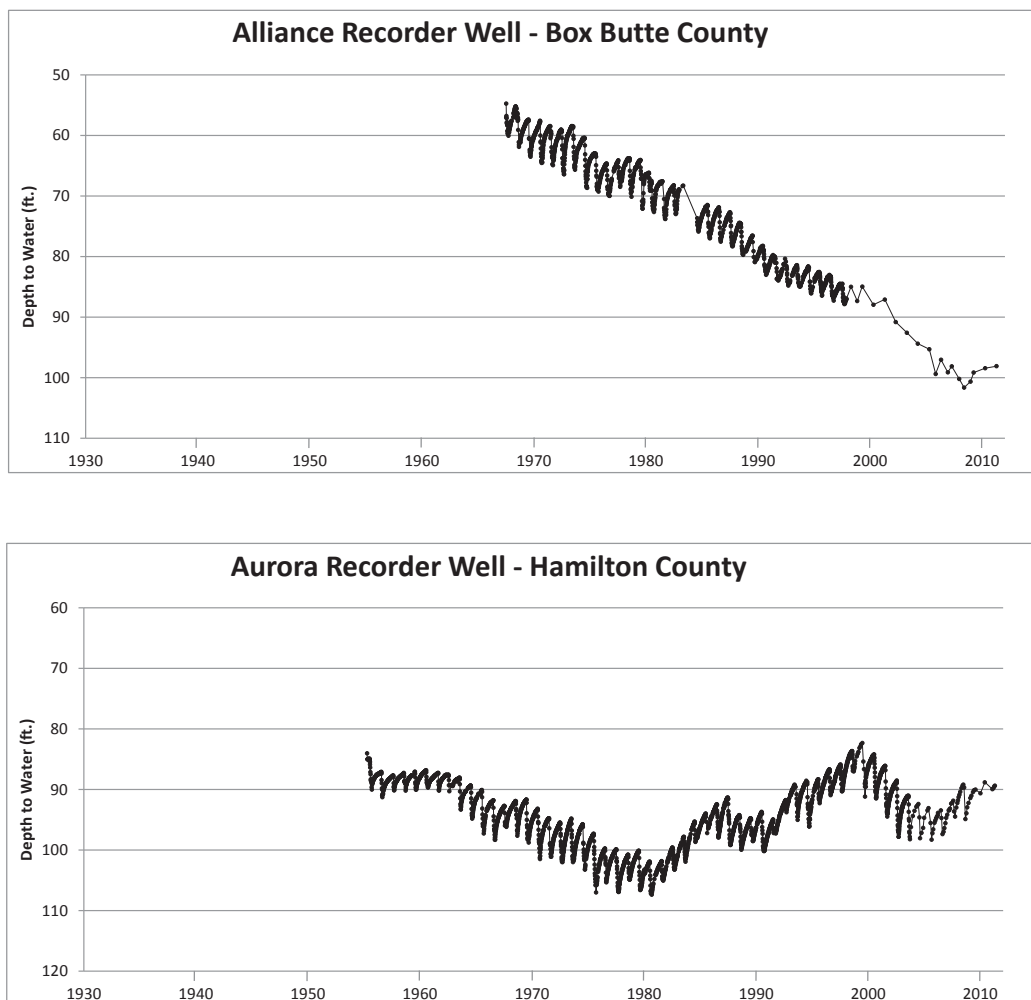


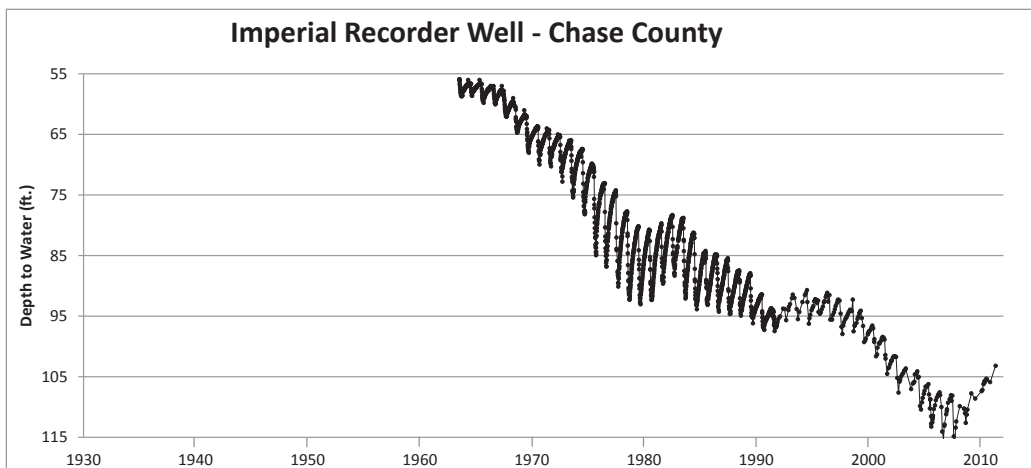
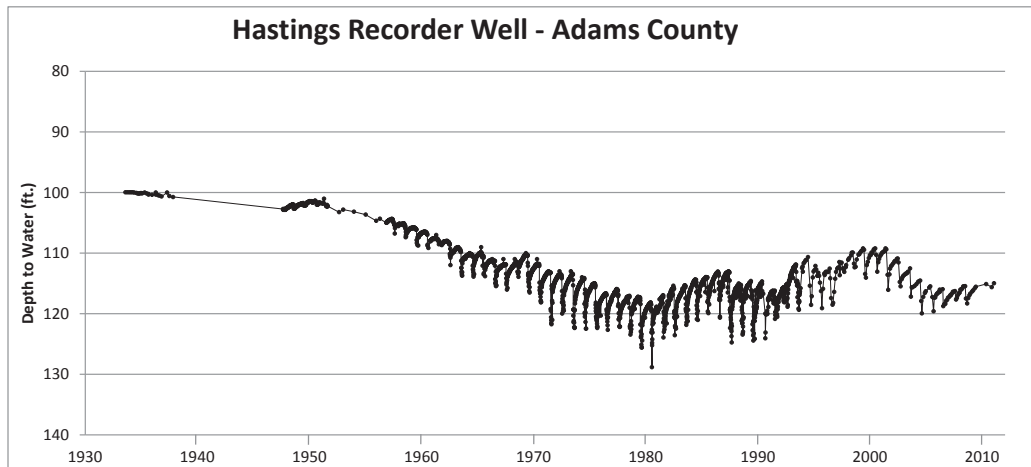
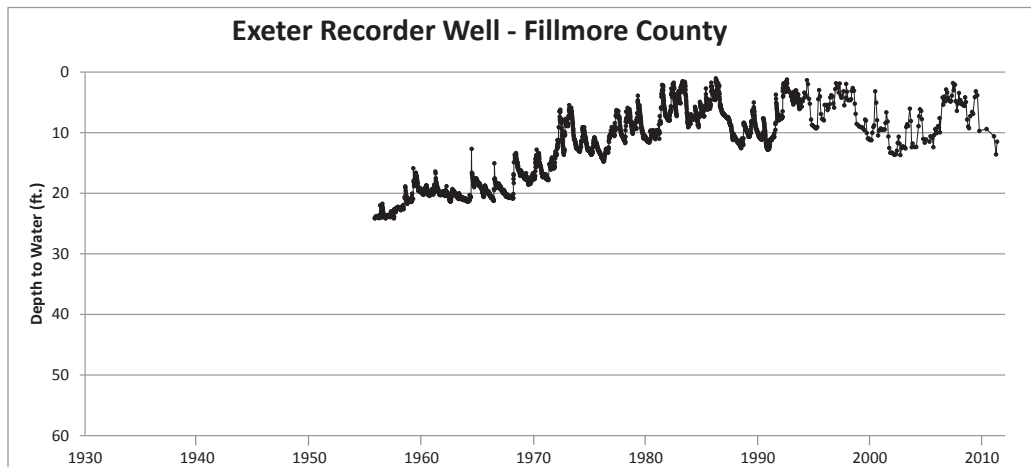
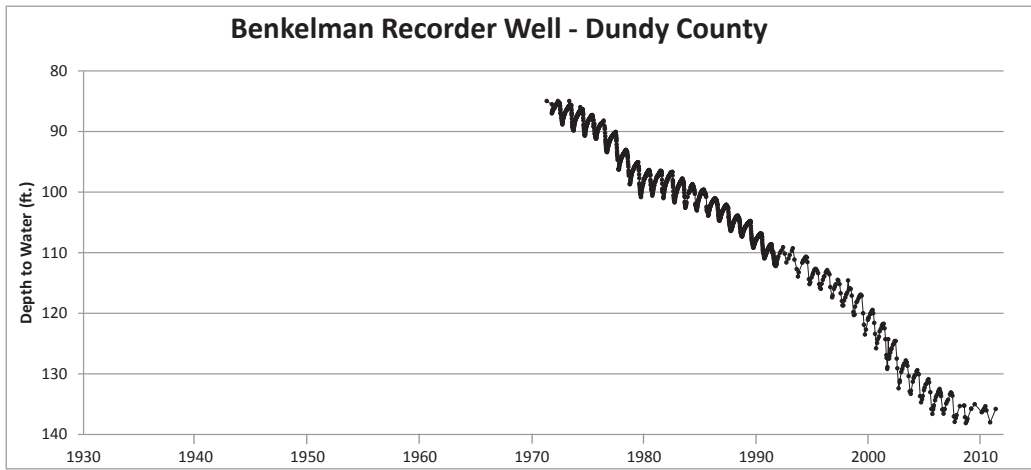
Sources: U.S. Geological Survey, Nebraska Water Science Center; U.S. Bureau of Reclamation, Kansas-Nebraska Area Office; Nebraska Natural Resources Districts; Central Nebraska Public Power and Irrigation District

In contrast to the groundwater-level rises in the east, levels continued to decline in parts of western Nebraska from 1981 to 2012 (Fig. 16). The Alliance, Benkelman, and Imperial Recorder wells show declines of 50 to 60 feet in just 50 years, an average of about 1 foot per year (Fig. 17). Brief periods of unchanging or rising groundwater levels occurred, but the rates of decline were steady overall despite changes in groundwater management practices, water use allocations, and fluctuations in the amount of annual precipitation over the past 30 years. The pattern of long-

term groundwater-level decline over a large region, such as the Southwest Tablelands and Box Butte County, is a normal response of aquifer to irrigation development. Such declines reflect the release of water from storage in the aquifer and the adjustment of the water table to new hydrological stresses (see Korus and Burbach, 2009a). These declines will stabilize only if groundwater withdrawals do not exceed the total yield of the aquifer, which is a function of its hydrogeological characteristics as well as its sources and rates of replenishment.

**Figure 17. Groundwater-Level Hydrographs typical of southeast and southwest Nebraska**





## AVERAGE DAILY STREAMFLOWS, 2010

*Above-average precipitation resulted in high streamflows throughout most of the State in 2010.*

The flows in Nebraska streams have several different sources. Snowmelt in the Rocky Mountains west of Nebraska provides springtime flows for the Platte River as it enters Nebraska. Variations in the amount of winter snowpack have a profound impact on discharges, but so also can the timing and amount of releases from dams in Nebraska, Wyoming, and Colorado. Runoff from precipitation is the source of many of the peak flows in Nebraska streams. Runoff is greatest on soils with low infiltration rates and/or high slopes. As such, many streams in eastern Nebraska have ‘flashy’ discharges characterized by high flows immediately following large precipitation events. Streams with headwaters in the Sand Hills are characterized by steady flows year-round because high infiltration rates in the sandy soils limit runoff and provide constant groundwater discharge to streams.

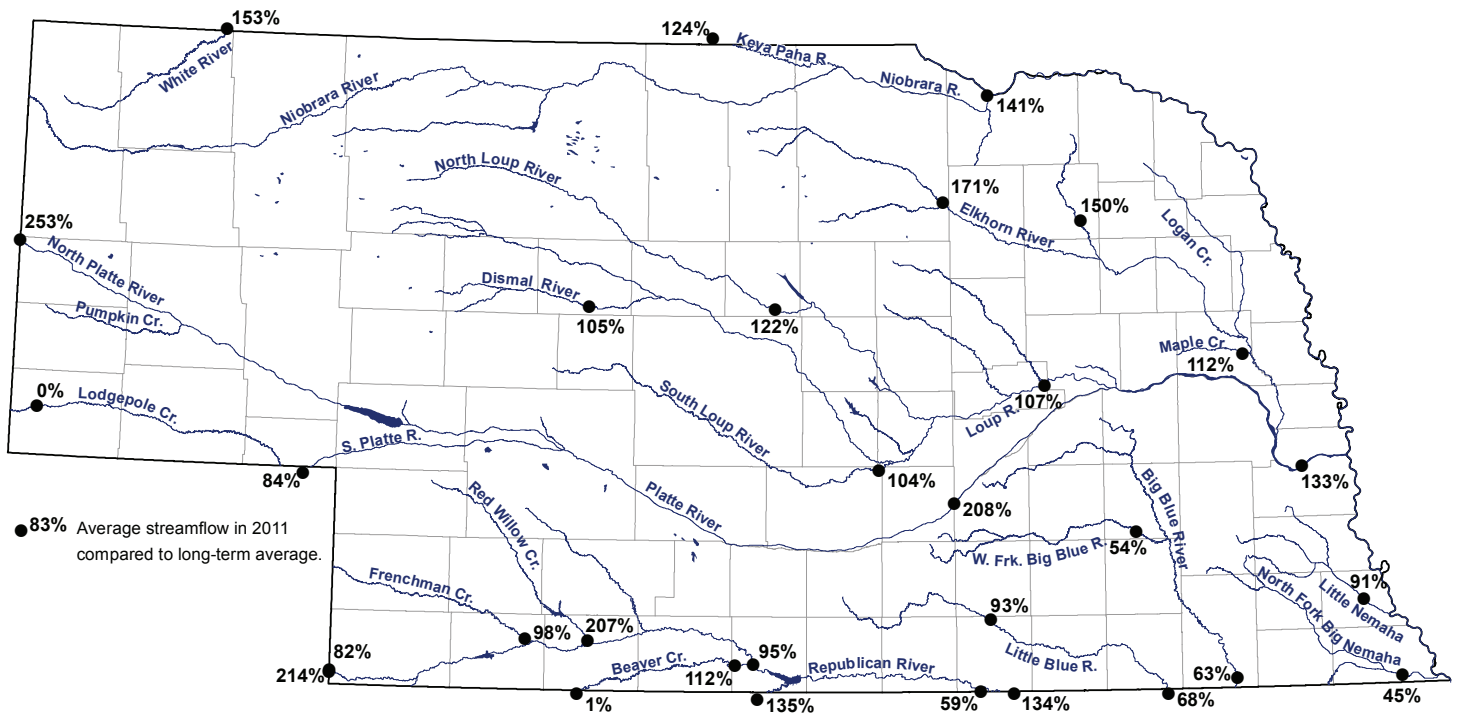
Average daily streamflow values were generally higher than the 30-year average for most of Nebraska’s streams

in water year 2011 (Fig. 18). In water year 2011, the flow of water on the North Platte River was 253% of the 30 year average at the State Line. These high flows resulted in flooding for the city of North Platte, as well as other smaller towns along the river. Flows were above average in most streams, except for streams in the southeast part of Nebraska, various tributaries of the Republican River, and the South Platte River at Julesburg, CO. Little or no flow was observed in Lodgepole Creek.

The factors affecting streamflows are numerous and complex. Nonetheless, groundwater-level declines in areas where streams are well-connected to aquifers have lowered or altogether halted flows to some streams that overlie the High Plains Aquifer (Sophocleous, 1998). Continued monitoring of groundwater-level changes throughout Nebraska is necessary in order to evaluate and manage these interconnected resources.



**Figure 18. Average Streamflow in Water Year 2011, as a Percentage of the 30-Year Average**



Sources: U.S. Geological Survey; Nebraska Water Science Center and Nebraska Department of Natural Resources

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<b>Year</b>	<b>Publication and Number</b>	<b>Author(s) and year published</b>
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ISBN 1-56161-025-9  
ISBN-13 978-1-56161-025-9