Final
Groundwater Evaluation Report
South Central Nebraska

Prepared for

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LIST OF ACRONYMS AND ABBREVIATIONS

CNPPID	Central Nebraska Public Power and Irrigation District
COHYST	Cooperative Hydrology Study
CSD	Conservation and Survey Division
DTM	Digital Terrain Model
EA	EA Engineering, Science, and Technology, Inc.
ET	Evapotranspiration
GIS	Geographic Information System
HU	Hydrostratigraphic Unit
NAD	North American Datum

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EXECUTIVE SUMMARY

The overall objective of this study was to provide a more thorough understanding of the groundwater mound in the vicinity of lands irrigated by Central Nebraska Public Power and Irrigation District (CNPPID) facilities. This information will assist CNPPID in making informed water resources management decisions.

ES.1 GENERAL

A prominent area of groundwater rise is located in the vicinity of the lands irrigated by CNPPID facilities. This area is generally referred to as the CNPPID "groundwater mound."

This study's area, time period, and method to determine the groundwater mound size and shape are described below.

This study's boundary includes a 1,620-square mile area that extends beyond the edges of the historic groundwater mound as shown on Figure ES-1.

Seven subareas were identified to represent areas of interest or key features. The subareas are as follows: Johnson Lake, Elwood Reservoir, E76 Canal, E65 Canal, Phelps Canal – Upper, Phelps Canal Middle, and Phelps Canal East. The subareas are shown on Figure ES-1.

This study's time period includes years 1954-2013 for long-term analysis and a more detailed evaluation for recent years (2000-2013).

A digital terrain model (DTM) of the groundwater mound was created using the University of Nebraska – Lincoln Conservation and Survey Division (CSD) yearly raw water level data.

CSD raw water level data are available from 1954 to 2013 and compare the yearly water level to the "pre-development" level. The pre-development level is defined by CSD as the estimated water levels that generally occurred before 1930s, 1940s, or early in the mid-1950s.

ES.2 GROUNDWATER MOUND TRENDS

The following trends in the growth and the decline of the groundwater mound were observed.

The volume of the groundwater mound was estimated for each year from 1954 through 2013. The general long-term trend through 2000 has been an increasing total groundwater mound volume, with occasional periods of decline. The size of the groundwater mound was largest in 2000. After a decline through 2006, groundwater water levels continued to steadily increase through 2012, to levels slightly less than the maximum in 2000. The yearly groundwater mound volume is shown on Figure ES-2.

The trends of the groundwater mound were determined to a high level of confidence, but the actual volume of water in the groundwater mound is less certain. The uncertainty is because the volume of water that can be stored in the geology of the groundwater mound (specific yield) is estimated and small changes in specific yield result in large changes in water volume.

As the volume has increased and decreased, the shape of the groundwater mound has grown and declined somewhat symmetrical vertically and horizontally over the years, with more growth to the south than to the north.

The western subareas (E67 Canal, Elwood Reservoir, E65 Canal, Johnson Lake, and Phelps Canal Upper Subareas) only comprise 48 percent of this study's area, but contain approximately 75 percent of the groundwater mound volume.

Table ES-1 shows the groundwater mound volume and the groundwater mound volume per unit area for each subarea.

Table ES-1 Subarea Groundwater Mound Volumes

Subarea	Area (sq. mi.)	2013 Groundwater Mound Volume (ac-ft)	2013 Groundwater Mound Volume per Unit Area (ac-ft/sq. mi.)
E67 Canal	16	127,240	7,953
Elwood Reservoir	250	1,012,747	4,051
E65 Canal	387	1,444,703	3,733
Johnson Lake	93	344,489	3,704
Phelps Canal Middle	329	502,860	1,528
Phelps Canal East	513	479,332	934
Phelps Canal Upper	32	14,543	454

The western subareas, except Phelps Canal Upper, have a significantly higher groundwater mound volume per unit area than the eastern subareas. The Phelps Canal Upper Subarea groundwater mound volume per unit area is much lower than the other western subareas because it is located on the edge of the groundwater mound. Conversely, the E67 Canal Subarea groundwater mound volume per unit area is much higher than the other subareas because it is located near the center of the groundwater mound and no portion of the subarea is beyond the edge of the groundwater mound.

During the years 1954 through 1970, the volume of the groundwater mound continued to grow despite years of varying annual precipitation. Throughout this study's time period, the groundwater mound's response to annual precipitation has varied. In some years of unusually high precipitation, the groundwater mound volume has a noticeable increase during the following year; and, in some unusually dry years, the groundwater mound volume has a noticeable decrease during the following year. However, there are many instances where the response is minimal or not apparent. Annual precipitation data was used to simplify the process, but annual data does not address factors that affect the individual storm events contribution to the groundwater mound. Numerous factors have an effect on the amount of rainfall from each storm event that will recharge the groundwater mound and the amount of rainfall that will runoff and be conveyed out of the area.

The number of registered irrigation wells within this study's area has generally increased since 1954. The steepest increase was from 1954 through 1977. The number of wells continued to increase gradually from 1978 to 2001, with a sharp increase from 2002 to 2005. Since 2005, the number of irrigation wells has remained steady. In general, the continued increase in the number of registered irrigation wells coincides with the reduced steepness of growth of the groundwater mound volume. A comparison of the registered irrigation wells in the area to the groundwater mound volume is shown in Figure ES-4.

ES.3 WATER BALANCE

A water balance analysis was completed for this study's area for 1985-2012, and the following results were found.

Precipitation and diversions are the prominent factors for adding water to the system. Groundwater flux in, reservoir seepage, and surface water streamflow in are additional factors. Evapotranspiration and surface water streamflow out are the prominent factors for removing water from the system. Groundwater flux out and evaporation are additional factors.

The volume of the groundwater mound was used as the basis of comparison between the groundwater mound volume calculated using the CSD raw well data and groundwater mound volume calculated using the water balance. The CSD groundwater mound volume for 1985 was used as the starting point for the water balance groundwater mound volume. After 1985, the water balance groundwater mound volume was calculated using the previous year's water balance. Both the CSD groundwater mound volume and the water balance groundwater mound volume have similar response patterns to different periods of time. One noticeable difference in the fluctuations is that the groundwater mound volume as calculated by the water balance rises and falls more rapidly than the groundwater mound volume determined by the CSD well data. Comparison of the water balance groundwater mound volumes and the CSD groundwater mound volumes are shown on Figure ES-5.

The amount of ET in this study's area is the largest factor for reducing water within the system. To evaluate the effects that changes to ET would have on the groundwater mound, the water balance groundwater mound volumes were recalculated with a range of adjusted ET volumes. Figure ES-6 shows the groundwater mound volumes as determined by the water balance adjusted by altering the ET to 105, 102, 98, and 95 percent of the historic ET estimates compared to groundwater mound volumes as determined by an un-adjusted water balance and un-adjusted ET. The results are shown on Figure ES-6. The variations in ET are small because management practices would typically have a small impact on ET.

Precipitation is the largest factor in the water balance, but it was not adjusted because it cannot be controlled. The amount of water imported into this study's boundary through surface water diversions is the second largest factor for adding water to the system. To evaluate the effects that changes to diversions would have on the groundwater mound, the water balance groundwater mound volume was recalculated with adjustments to the amount of water diverted. The historic diversions were adjusted to 125, 75, 50, 25, and 0 percent of the actual diversions and compared to unadjusted results. The results are shown on Figure ES-7.

ES.4 CONCLUSIONS

The following conclusions are presented related to the growth and decline of the groundwater mound:

- The groundwater mound has been increasing in size and volume for the last 60 years, but appears to be at a critical point where the general trend is no longer rising. The groundwater mound has not grown from 2000 to 2012 despite the average precipitation being slightly higher than the average precipitation for 1954-1999 for this study's area.

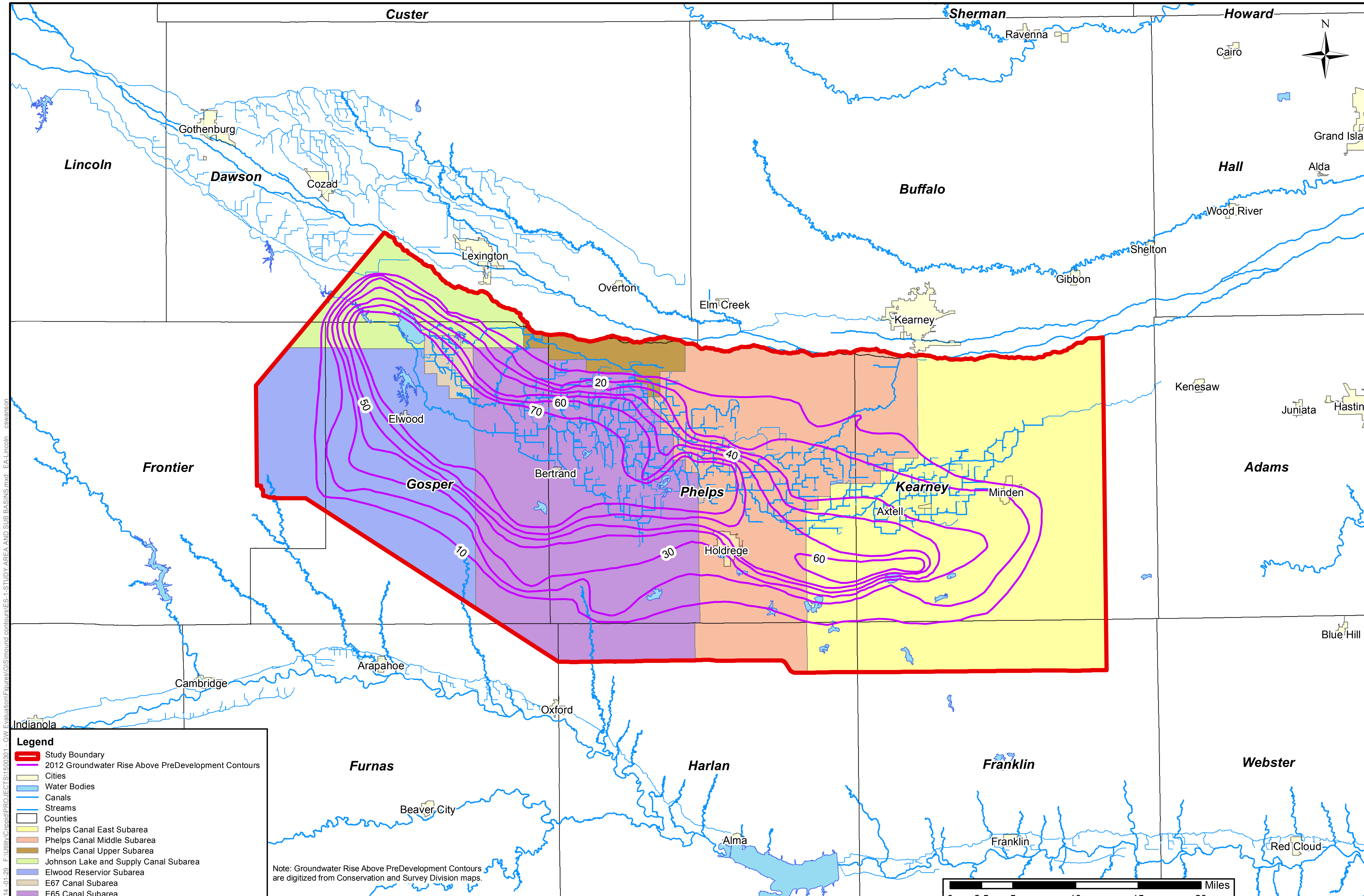
- The groundwater mound is growing the most in the western half of this study's area. Groundwater mound growth has been somewhat symmetrical horizontally and vertically, with more growth to the south than to the north.

- Precipitation is a significant factor in the water balance; however, the effects of both extremely low and high precipitation are dampened in the CSD groundwater mound volumes compared to the water balance groundwater mound volumes.

- Small alterations to ET across this study's area would have a significant impact on the groundwater mound.

- If diversions were eliminated or significantly reduced, the groundwater mound would significantly decrease. It also appears that even small reductions to current surface water diversions would lead to slow declines in the groundwater mound.

Executive Summary Figures



SUBAREAS WITH 2012 DIGITIZED GROUNDWATER MOUND CONTOURS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	ES-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	CNS
DESIGNED BY	CNS
PROJECT MGR.	DJS

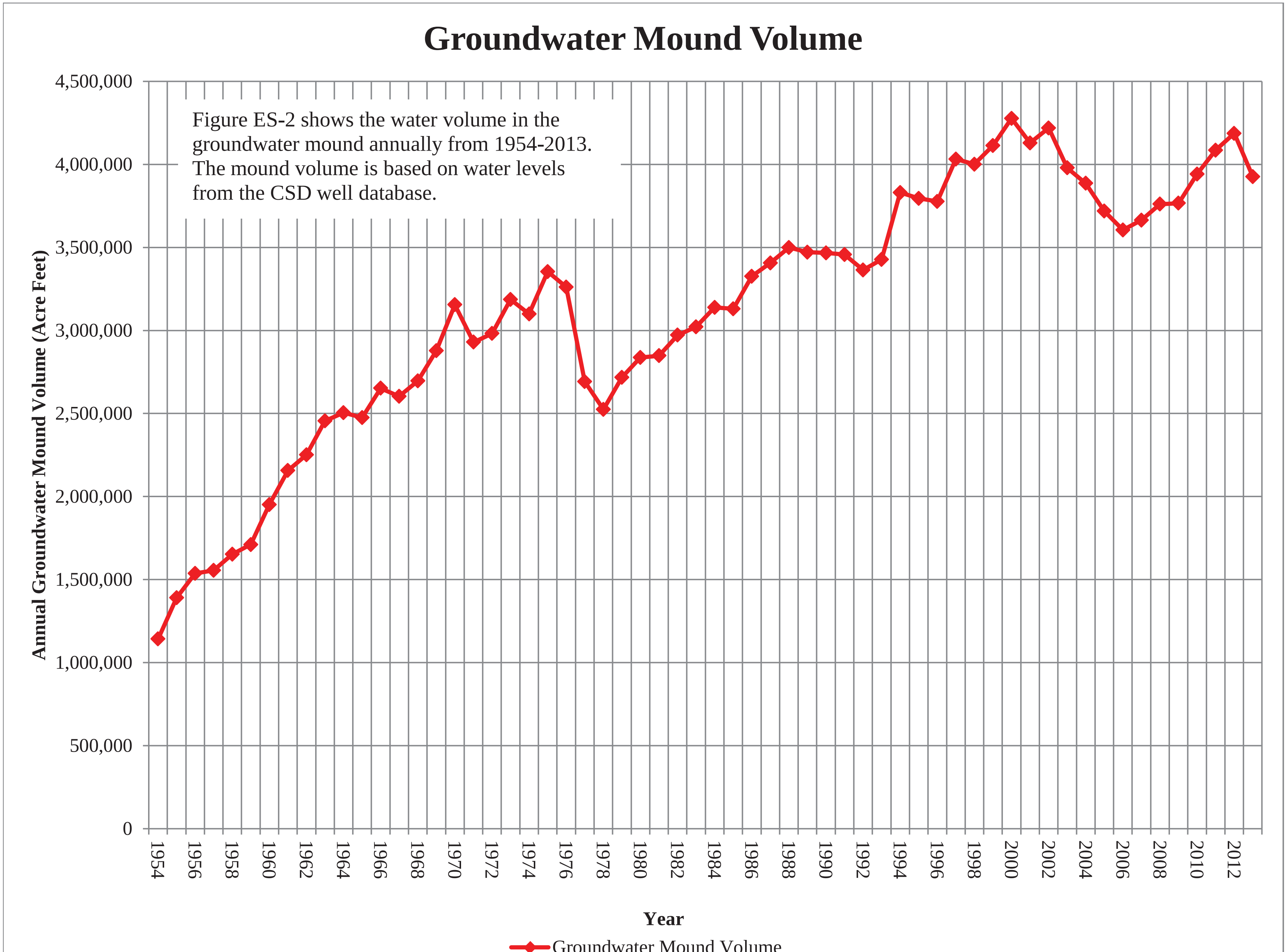


Figure ES-2. Calculated volume of the groundwater

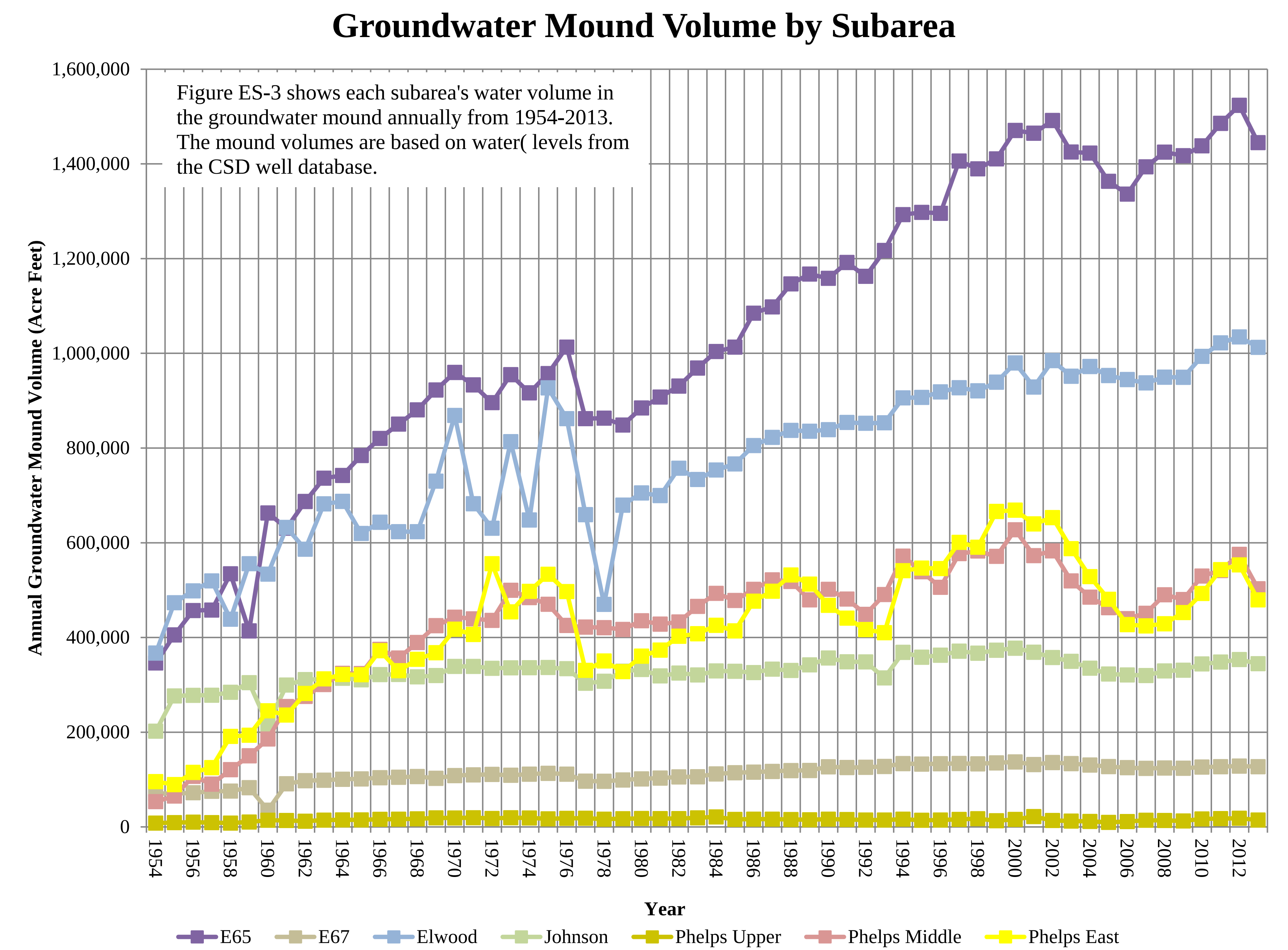


Figure ES-3. Calculated volume of the groundwater mound in each subarea.

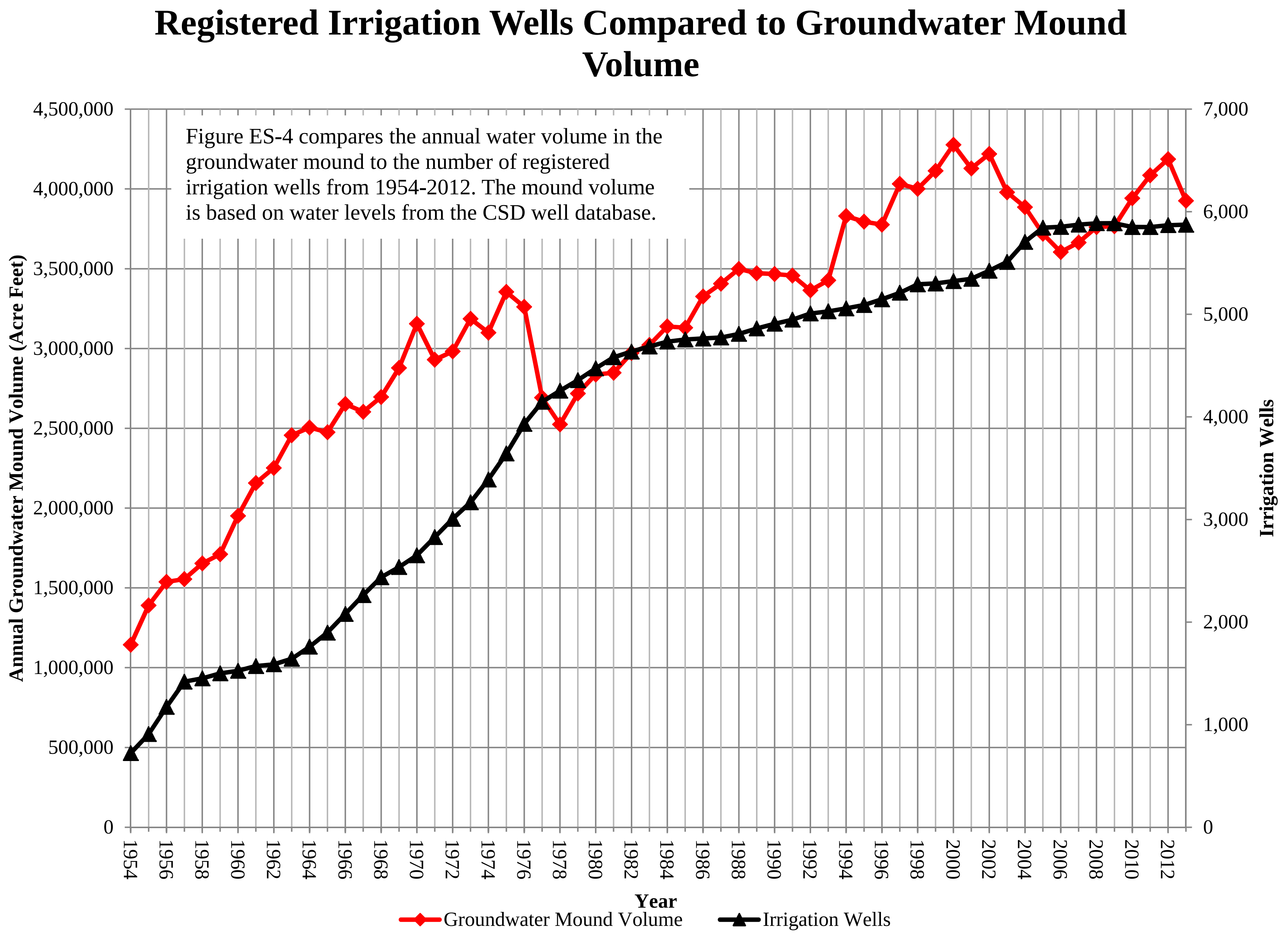


Figure ES-4. Registered irrigation wells in the study area.

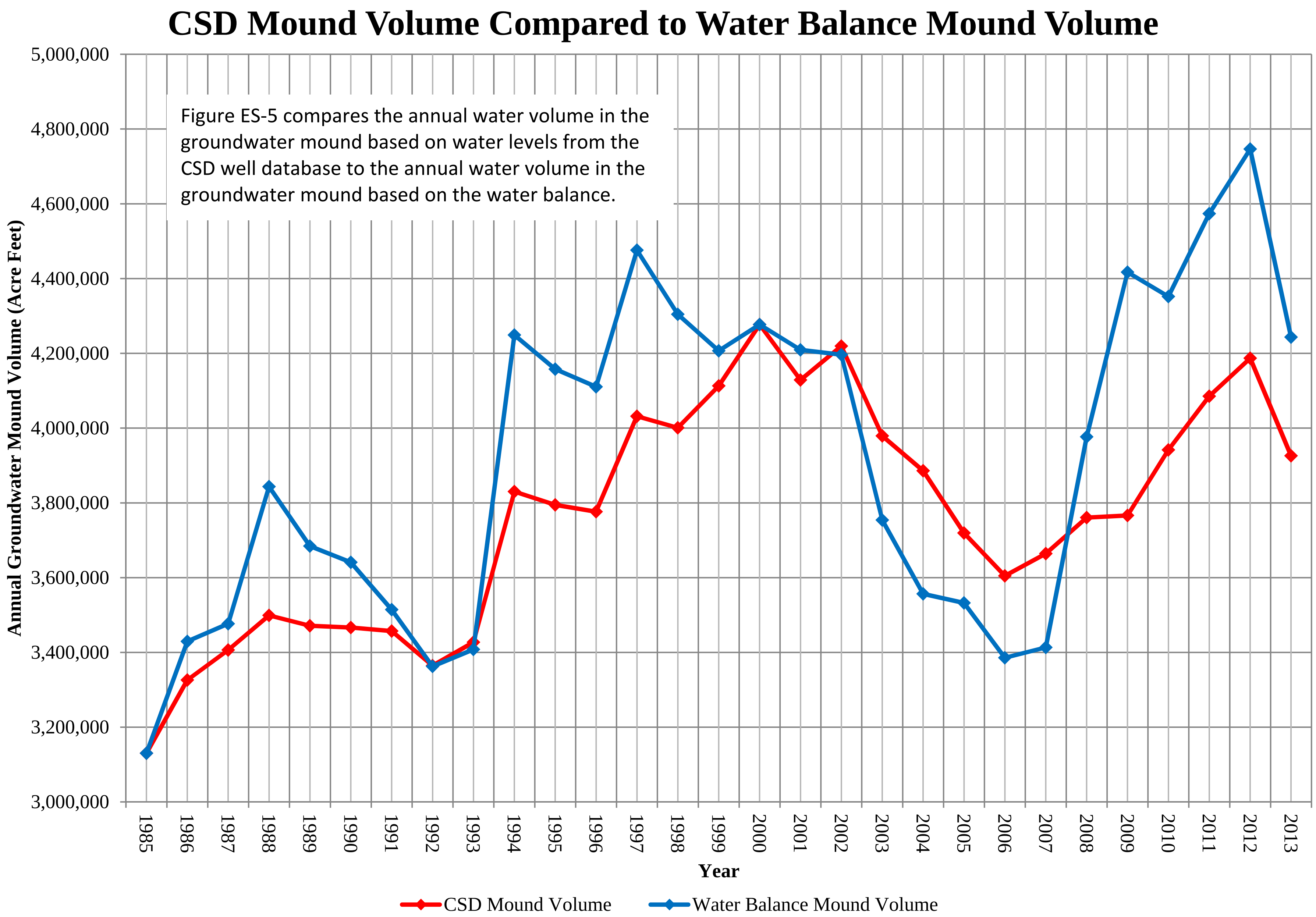


Figure ES-5. Comparison of the calculated water balance mound volume and the CSD mound volume.

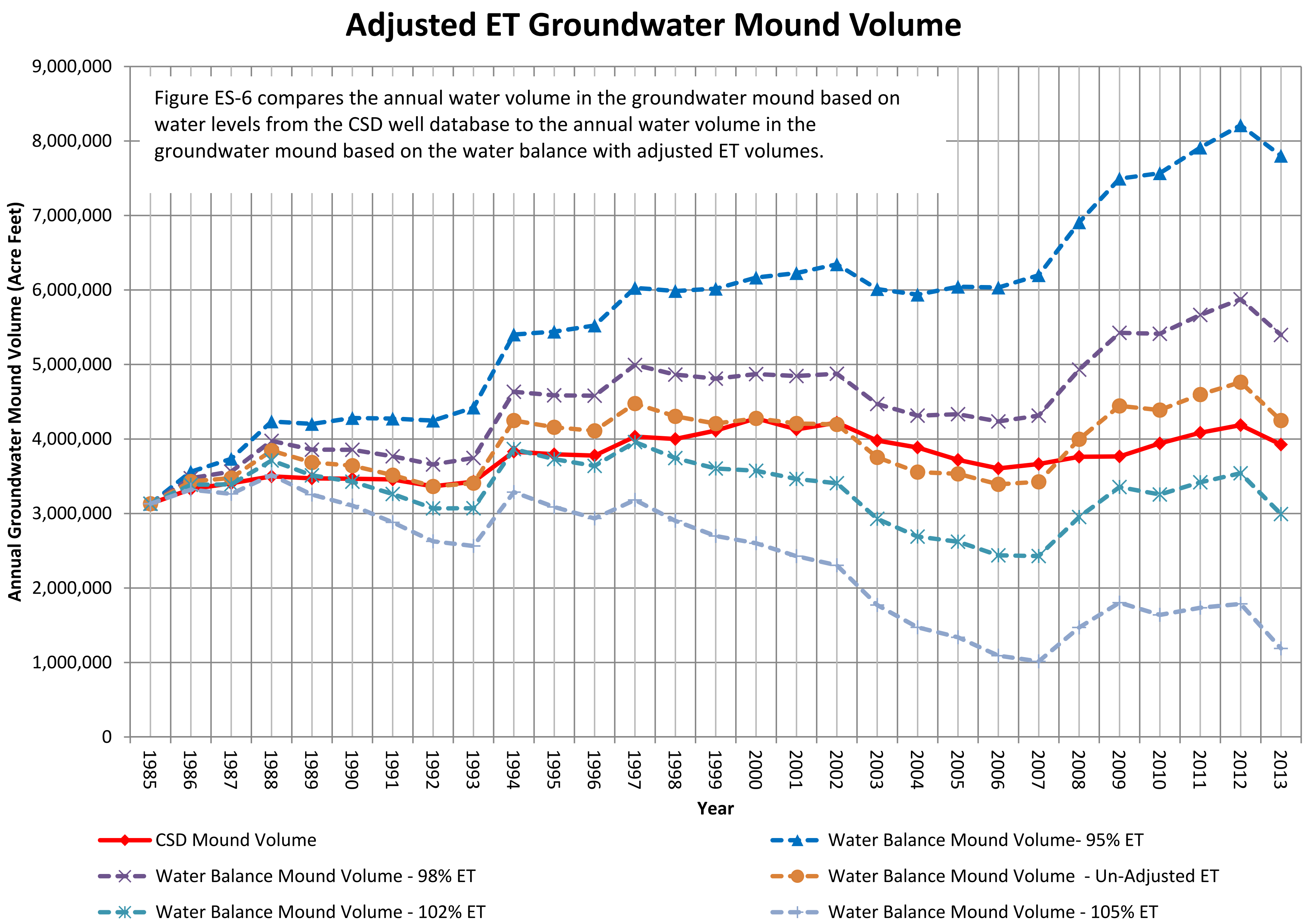


Figure ES-6. Comparison of the water balance mound volume with adjusted ET volumes.

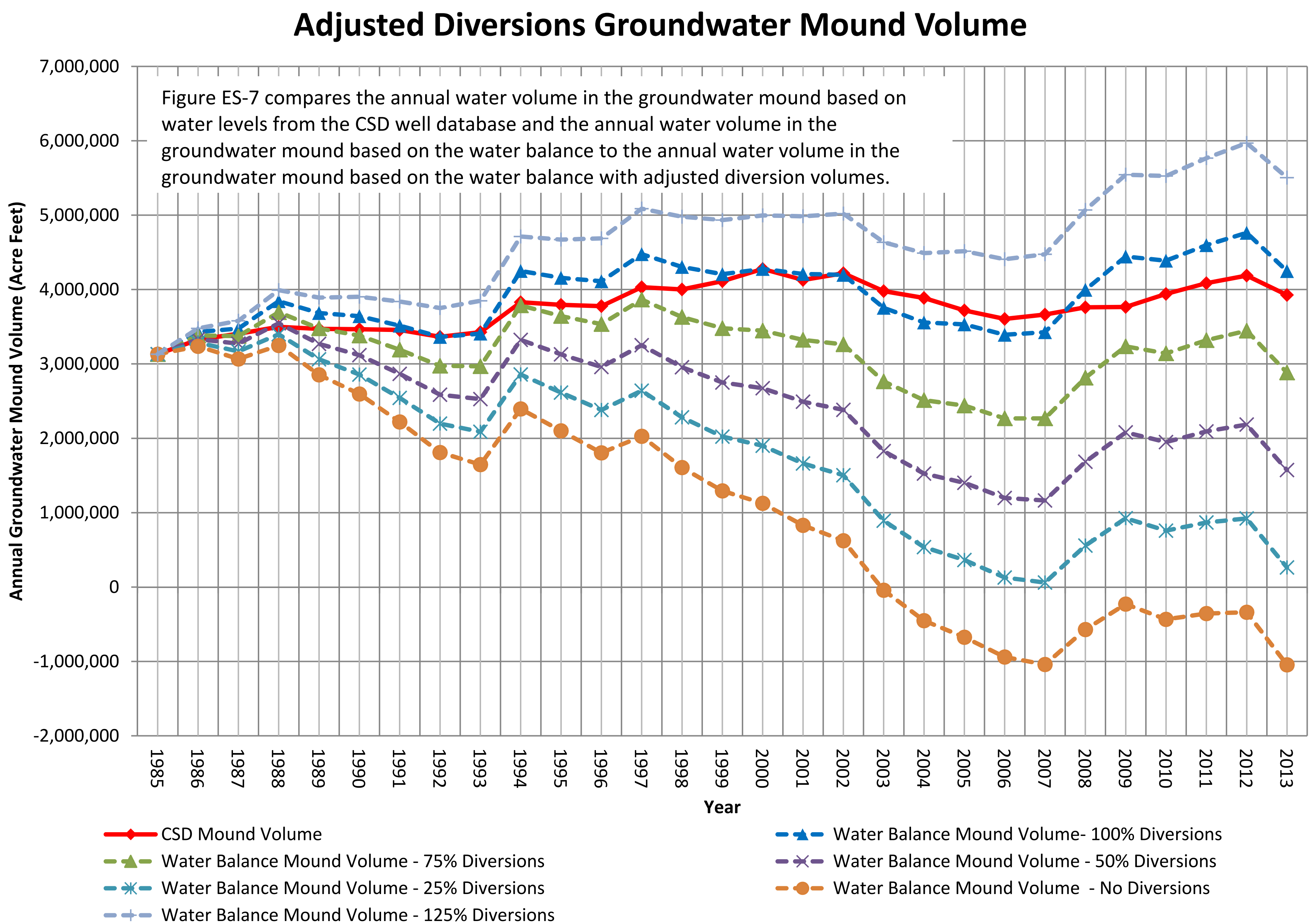


Figure ES-7. Comparison of the water balance mound volume with adjusted diversion volumes.

1. INTRODUCTION

This report has been prepared by EA Engineering, Science, and Technology, Inc. (EA) for work related to an evaluation of groundwater conditions in the vicinity of CNPPID irrigated areas. In this report the term groundwater applies to both naturally occurring groundwater and water that has been incidentally or intentionally recharged or stored underground.

1.1 BACKGROUND

Groundwater level changes in Nebraska have been monitored for many years and have been published in the Nebraska Statewide Groundwater Level Monitoring Report, prepared by University of Nebraska – Lincoln CSD. These reports compare water levels within a specific year to baseline conditions designated as “Pre-Development.” See Section 3.3.3 for CSD’s definition of pre-development water levels. While many areas of Nebraska have reported declines in groundwater levels, a few areas have exhibited rises in groundwater levels. The most prominent area of groundwater rise is located in the vicinity of the lands irrigated by CNPPID facilities, generally located on the south side of the Platte River from approximately Johnson Lake to Minden, Nebraska. This area is generally referred to as the CNPPID “groundwater mound.” A site location map of the groundwater mound area is shown in Figure 1.

The groundwater mound has been repeatedly mapped by CSD as part of the state-wide mapping efforts; however, minimal activities have been conducted to provide a more detailed understanding of the geometry of the groundwater mound and changes in geometry over time. A more thorough understanding of groundwater levels within the vicinity of the CNPPID groundwater mound will be helpful in making informed water resources management decisions.

1.2 PURPOSE

The purpose of this study is to evaluate the groundwater mound in the vicinity of lands irrigated by CNPPID facilities, provide an understanding of the temporal and spatial changes of the groundwater mound, and identify factors affecting the groundwater mound. The evaluation consisted of two primary elements. The first element included an evaluation of the geometric configuration of the groundwater mound. The second element included a water balance analysis within this study’s area.

The evaluation was conducted in multiple phases. Phase I included a review of available information, identification of preliminary factors that could impact the groundwater mound, delineation of preliminary subareas, and development of the planned approach to data evaluation. Phase II included the completion of the detailed evaluation.

Both Phase I and Phase II of this study were completed through close coordination with CNPPID staff.

1.3 PHASE I – DATA EVALUATION MEMORANDUM

Phase I activities began in October 2012. The primary deliverable for Phase I was the Data Evaluation Memorandum (January 2013), which is provided in Appendix A. EA also provided a detailed Scope of Services for Phase II and a budgetary cost estimate.

2. HYDROGEOLOGIC SETTING

The hydrogeologic setting for the region surrounding this study's area is summarized in the following sections.

2.1 REGIONAL HYDROGEOLOGIC CONDITIONS

This study's area is in the Great Plains physiographic providence as defined by Fenneman (1931). A detailed description of the Great Plains Geology and Aquifer Systems is provided in the Cooperative Hydrology Study (COHYST) Hydrostratigraphic Units (HUs) and Aquifer Characterization Report (2006). COHYST was a geohydraulic study of surface and groundwater resources in the Platte River Basin of Nebraska. This study's area in its entirety lies within the COHYST study area and this study uses COHYST data, but it is important to note that this study is not associated with the COHYST effort. The following sections are a summary of the relevant hydrogeologic information from the COHYST HUs and Aquifer Characterization Report, and will be referred to as the HU Report.

The HU Report divided the geologic units in the COHYST study area into 10 HUs. The HUs are described and illustrated in of the HU Report (Table 1 and Figure 12) and provided in Appendix B. These units were grouped based on hydraulic properties such as water storage, water, capacity, and permeability. They extend from the surface to the base of the deep High Plains aquifer. The following are the six upper HUs:

- HU 1 (Upper Quaternary Fines) is typically the overlying unit and is Pleistocene in age. HU 1 is primarily composed of silt, but also may contain fine sand and clay. HU 1 has low permeability.

- HU 2 (Quaternary Alluvial/Valley Fill Deposits) directly underlies HU 1 in most areas and is Pleistocene in age; though in areas where HU 3 is absent, it is Pliocene-Pleistocene in age. HU 2 is primarily composed of sand and gravel, with layers of finer material that may be present. HU 2 is generally the main water transmitter of the three upper HUs.

- HU 3 (Lower Quaternary Fines) directly underlies HU 2, but is not present throughout this study's area.

- HUs 4, 5, and 6 (Tertiary Ogallala Group) underlie HUs 2 or 3 and are composed of the Miocene Ogallala Group. Unit 4 is composed of siltstone, with layers of fine sand or clay present. Unit 5 is composed of sand and gravel, sandstone, and siltstone and may contain layers of finer material. Unit 6 is composed of silt, but may contain some fine sand or clay.

The focus of this study is the geologic formations where the groundwater levels have fluctuated, thus the upper portions of the stratigraphy, even though deeper HUs may be present within this study's area. To determine which HUs were of interest for this study, simplified geologic cross sections were plotted that illustrated the HUs in comparison to the approximate ground surface and select groundwater levels. The elevations of the various HU boundaries were downloaded as coverages from the COHYST website. The ground surface DTM was developed using the ground elevations listed in the CSD well information. Two groundwater elevations were plotted in the cross sections to represent the range of fluctuation. Groundwater levels from 1954 were selected to represent the low end of the range, and groundwater levels for 2000 were selected to represent the high end of the range. The cross section locations and resulting cross sections are included in Appendix C. Based on these cross sections, it was found that a majority of the rise in groundwater levels in the CNPPID service area has occurred in HU 1 (Upper Quaternary Fines). In a portion of this study's area, primarily in the south, the rise in groundwater levels has occurred in HU 2 (Quaternary Alluvial/Valley Fill Deposits).

2.2 AQUIFER PARAMETERS

Specific yield is the primary aquifer parameter of interest for this study. Specific yield is defined as the ratio of volume of water from a saturated rock mass (i.e., aquifer) to the total volume that was yielded by gravity draining (Weight and Sonderegger 2000). Specific yield was used in this study to estimate the volume of water present within a volume of saturated aquifer. For example, if 100 acre-feet of saturated aquifer was drained by gravity and the specific yield for the aquifer was 0.12, then the volume of water yielded would be 12 acre-feet.

COHYST estimated values for specific yield for the different HUs based on test-hole data. The test hole specific yield values for HUs 1 and 2 were downloaded as Geographic Information System (GIS) shapefiles from the COHYST website. The coverages were trimmed by the boundary of this study's area. For HU 1, the resulting average specific yield (expressed as a ratio) within this study's area was 0.12 from 90 test holes with a range of 0.01 to 0.25. For HU 2, the resulting average specific yield within this study's area was 0.24 from 83 test holes with a range of 0.12-0.27.

Groundwater levels from pre-development and 2000 were compared to the HUs 1 and 2. It was found that the about 65 percent of the pre-development groundwater surface was within HU 1 and about 35 percent was within HU 2. For the 2000 groundwater levels, about 80 percent of the groundwater surface was within HU 1 and about 20 percent was within HU 2. Since the water balance analysis will focus more on recent years, the specific yield used in this study was calculated as a weighted average of the specific yields based on the year 2000 groundwater levels; therefore, the resulting specific yield used in this study is 0.14.

3. EVALUATON PARAMETERS AND DATA

3.1 STUDY BOUNDARY

The site boundary was selected to include the estimated extent of the groundwater mound. The historic groundwater mound contours published by CSD were digitized and the study boundary was delineated to include all of the historic groundwater mound contours. The study's boundary was adjusted to landmarks, such as the Platte River, county roads and highways, where feasible as shown in Figure 2. Since the site boundary was adjusted to landmarks, the site boundary shown on Figure 2 extends slightly beyond the edges of the groundwater mound boundary. The digitized groundwater mound contours for 2012 are shown on Figure 2 to illustrate the general location of the groundwater mound in this study's boundary.

The resulting study boundary for this study is 1,620 square miles in total area and is bound by the Platte River on the north, 40 Road to the east, and State Highway 4 on the south and southeast. The southwestern and western boundaries were aligned diagonally to reflect the general shape of the groundwater mound, with the northeast corner of the boundary passing near Gallagher Canyon State Recreation Area.

3.2 SUBAREAS

In addition to analyzing groundwater level change for the entire study area, seven subareas were identified for individual analysis and comparison. The seven subareas are shown in Figure 2. These subareas were chosen to represent various areas of interest or key features. The purpose of the subareas was to analyze the effects of the areas of interest or key features to compare trends within the subarea to the study area. The subareas collectively cover this study's entire area and do not overlap.

Table 1 Subareas

Subarea	Square Miles	Description
Johnson Lake	93	Area in the vicinity of Johnson Lake, including the Supply Canal down to the J2 Return. The subarea is bound by the Platte River to the north.
Elwood Reservoir	250	Area in the vicinity of Elwood Reservoir, including a portion of the E65 Main, and extending south and west to the study boundary.
E67 Canal	16	Area in the vicinity of the canals/laterals and surface irrigated land associated with the E67 Canal.
E65 Canal	387	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the E65 Canal, extending south to the study boundary.
Phelps Canal Upper	32	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the Phelps County Canal, <u>upstream of Mile 13.3.</u> The subarea is bound by the Platte River to the north.
Phelps Canal Middle	329	Area in the vicinity of the canals/laterals and surface irrigated land associated with the Phelps County Canal, <u>from Mile 13.3 to Mile 31.8</u>, with a portion extending south to the study boundary. The subarea is bound by the Platte River to the north.
Phelps Canal East	513	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the Phelps County Canal, <u>downstream of Mile 31.8, extending south to the study boundary.</u> The subarea is bound by the Platte River to the north.

3.3 TIME PERIOD

The time period of interest for the groundwater evaluation includes approximately the last 60 years (long term) with an emphasis on the dates from 2000 to 2013 (recent years).

3.3.1 Long Term

The range of dates for the long-term portions of the study includes the years 1954-2013. These dates were selected to correspond to the period of time that CSD has published maps of groundwater level changes in Nebraska.

It is recognized that the data utilized and the mapping techniques implemented during the earlier years is not as robust as in more recent years; therefore, the information from the more recent years is considered to be more reliable and useful than information from the earlier years.

The purpose of evaluating the data for the past 60 years is to provide an understanding of how the groundwater mound has grown and expanded over time to provide a frame of reference for the changes in the groundwater mound in recent years. The long-term perspective also provides an understanding of the changes in groundwater levels in response to unusually dry or wet periods. The following data were evaluated to understand how the groundwater mound has grown and how it responds to unusually wet and unusually dry periods:

- Estimates of the total volume of water contained in the groundwater mound for each year.
- The geometric configuration of groundwater for select years over time.
- Various environmental and operational factors that may have an impact on groundwater levels.

3.3.2 Recent Years

A more detailed analysis was performed for recent years (2000-2013). The recent years were evaluated in more detail because they best reflect the current irrigation practices, land uses, conservation practices, etc. The recent years also have better available data and include both wet and dry years.

The additional analysis includes geometric configuration of groundwater mound for each year and a water balance for each year during this time period.

3.3.3 Pre-Development

The groundwater level change mapping conducted by the CSD has typically compared changes in spring water levels over set periods, such as 1, 5, and 10 years, or benchmark periods such as 1981 and pre-development. Pre-development water levels were determined as follows by CSD:

> *An estimated pre-development water level is the approximate average water level at a well site prior to any development that significantly affects water levels. Pre-development water levels for most of the state are the estimated water levels that generally occurred before 1930s, 1940s, or early in the 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 pre-development water levels. Contours were drawn manually with the aid of previously existing maps for similar time periods and with the knowledge of major hydrogeologic boundaries* (CSD 2012).

Pre-development conditions are particularly important for this study because they provide a common basis of comparison for all years to track changes in the size, shape, and volume of the groundwater mound over time. As described above, pre-development levels were estimated for each well by CSD. To better understand the water levels used by CSD as pre-development, a pre-development groundwater surface was created using all wells (for all years) within the data set that had a pre-development water level. Wells within the study area and within 5 miles of the study area were included. The resulting pre-development groundwater surface is shown in Figure 3. It should be noted that a small groundwater level mound is evident in the pre-development groundwater contours. The groundwater mound is evident across the study area, particularly in the north-central portion of the study area. While this small rise is noted, it was determined that it would not be beneficial to create a revised basis of comparison surface because if a different surface was created, the results would not be as easily compared to the published mapping by CSD. In addition, as long as the same basis of comparison is used for all years, the results will still reflect the relative change in water levels over the study's time period.

3.3.4 Key Years

Table 2 summarizes the key years during the time period of interest and a description of the event, activity, or management action.

Table 2 Key Years

Years	Description
1954–2013	CSD publishing Nebraska Statewide Groundwater-Level Monitoring Reports
Early 1940s	Construction of Johnson Lake. Construction and early operation of Phelps Canal and E65 Canal
Mid 1950s	Construction and early operation of the E67 Canal
Early 1950s	Began construction of drains
1956	Dry year*
1965	Wet year*
1974	Dry year*
1977	Construction of Elwood Reservoir
1993	Wet year*
1994	Elwood Reservoir management changed to a Target Operating Curve
2001–2003	E67 and E65 lining projects
2002	Dry year*

Table 2 Key Years (Continued)

Years	Description
2005–2009	Allocation seasons for CNPPID customers • Diversions into canals decreased and irrigation season was shortened • Elwood Reservoir was not used for irrigation during allocation seasons, only some diversions into reservoir to preserve fish and wildlife • Johnson Lake was dropped around 6-10 feet in August a few times during the final run of irrigation during allocation seasons
2007–2008	Wet years*
2012	Dry year*

*Note: Years were determined to be wet or dry if they are more than 1.5 standard deviations from the 1954 to 2013 average annual rainfall.

3.4 DATA SOURCES

Table 3 summarizes the data utilized for the study.

Table 3 Data Sources

Data	Source
Maps of Canal System	CNPPID
Canal Diversions and Deliveries	CNPPID
Historical Information and Construction Events and Management Periods	CNPPID
Precipitation Data	CNPPID and High Plains Regional Climate Center
Losses from Johnson Lake	CNPPID
Losses from Elwood Reservoir	CNPPID
MODFLOW DATA	COHYST
Groundwater Flux	COHYST
Streams and Drains Base Flow	COHYST
Groundwater Recharge	COHYST
Groundwater Pumping Data	COHYST
CROPSIM DATA	COHYST
Field Evapotranspiration (ET)	COHYST
Stream ET	COHYST
Field Losses	COHYST
Lateral Losses	COHYST
Net Runoff (across study boundary)	COHYST
Hydrogeologic Conditions (within the study area)	COHYST
Registered Wells	Nebraska Department of Natural Resources
Streams and Drains	U.S. Geological Survey and Nebraska Department of Natural Resources
Groundwater Level Changes in Nebraska Maps	CSD
Groundwater Levels	CSD

Additional information regarding the data and its sources is as follows.

3.4.1 Groundwater Level Data

Groundwater level data presented in this report were obtained from the Nebraska CSD groundwater database. Records were obtained for Buffalo, Dawson, Franklin, Frontier, Furnas, Gosper, Harlan, Kearney, and Phelps counties. Water records from wells outside of the study area were removed from the study. The well elevations in the CSD database are approximations based on ground surface elevation maps. Groundwater levels were used to calculate groundwater volume.

EA also used the groundwater level change maps published on the CSD website (http://snr.unl.edu/csd/). These data were used to map the extent of the groundwater mound and to establish the study boundary.

3.4.2 Precipitation Data

Precipitation data were compared to groundwater volume to assess the potential impact of precipitation on groundwater volume change. Precipitation data were also used to calculate water balance. Precipitation data were obtained from CNPPID rain gauge records and the High Plains Regional Climate Center (http://www.hprcc.unl.edu/index.php). The precipitation data were divided into six periods: 1954-1971, 1972-1985, 1986-1987, 1988-1999, 2000-2009, and 2010-2012. The data were divided into separate periods to account for the addition and removal of rain gauges. Annual mean precipitation for the study area was calculated using the weighted Theissen polygon method. Table 4 displays the weather stations used in each time period.

Table 4 Weather Stations

Years	Data Source	Station Identification
1954–1971	CNPPID Weather Stations	44, 49
	High Plains Regional Climate Center	Atlanta, Elwood, Eustis, Holdrege, Kearney, Lexington, Minden, Ragan, and Upland
1972–1985	CNPPID Weather Stations	44, 49, 50
	High Plains Regional Climate Center	Atlanta, Bertrand, Canaday, Elwood, Eustis, Holdrege, Kearney, Minden, Ragan, and Upland
1986–1987	CNPPID Weather Stations	44, 49, 50
	High Plains Regional Climate Center	Atlanta, Bertrand, Elwood, Eustis, Holdrege, Kearney, Minden, Ragan, and Upland
1988–1999	CNPPID Weather Stations	44, 49, 50
	High Plains Regional Climate Center	Atlanta, Bertrand, Canaday, Elwood, Eustis, Holdrege, Kearney, Minden, Ragan, and Upland
2000–2009	CNPPID Weather Stations	44, 49, 50
	High Plains Regional Climate Center	Bertrand, Canaday, Elwood, Eustis, Holdrege, Kearney, Minden, Ragan, and Upland
2010–2012	CNPPID Weather Stations	44, 49, 50
	High Plains Regional Climate Center	Canaday, Elwood, Eustis, Holdrege, Kearney, and Minden

Annual precipitation data was used to simplify the process, but annual data does not address factors that affect the individual storm events contribution to the groundwater mound. Numerous factors have an effect on the amount of rainfall from each storm event that will recharge the groundwater mound and the amount of rainfall that will runoff and be conveyed out of the area. Those factors include, but are not limited to, the intensity of storm events, soil saturation, and the ambient temperature.

3.4.3 MODFLOW Data

Data from COHYST's MODFLOW groundwater model were utilized for the study. The data were limited to the years 1985-2005.

The data were obtained from MODFLOW output files through Lytle Water Solutions, LLC at the request of CNPPID.

3.4.4 CROPSIM Data

Data from COHYST's CROPSIM model were utilized for the study. The data were limited to the years 1985-2005.

The data were obtained from CROPSIM output files through Lytle Water Solutions, LLC at the request of CNPPID.

3.4.5 Registered Wells

The number of registered irrigation wells within the study boundary was obtained from the Nebraska Department of Natural Resources on-line registered well database. All wells were downloaded and filtered for irrigation use. The dates that wells were installed and abandoned were evaluated to estimate the number of active irrigation wells in the study area for each year.

3.4.6 Streams and Drains

Stream flow data were obtained from the Nebraska Department of Natural Resources, the U.S. Geological Survey, and COHYST. Data for each stream were compiled from all available sources. Data were not used if a complete record for a respective year was not available.

4. GROUNDWATER MOUND RESULTS AND DISCUSSION

4.1 METHODS AND PROCEDURES

Two approaches were used to evaluate the size and shape of the groundwater mound. The first approach was based on digitizing the groundwater contours prepared and published by CSD. CSD's "Groundwater-Level Changes in Nebraska Predevelopment to Spring 2011" map is shown in Figure D-3 as an example of the CSD Groundwater Level Changes in Nebraska Maps. The digitized contours were then used to create a DTM of the groundwater mound and estimate the volume. The second approach was based on importing the raw water level data used by CSD for each year, then creating a DTM from the raw water level data.

The groundwater contours prepared and published by CSD were digitized by the following process:

- Exporting the PDF into a JPG.
- Placing the JPG into GIS and geo-referencing the JPG to Nebraska state plane coordinates (North American Datum [NAD 83]).
- Tracing the contouring on the PDF in GIS to create contouring shapefiles for each year (1954-2012).
- Loading the shapefiles into AutoCAD Civil3D 2011 to Nebraska State plane (NAD83).
- Creating at DTM in AutoCAD civil3D 2011 with shapefiles.

The following are assumptions and techniques used to create the groundwater mound DTM based on the raw CSD well data:

- The entire well database was filtered by the study area to include wells within the boundary and within 5 miles adjacent to the study area boundary.
- The well database was also filtered for each year to determine which wells had water level measurements for each individual year.
- If the database included more than one water level measurement in the same well in one year, the water level date closest to April was used to represent "spring" conditions.
- For each year, the data were imported and evaluated to identify points that were outliers. Each outlier was evaluated individually to determine if the data point would be included, removed, or corrected. After evaluation, the data from nine wells were removed from the data set. These wells are listed in Appendix D.

- As expected, the number of data points available for each individual year generally increased with time. A table listing the number of well data points available for each year is included in Appendix D.

- In some years, no well data were available near portions of the study boundary. This caused the DTM to create a surface that did not extend to the boundary. To more accurately estimate the groundwater mound volume and provide a more consistent comparison of volumes between years, additional "ghost" points were added outside the study boundary in areas where coverage was needed. The elevation of the water levels for the ghost points was set at pre-development water levels.

- A DTM of the groundwater mound was created by comparing the water levels that year to the pre-development water levels. This was done by subtracting the DTM representing pre-development conditions from the DTM created for the water levels from the specific year. The resulting DTM represents the groundwater mound for the specific year.

- The resulting DTM of the groundwater mound for each year was then used to estimate the total volume of the groundwater mound (water plus aquifer material) trimmed by the study area boundary.

- The volume of the water within the total volume of the groundwater mound formation was estimated by multiplying by a representative specific yield for the aquifer.

- The trends of the groundwater mound were determined to a high level of confidence, but the actual volume of water in the groundwater mound is less certain. The uncertainty is because the volume of water that can be stored in the geology of the groundwater mound (specific yield) is estimated, and small changes in specific yield result in large changes in water volume.

The results from the two approaches to creating the DTMs were compared and it was found that the approach based on raw water level data was the better approach. There were several main reasons that the approach using the raw water level data were found be to be better. First, the CSD contours are prepared state-wide, resulting in coarser data interpretation, while the raw water level data can be interpreted in greater detail because they are focused on only the study area. Also, the contour intervals on the CSD maps vary from year to year and several have large intervals for rise, causing reduced accuracy compared to using the raw water levels data. Finally, interpretation and mapping techniques have varied on the CSD contour maps over the years, as would be expected as technology has advanced over the last 60 years. Using the raw water level data allows a consistent interpretation of data, providing a more accurate comparison between years. A comparison of the groundwater mound volumes for each year based on the two different approaches is included in Appendix D.

4.2 GROUNDWATER MOUND VOLUME

The volume of the groundwater mound from 1954 through 2013 is illustrated in Figure 4.

4.2.1 Volume Trends

The following observations and trends have been identified:

- The first year included in the study is 1954. The volume of the groundwater mound was already significant in 1954, indicating the groundwater mound was already forming. This is reasonable, since Johnson Lake, Phelps Canal, and E65 Canal were constructed and began operating in the early 1940s.

- The general long-term trend is an increasing total volume of the groundwater mound, with occasional periods of decline as shown in in Figure 4.

- One period of significant decline is from 1976 through 1978. Elwood Reservoir was constructed in 1977. After 1978, the groundwater levels continued to steadily increase, exceeding 1975 levels by 1987.

- A second significant decline occurred from 2001 through 2006. The size of the groundwater mound was the maximum in 2000. After the decline through 2006, groundwater water levels continued to increase through 2012, to levels slightly less than the maximum in 2000.

- Summer and Fall 2012 were an unusually dry period. The resulting volume of the groundwater mound decreased from 2012 to 2013.

- Additional trend analysis and comparison to various factors are provided in later sections of the report.

4.2.2 Subareas

The volume of the groundwater mound within each of the subareas from 1954 through 2013 is presented in Figure 5. The groundwater mound volume per unit area and the groundwater mound volume for each subarea plotted on separate graphs are presented in Appendix J. Each subarea's surface area, 2013 groundwater mound volume, and 2013 groundwater mound volume per unit for each subarea is shown in Table 5.

Table 5 Subarea Groundwater Mound Volumes

Subarea	Area* (sq. mi.)	2013 Groundwater Mound Volume (ac-ft)	2013 Groundwater Mound Volume per Unit Area (ac-ft/sq. mi.)
E67 Canal	16	127,000	8,000
Elwood Reservoir	250	1,013,000	4,100
E65 Canal	387	1,445,000	3,700
Johnson Lake	93	344,000	3,700
Phelps Canal Middle	329	503,000	1,500
Phelps Canal East	513	479,000	900
Phelps Canal Upper	32	15,000	500

* Note: The subareas collectively cover this study's entire area and do not overlap.

The following observations and trends have been identified:

- The western subareas (E67 Canal, Elwood Reservoir, E65 Canal, Johnson Lake, and Phelps Canal Upper Subareas) only comprise 48 percent of the study area, but contain approximately 75 percent of the groundwater mound volume.

- The E67 Canal Subarea is located near the center of the groundwater mound and no part of the subarea extends to the edge of the groundwater mound. As a result, its groundwater mound volume per unit area is significantly higher than all other subareas. The E67 Canal Subarea groundwater mound volume had a general long-term trend of increasing volume until the 2000s with occasional periods of slight decline. In the 2000s the E67 Canal Subarea groundwater mound volume has had a declining trend.

- The Elwood Reservoir Subarea has the second largest groundwater mound volume per unit area despite the subarea's western boundary extending miles beyond the groundwater mound edge. The density of registered wells in the subarea is relatively low compared to the rest of the study area as shown on Figure 25. Also, the largest rise in groundwater levels since CSD's pre-development has occurred near Elwood Reservoir. From 1968 to 1978, the subarea volume fluctuated considerably, but has had a relatively consistent rate of increase since 1978. The construction of Elwood Reservoir in 1977 has apparently had a stabilizing influence. It is also noted that the decline in the entire groundwater mound volume observed between 2000 and 2006, and the decline in 2013 is less evident in the Elwood Reservoir Subarea. A sharp decrease in subarea volume occurred between 1976 and 1978. There does not appear to be an apparent reason for this decrease. Other subareas (E65 Canal and Phelps Canal East) also had a decrease in volume from 1976 to 1977; however, the Elwood Reservoir subarea was the only subarea that had additional decrease from 1977 to 1978.

- The E65 Canal Subarea has the third largest groundwater mound volume per unit area. The density of registered wells in the E65 Canal Subarea is slightly higher than the Elwood Reservoir Subarea, but it is relatively low compared to the rest of the study area as shown on Figure 25. The E65 Canal Subarea water volume reached its peak in 2012, fully recovering from the declines through 2006. The groundwater mound volume has had a general long-term trend of increasing volume with occasional periods of slight decline. The E65 Canal Subarea groundwater mound volume trend is similar to the overall groundwater mound trend.

- The Johnson Lake Subarea has the fourth largest groundwater mound volume per unit area. The registered well density in the area is similar to rest of the study area, but the groundwater levels near Johnson Lake have risen as much as 140 feet since CSD's pre-development. The Johnson Lake Subarea has a similar groundwater mound volume per unit area compared to the Elwood Reservoir Subarea and the E65 Canal Subarea, but has not increased as much over the study's time period as shown on Figure J-1. It is possible that the groundwater mound in this subarea may have risen prior to 1954. The Johnson Lake Subarea groundwater mound volume trend was very similar to the overall groundwater mound volume from the 1970s to the 1990s, but has had a generally decreasing trend since the 1990s.

- The Phelps Canal Middle Subarea has the fifth largest groundwater mound volume per unit area. The density of registered wells in the Phelps Canal Middle Subarea is higher than the western subareas. The Phelps Canal Middle Subarea groundwater mound volume trend has been similar to the overall groundwater mound volume, except for 1994-1996 and 2000-2006. During those periods the Phelps Canal Middle Subarea groundwater mound volume has decreased more than the overall groundwater mound volume (in terms of volume per unit area).

- The Phelps Canal East Subarea has the sixth largest groundwater mound volume per unit area. The density of registered wells similar to the Phelps Canal Middle Subarea, but a significant portion of the Phelps Canal East Subarea is beyond the edge of the groundwater mound. The Phelps Canal East Subarea groundwater mound volume trend has been very similar to the overall groundwater mound volume, except for 1988-1993 and 2000-2006. During those periods the Phelps Canal East Subarea groundwater mound volume has decreased more than the overall groundwater mound volume (in terms of volume per unit area).

- Phelps Canal Upper Subarea has the lowest groundwater mound volume per unit area. It is the only western subarea with a low groundwater mound volume per unit area. The low volume per unit area is a result of the subarea being located on the edge of the groundwater mound. The Phelps Canal Upper Subarea groundwater mound volume trend was very similar to the overall groundwater mound volume until the 1980s, but has had significant fluctuations in groundwater mound volume with a slightly decreasing trend since the 1980s.

4.3 GROUNDWATER MOUND SHAPE

The shape of the groundwater mound was evaluated by plotting the contour maps of the groundwater mound and cross sections through the groundwater mound for select years. Cross section locations are shown in Figure 6, along with groundwater mound contours for 2013.

4.3.1 Long-Term Trends

To evaluate long-term trends, cross-sections were plotted on 10-year intervals. The specific years included 1960, 1970, 1980, 1990, 2000, and 2010. For each of these years, figures were prepared, including a plan view of groundwater mound contours and five cross sections (A-A' through E-E'). These figures are included in Appendix E for each of the six decades. For comparison, all 6 years have been plotted on the same cross section as shown in Figures 7 through 9.

The following observations and trends have been identified:

- The east-west cross section through the study area (Cross Section A-A') shows the following:
  - A large increase in groundwater mound levels across the groundwater mound from 1960 to 1970 (Figure 7).
  - An increase in groundwater mound levels from 1970 to 2000 east of Elwood; a consistent trend does not appear near Elwood from 1970 to 2000 (Figure 7).
  - A large increase in groundwater mound levels in a small area near Cross Section D-D' from 1990 to 2000 (Figure 7).
  - A slight decrease in groundwater mound levels from 2000 to 2010 across the groundwater mound (Figure 7).
- The north-south cross section through Elwood (Cross Section B-B') shows significant groundwater mound growth in the middle and to the south. The 1970 groundwater mound level spike correlates to a spike in the groundwater mound volume (Figure 8). The spike occurred prior to Elwood Reservoir construction, therefore the spike is not related to Elwood Reservoir.
- The north-south cross section through Bertrand (Cross Section C-C') shows a consistent growth in the middle and to the south from 1960 to 2000 and a slight decrease from 2000 to 2010. This correlates with consistent growth in the cross section's subarea (E65 Canal Subarea) (Figure 8).

- The north-south cross section through Holdrege (Cross Section D-D’) shows a relatively small groundwater mound with rise in groundwater mound levels from 1960 to 2000. The increase occurs mostly in the middle and an increase to the south to a lesser extent. The groundwater mound levels decreased slightly from 2000 to 2010 (Figure 9).

- The north-south cross section through Kearney (Cross Section E-E’) also shows a relatively small groundwater mound. The groundwater mound level increased slightly across the cross section of the groundwater mound from 1960 to 2000 and had a significant decrease from 2000 to 2010 (Figure 9).

4.3.2 Recent Year Trends

Similar cross sections were plotted for recent years to determine if different trends are evident. A similar group of figures, as described in the previous section, were prepared to compare the years 2000-2006 (Figures 10 through 12). The following observations and trends have been identified for the years 2000-2006:

- Cross Section A-A’ shows a general trend of decreasing groundwater mound levels across the cross section from 2000 to 2006. The groundwater mound level in 2001 does not fit the trend across the cross section. It shows significant rise on the west edge of the groundwater mound and significant decrease near the location of Cross Section D-D’ (Figure 10).

- Cross Section B-B’ shows little change from 2000 to 2006 except in the middle of the cross section (Miles 10-15). The groundwater mound levels decreased from 2000 to 2006, with 2001 being an outlier. The middle of the groundwater mound had a large decrease in 2001, but recovered by 2002 (Figure 11).

- Cross Section C-C’ shows a very slight decrease in groundwater mound levels from 2000 to 2006 with the exception of an increase in groundwater mound levels on the south side in 2002 and 2004 (Figure 11).

- Cross Section D-D’ shows a general trend of decreasing groundwater mound levels across the cross section from 2000 to 2006. The groundwater mound level decreases significantly in 2001, but mostly recovers in 2002 (Figure 12).

- Cross Section E-E’ shows a general trend of decreasing groundwater mound levels across the cross section from 2000 to 2006 with a larger decrease on the north end (Figure 12).

A separate group of figures was prepared to compare the years 2007-2013 (Figures 13 through 15). The following observations and trends have been identified for the years 2007-2013:

- Cross Section A-A' shows a general trend of increasing groundwater mound levels across the cross section from 2007 to 2012. The groundwater mound level has a slight decrease in 2013 (Figure 13).

- Cross Section B-B' shows little change from 2007 to 2013 except in the middle of the cross section (Miles 10-15). The groundwater mound levels increased in the middle from 2007 to 2013 (Figure 14).

- Cross Section C-C' shows a very slight increase in groundwater mound levels from 2007 to 2012. The groundwater mound level has a slight decrease in 2013 with the exception of a portion of the southern edge of the groundwater mound (Miles 18-24), which had a significant decrease in level (Figure 14).

- Cross Section D-D' shows a general trend of increasing groundwater mound levels in the northern and middle portions of the groundwater mound from 2007 to 2012. The groundwater mound levels on southern edge are mostly unchanged from 2007 to 2012. The northern and middle portions of the groundwater mound decreased in 2013 and southern edge of the groundwater mound increased in 2013 (Figure 15).

- Cross Section E-E' shows a general trend of increasing groundwater mound levels across the cross section from 2007 to 2012. The groundwater mound level has a slight decrease in 2013 (Figure 15).

5. INVESTIGATING FACTORS THAT INFLUENCE THE GROUNDWATER MOUND

Many factors have an influence on the groundwater mound. To gain an understanding of the level of impact over the long term, several of these factors were plotted against the estimated volume of water within the entire groundwater mound and within the different subareas of groundwater mound.

5.1 PRECIPITATION

Annual precipitation is compared to the volume of water within the groundwater mound in Figure 16.

The following observations and trends have been identified:

- Annual precipitation ranged from about 13 to 37 inches per year.

- During the years 1954 through 1970, the volume of the groundwater mound appears to only have a minimal response to precipitation. In some years of unusually high precipitation, such as 1993 and 1996, the groundwater mound volume has a noticeable increase the following year. Similarly, in some unusually dry years, such as 2002 and 2012, the groundwater mound volume has a noticeable decrease the following year. However, there are many instances where the response is minimal or non-existent, such as in 2007 and 2008.

Further investigation of precipitation per month or individual storm events could possibly explain some of the instances where annual precipitation volumes do not correlate very well to the change in groundwater mound volume.

5.2 DIVERSIONS

Total diversions are compared to the volume of water within the groundwater mound in Figure 17, including deliveries and canal losses for reference.

The diversions for the E65 and E67 are compared to the volume of water within their respective subareas in Figures 18 and 19. Diversions for the Phelps Canal are compared to the volume of water within three subareas (Phelps Canal East, Phelps Canal Middle, and Phelps Canal Upper) in Figure 20.

The following observations and trends have been identified:

- Overall diversions have a decreasing trend and deliveries stayed mostly stable from 1960s to the early 2000s. During this period, the groundwater mound volume has steadily increased with a few periods of decline.

- Overall deliveries and the diversions are less than average from 2005 to 2011. The decrease in deliveries and diversions corresponds with the decrease in the groundwater mound volume in this period.

- The groundwater mound volume increased in 1993 and 1994 despite a significant decrease of overall diversions and deliveries in 1993; 1993 was also a year of record rainfall.

- The E65 Canal diversions and deliveries and the E65 Canal Subarea groundwater mound follow the same trends as the overall diversions, deliveries, and groundwater mound volume.

- The E67 Canal diversions and deliveries prior to the 1980s were much more sporadic than the overall diversions and deliveries; however, E67 Canal Subarea groundwater mound volume trend was similar to the overall groundwater mound volume trend.

- The E67 Canal delivery, diversion, and groundwater mound volume trends from 1980 to 2013 were similar to the overall trends.

- The Phelps Canal delivery, diversion, and groundwater mound volume trends were similar to the overall trends.

5.3 RESERVOIR SEEPAGE FROM ELWOOD RESERVOIR

Seepage from Elwood Reservoir is compared to the volume of water within the groundwater mound in Figure 21. A similar comparison is made for Elwood Reservoir seepage to the volume of the groundwater mound within the Elwood Reservoir subarea in Figure 22.

The following observations and trends have been identified:

- Elwood Reservoir seepage has a decreasing trend from 1985 to 2004.

- The impact of the reservoir seepage is not seen in the overall groundwater mound volume and the Elwood Reservoir Subarea groundwater mound volume.

5.4 GROUNDWATER IRRIGATION

Groundwater irrigation was investigated with two different methods: the number of registered irrigation wells and the estimated groundwater pumping volume.

5.4.1 Registered Irrigation Wells

The number and location of irrigation wells provides a general indication of potential groundwater withdrawals across the study area. The number of registered irrigation wells is compared to the volume of water within the groundwater mound in Figure 23. A similar comparison is made for the total number of registered irrigation wells to the volume of water within each of the seven subareas in Figure 24. The locations of the registered wells that have existed for the years included in the study (1954-2013) are shown in Figure 25 to provide an understanding of the spatial distribution of irrigation wells within the study area. The map shows that the Elwood Reservoir and E65 Canal Subareas are least densely populated with wells due to the sparse distribution of wells in the southern parts of both subareas.

The following observations and trends have been identified:

- The number of registered wells and the groundwater mound volume have steadily increased since 1954.

- The steepest increase was from 1954 through 1977. The number of wells continued to increase gradually from 1978 to 2001, with a sharp increase from 2002 to 2005. Since 2005, the number of irrigation wells has remained steady. In general, the continued increase in the number of registered irrigation wells coincides with the reduced rate of growth of the groundwater mound volume.

5.4.2 Groundwater Pumping

The estimated annual groundwater pumping is compared to the volume of water within groundwater mound in Figure 27. The estimated groundwater pumping was obtained from COHYST for 1985-2005. The pumping in 2006-2013 was estimated based on a polynomial relationship between 1985 and 2005 surface water applied plus groundwater pumping data and precipitation data. The pumping data were extrapolated. The relationship had a coefficient of determination (R^2 Value) of 0.97. Some flow meter information was available within the study area through Tri-Basin Natural Resources District and the Lower Republican Natural Resources District, but was insufficient to obtain a more refined estimate of total groundwater pumping within the study area.

The following observations and trends have been identified:

- A below average pumping year typically leads to an increase in groundwater mound volume in the following year and an above average pumping year typically leads to a decrease in groundwater mound volume the following year. The results of an above average pumping year lead to a decrease in groundwater mound volume the next year because the groundwater mound levels are typically recorded in the spring and the pumping is conducted in the summer months. It should be noted that below average precipitation years typically correspond with above average pumping years. During these years, the mound is being simultaneously impacted by both factors.

5.5 STREAM FLOW

Stream flow data from COHYST's CROPSIM and MODFLOW models are compared to the volume of water within groundwater mound in Figure 26. The COHYST stream flow data include all base flow and runoff that leave the study boundary. The stream flow data does not include Platte River flows because the river is not within the study boundary. Available stream flow records the study boundary were reviewed, but it was determined that data was too limited to provide any value to the analysis.

The following observations and trends have been identified:

- The stream flow volume leaving the study boundary is very small compared to the groundwater mound water volume. The average stream flow is less than 4 percent of the average groundwater mound water volume from 1985 to 2005.

6. WATER BALANCE RESULTS AND DISCUSSION

6.1 WATER BALANCE CONCEPT

An annual water balance was conducted within the study area to understand conditions and changes in the groundwater mound in recent years. A schematic diagram of the factors included in water balance is shown in Figure 28.

A water balance can be approached several different ways, depending on the domain included in the water balance. For example, an approach that focuses on groundwater only (i.e., a groundwater model) would be limited to factors that add/remove water from the saturated zone of an aquifer. Recharge from the surface and vadose zone would be treated as an increase and groundwater pumping as a removal. Similarly, a water balance at the land surface/root zone would only be limited to factors that add/remove water from the land surface/root zone. In this case, deep percolation (recharge) would be treated as a removal of water and water applied through groundwater pumping would be treated as an addition.

A wholistic water balance approach was used for this evaluation. The domain included the entire study from the land surface to the bottom of the aquifer, including the root zone, vadose zone, and groundwater in the saturated zone. The water balance was completed on an annual basis to identify trends over multiple years; therefore, minimizing the importance of short-term temporal effects.

6.2 WATER BALANCE FACTORS

The factors included in the water balance are described in the followings sections and have been organized into the three groups based on level of importance for this evaluation. The percentages that each factor contributes to the water balance are shown in Figure 29.
Data for the water balance were obtained through several sources, but primarily CNPPID, COHYST, and CSD. One limitation of the COHYST was that the data were typically from the period of 1985-2005. The original intent of the water balance was to only include recent years (2000-2012). Based on the limitations of the time period for the COHYST data, the data for several of the factors had to be estimated for years 2006-2012. These estimates were based on regression analysis of data for the years 1985-2005. The2006-2012 data for groundwater flux in and drain flow out was estimated by averaging recent year values because there was little variance in the values over the years. Additional information on the regression relationships for the remaining factors are summarized in the following sections and illustrated in Appendix G.

Even though the original intent was to only include recent years (2000-2012), it was found that extending the time period to include back to 1985 provided additional perspective, and was therefore included in the evaluation. In addition, the water balance is compared to the groundwater mound volumes through 2013. This was done because the 2013 groundwater mound volume represents Spring 2013 conditions and provides a comparison to factors that occurred throughout the year of 2012.

6.2.1 Key Factors

The following key factors in the water balance are described below:

- ***Groundwater Storage***—The change in storage in the saturated zone is one of the key factors in the water balance, reflected in the changes in the volume of water in the groundwater mound over time. The data from the CSD were used to estimate the volume of water stored in the groundwater mound for years 1985-2013.

- ***Precipitation***—Annual precipitation is the largest factor providing water to the water balance domain. Precipitation was estimated based on CNPPID and High Plains Regional Climate Center rain gauges for years 1985-2012.

- ***Evapotranspiration***—ET is the largest factor that removes water from the domain of the water balance. This factor includes ET from irrigated cropland, non-irrigated cropland, and non-cropland. ET estimates included the following outputs from COHYST's CROPSIM model:

  — Field ET
  — Trans ET (ET of runoff as it flows from the field to the stream).

  The COHYST estimates of field ET and trans ET were available for the years 1985-2005 and were estimated through regression analysis for years 2006 to 2012. The sources of the data and the estimation methods for ET are summarized in Table 6.

Table 6 Data Sources for Subfactors Related to Evapotranspiration

Subfactor	Years	Source	Coefficient of Determination
Field ET	1985–2005	COHYST CROPSIM Model	Not applicable
Field ET	2006–2012	Polynomial relationship between 1985-2005 field ET data and total water applied data (diversions + groundwater pumping + precipitation)	0.93
Trans ET	1985–2005	COHYST CROPSIM Model	Not applicable
Trans ET	2006–2012	Linear relationship between 1985-2005 trans ET data and runoff out data	1.00
Runoff Out	1985–2005	COHYST CROPSIM Model	Not applicable
Runoff Out	2006–2012	Polynomial relationship between 1985-2005 runoff out data from COHYST CROPSIM Model and precipitation data	.98
Diversions	2006–2012	CNPPID records	Not applicable
Groundwater Pumping*	1985–2005	COHYST CROPSIM Model	Not applicable
Groundwater Pumping*	2006–2013	Polynomial relationship between 1985-2005 groundwater pumping plus diversions data and precipitation data	0.97

* Note: Groundwater pumping is not directly used in water balance calculations, but is used to estimate factors that are used to calculate the water balance.

- ***Surface Water Diversions*—**Surface water diversions were estimated based on CNPPID diversion records for total diversions from Phelps Canal, E65 Canal, and E67 Canal for years 1985-2012. Ideally, diversions would be measured at the locations where the Supply Canal crosses the study area boundary; however, flow measurements are not available at that specific point and other water withdrawals occur such as through the J2 Return. The diversions were measured at Mile 1.6 on the Phelps Canal, Mile 5.9 for the E65 Canal, and measured at E67 Canal's point of diversion from the Supply Canal.

- ***Groundwater Flux (In and Out)*—**Groundwater flux in and out represents the water flowing through the aquifer across the edges of the study area boundary. Estimates of groundwater flux in and groundwater flux out were obtained from the COHYST MODFLOW model for years 1985-2005 and were estimated for years 2006-2012. The sources of the data and the estimation methods for groundwater flux are summarized in Table 7.

Table 7 Data Sources for Subfactors Related to Groundwater Flux

Subfactor	Years	Source	Coefficient of Determination
Flux In	1985–2005	COHYST MODFLOW Model	Not applicable
Flux In	2006–2012	Average 1985-2005 flux in	Not applicable
Flux Out	1985–2005	COHYST MODFLOW Model	Not applicable
Flux Out	2006–2012	Linear relationship between 1985-2005 net flux data and groundwater mound water volume data	0.83

- ***Surface Water Streamflow*—**Surface water in and out includes water moving out of the study boundary from streams, drains, and rivers. It does not include canal flows. This includes base flow and runoff from storm events. The Platte River is adjacent to the northern boundary of the site but does not cross the study boundary, so river flows are not included in the water balance. Surface water out estimates included the following outputs from CROPSIM and MODFLOW:

  — Base flow out (MODFLOW)
  — Base flow in (MODFLOW)
  — Drain flow out (MODFLOW)
  — Runoff flow out (CROPSIM).

  The COHYST estimates for base flow, drain flow, and runoff flow were available for years 1985-2005 and were estimated for the years 2006-2012. The sources of the data and the estimation methods for surface water in and out are summarized in Table 7.

Table 8 Data Sources for Subfactors Related to Surface Water In and Out

Subfactor	Years	Source	Coefficient of Determination
Base Flow Out	1985–2005	COHYST MODFLOW Model	Not applicable
Base Flow Out	2006–2012	Polynomial relationship between 1985-2005 base flow out data and recharge data	0.52
Recharge*	1985–2005	COHYST MODFLOW Model	Not applicable
Recharge*	2006–2012	Polynomial relationship between 1985-2005 recharge data and total water applied data	0.97
Base Flow In	1985–2005	COHYST MODFLOW Model	Not applicable
Base Flow In	2006–2012	Polynomial relationship between 1985-2005 base flow in data and base flow out data	0.79
Drain Flow Out	1985–2005	COHYST MODFLOW Model	Not applicable
Drain Flow Out	2006–2012	Average drain flow out volume for 1994-2005	Not applicable

* Note: Recharge is not directly used in water balance calculations, but is used to estimate factors that are used to calculate the water balance.

6.2.2 Additional Factors

The following additional factors, described below, are included in the water balance but have a smaller influence than the previously described key factors:

- ***Evaporation*****—**Evaporation occurs from the open water surface in the lakes, canals, laterals, and water applied to fields within the study area. This factor does not include ET; as ET is accounted for separately. The impact of evaporation on the water balance needs to be carefully considered because it may have already been included in one of the other factors. For example, evaporation would be considered a removal of water from the system from canals and lakes downstream of the canal measuring point for determining diversions. Evaporation is not considered a removal of water from a point upstream of the measuring point because the total diversion flow is not measured at the study area boundary. Therefore, evaporation is included as a removal in the water balance for the Phelps Canal downstream of Mile 1.6, Mile 5.9 for the E65 Canal, and at E67 Canal's point of diversion from the Supply Canal. Evaporation is not determined for the Supply Canal, Johnson Lake, or Elwood Reservoir. Main channel canal evaporation was estimated based on the length of the canals, the average width, and an estimated 50 inches of evaporation per year. The canal dimensions used to estimate canal evaporation are summarized in Table 8.

Table 9 Canal Dimensions Used to Estimate Evaporation from the Main Channels

Canal	Average Width (feet)	Length (miles)	Area (acre)
Phelps	70	68.7	583
E65	30	40	145
E67 (Prior to 2003)	15	21.3	39
E67 (2003 and after)	15	3.3	6

Evaporation from canal laterals and evaporation of applied water at the fields were outputs of the COHYST CROPSIM model. The total amount of evaporation was found to be small relative to other factors. The COHYST estimates were available for the years 1985-2005 and were estimated for the years 2006-2012. The sources of the data and the estimation methods for evaporation from canal laterals and water applied to fields are summarized in Table 9.

Table 10 Data Sources for Subfactors Related to Evaporation from Laterals and Fields

Subfactor	Years	Source	Coefficient of Determination
Lateral Evaporation	1985–2005	COHYST CROPSIM Model	Not applicable
Lateral Evaporation	2005–2012	Linear relationship between 1985-2005 lateral evaporation data and diversions data	0.58
Field Evaporation	1985–2005	COHYST CROPSIM Model	Not applicable
Field Evaporation	2006–2012	Polynomial relationship between 1985-2005 field evaporation data and diversions plus groundwater pumping data	0.96

- ***Recharge from Reservoirs*—**Similar to evaporation, recharge from reservoirs needs to be carefully considered depending on the location of measuring points. The water balance included recharge from Johnson Lake and Elwood Reservoir because they are upstream of the canal measuring points. Therefore, water seeping from the reservoirs was included as a separate factor representing water being added to the water balance domain through recharge. Seepage estimates provided by CNPPID were used for the evaluation.

- ***Recharge from Canals*—**The water balance included recharge from canals that are upstream of the measuring points for the same reasons as previously described. Recharge from canals downstream of the measuring points was not included because it is already accounted for with the diversion records. Seepage from canal sections upstream of the measuring points to the study area boundary were estimated based on area of canal and an estimated canal seepage rate of 80 acre-feet of seepage per acre per year.

6.2.3 Other Factors Considered

The following factors, described below, were considered in the water balance but were determined to either have negligible influence or the influence would reside completely within the domain of the water balance:

- ***Root Zone and Vadose Zone Storage*—**The change in storage in the root zone and the vadose zone was assumed to be negligible since the evaluation is being completed on an annual basis.

- ***Groundwater Pumping*****—**Groundwater pumping is removed from the groundwater within the saturated zone, but is applied to the surface. Therefore, groundwater pumping is not a direct factor in the water balance calculations, but is related indirectly to the water balance through evapotranspiration.

- ***Recharge from Deep Percolation*****—**Recharge through deep percolation from irrigated cropland, non-irrigated cropland, and non-cropland within the study area was not included as a separate factor because the water remains within the domain of the water balance as it moves through the root zone and vadose zone to the saturated zone.

- ***Recharge from Streams*****—**The recharge from streams within the study area was not included as a separate factor because the water remains within the domain of the water balance as it moves through the root zone and vadose zone to the saturated zone.

6.3 WATER BALANCE RESULTS

The water balance factors were used to calculate changes in the groundwater mound volume for years 1985 through 2012. The resulting volume of the groundwater mound based on the water balance (water balance groundwater mound volume) was then compared to the groundwater mound water volume as determined previously using the CSD water level data (CSD groundwater mound volume). This comparison is shown in Figure 30.

The 1985 CSD groundwater mound volume was used as a starting point for the water balance groundwater mound volume. Each year after 1985, the groundwater mound volume was determined as a cumulative volume since 1985. The CSD groundwater mound volume generally represents spring conditions for a given year. The water balance groundwater mound volume generally represents the conditions at the end of year. To provide a better comparison, the resulting groundwater mound volume calculated by the water balance was compared to the CSD groundwater mound volume for the following year. For example, the water balance results based on 2012 data (precipitation, diversions, etc.) represent conditions at the beginning of 2013 and are, therefore, compared the 2013 CSD groundwater mound volumes representing Spring 2013.

As seen in Figure 30, the water balance groundwater mound volume and CSD groundwater mound volume have several similarities. Both volumes have similar response patterns to different periods of time. For example, both volumes increase from 1985 through 1988, then decrease through 1992. Both rise sharply in 1994 and decline sharply from 2002 through 2006. Both increase from 2006 through 2012 before declining sharply in 2013. The cumulative volume through 2013 for the CSD groundwater mound volume is about 3.9 million acre-feet and the water balance groundwater mound volume is about 4.2 million acre-feet, about 8 percent higher.

One noticeable difference in the fluctuations is that the groundwater mound volume as calculated by the water balance rises and falls more rapidly than the groundwater mound volume determined by the CSD well data. Several possible reasons for the difference in amplitude were considered, and discussed in later sections. However, it appears that the years that are exceptionally dry or exceptionally wet are the years that the differences between the CSD groundwater mound volume and the water balance groundwater mound volume are most exaggerated.

6.3.1 Sensitivity Analysis

Travel time through the vadose zone, surface water streamflow that leaves this study's boundary, and specific yield of the aquifer that contains the groundwater mound were adjusted independently to determine their effect on the water balance. The adjusted factors were used to calculate the groundwater mound volumes as determined by the water balance and compared to the groundwater mound volumes as determined by the CSD well data. The purpose of the sensitivity analysis was to determine if adjusting any of these factors could provide groundwater mound volumes as determined by the water balance that more closely matched the groundwater mound volumes as determined by the CSD well data. The adjustment of each factor and the results of the adjustments are described below.

6.3.1.1 Evaluation of Travel Time through Vadose Zone

The time necessary for water to travel through the vadose zone and temporary storage within the vadose zone may have a temporal effect on water balance mound volume. The slower the water moves through the vadose zone, the more dampened the response to the groundwater mound volume will become. To estimate the effect of the vadose zone dampening, the water balance groundwater mound volume was recalculated assuming it would take multiple years for all of the water to reach the groundwater mound. The calculated water balance volume was spread over the following multi-year period. The approach was used for periods of time ranging from 2 to 5 years. For example, if the travel time was 3 years, it was assumed that one third of the water volume reached the groundwater mound each of the following 3 years. The water balance groundwater mound volume with the increased travel time through the vadose zone was compared to the CSD groundwater mound. It was found that the 3-year recharge time provided the best results and is shown in Figure 31.

As expected, the adjustment to the calculated water balance groundwater mound volume has a smoothing effect. The adjusted water balance groundwater mound volume provides a better match to the CSD groundwater mound volume in several areas than the non-adjusted, such as during 2003-2009. However, the smoothing makes the match worse for years where a shape change is evident, such as from years 1994-1999 and from 2012 to 2013. It was determined that the net results of the travel time adjustment did not result in a significantly improved match to the CSD groundwater mound volumes and were, therefore, not considered further.

6.3.1.2 Evaluation of Runoff

The surface water leaving the system is comprised of base flow and runoff from storm events. The amount of runoff is difficult to estimate on an annual basis and would be influenced by the magnitude of rainfall events for a specific year. To estimate the effect of runoff, the water balance groundwater mound volume was recalculated with an adjustment to the CROPSIM model runoff estimates for years with more precipitation than the normal heavy annual precipitation. Annual precipitation was determined to be greater than normal heavy precipitation if it exceeded the 60-year average precipitation by more than one standard deviation. Years with more precipitation than the normal heavy precipitation were 1993, 1996, 2007, and 2008. The intention of the runoff adjustment was to assume much more of the precipitation above the normal heavy precipitation was conveyed out of the study area than estimated with COHYST's CROPSIM model.

On average, the CROPSIM model estimates that 2 percent of the annual runoff is conveyed out of the study area. For the runoff adjustment, it is assumed that 50 percent of the annual precipitation above normal heavy annual precipitation is conveyed out of the study area (Runoff = ½ [Annual Precipitation – Average Precipitation – 1 Standard Deviation]). Figure 32 shows the water balance groundwater mound volume with an adjusted runoff volume compared to the CSD groundwater mound volume.

The results from the adjustment appeared to improve the match between the CSD groundwater mound volumes for 1994-1996, and 2010-2013; however, separation was increased for the years 2000-2006. Adjustment of the runoff in extremely dry years did not have a noticeable effect on the water balance groundwater mound volume, so a dry year adjustment was not included. It was determined that the net results of the runoff adjustment did not result in a significantly improved match to the CSD groundwater mound volumes and were, therefore, not considered further.

6.3.1.3 Evaluation of Specific Yield

A key factor for estimating the volume of water present in the groundwater mound is the aquifer parameter of specific yield. The values for specific yield were estimated as described in previous sections. A sensitivity analysis was conducted to determine the effects of incremental changes to specific yield. The adjusted CSD groundwater mound volumes from the sensitivity analysis were compared to the water balance groundwater mound volume. The results are provided in Appendix H.

The specific yield used throughout this evaluation is 0.14. It was found that reducing the specific yield did not provide improvements to the match between the adjusted CSD groundwater mound volume and the water balance groundwater mound volume, but did cause a significant reduction in the total volume of water contained within the groundwater mound. For example, the CSD groundwater mound volume was estimated to be about 3.8 million acre-feet in 2013 when using a specific yield of 0.14, but reduced the volume to about 3.3 million acre-feet when using a specific yield of 0.12.

It was found that increasing the specific yield improved the match between the adjusted CSD groundwater mound volume and the water balance groundwater mound volume for some years and makes the match worse for other years. For example, when a specific yield of 0.18 was used, the match between the adjusted CSD groundwater mound volume and the water balance groundwater mound volume is excellent from 1985 through 1998, and from 2010 through 2013. However, for years 1999 through 2007, the adjusted CSD groundwater mound volume is significantly higher than the water balance groundwater mound volume. Increasing the specific yield to 0.18 results in an estimated groundwater mound volume of 5.1 million acre-feet in 2013, compared to 3.8 million acre-feet for a specific yield of 0.14.

6.3.2 Adjustment of Water Use Factors

Historic surface water diversions and historic ET values were also adjusted to determine their effect on the water balance. As with the sensitivity analysis, the adjusted factors were used to calculate the groundwater mound volumes as determined by the water balance and compared to the groundwater mound volumes as determined by the CSD well data. Surface water diversions and ET were chosen because they are the largest factors that can be influenced by operational practices. Precipitation was not adjusted despite being the largest factor in the water balance because it cannot be controlled. The purpose of the adjustment of water use factors was to estimate how water use operations effect the growth and decline of the groundwater mound. The adjustment of each factor and the results of the adjustments are described below.

6.3.2.1 Evaluation of ET

The amount of ET in this study's area is the largest factor for reducing water within the system. To evaluate the effects that changes to ET would have on the groundwater mound, the water balance groundwater mound volumes were recalculated with a range of adjusted ET volumes. Figure 33 shows the groundwater mound volumes as determined by the water balance adjusted by altering the ET to 105, 102, 98, and 95 percent of the historic ET estimates compared to groundwater mound volumes as determined by an un-adjusted water balance and un-adjusted ET. The variations in ET are small because management practices would typically have a small impact on ET.

The results shown in Figure 33 provide a range of potential impacts that could be encountered if ET is altered. ET could be altered by changing irrigation practices, crop production, advances in crop hybrids, and various uncontrollable environmental factors. Because the annual ET volume comprises nearly 90 percent of the factors that reduce water within the system, even a small change can have a large effect on the groundwater mound over time.

6.3.2.2 Evaluation of Surface Water Diversions

The amount of water imported into the study area boundary through surface water diversions is the second largest factor for adding water into the system following precipitation. To evaluate the effects that changes to diversions would have on the groundwater mound, the water balance groundwater mound volumes were recalculated with a range of adjusted water diversions. Figure 34 shows the groundwater mound volumes as determined by the water balance adjusted by altering the diversions to 125, 75, 50, 25, and 0 percent of the historic diversions compared to groundwater mound volumes as determined by an un-adjusted water balance and un-adjusted diversions. It should be noted that ET was not reduced in Figure 34, so this evaluation assumes that the supplemental water would have been applied through groundwater pumping to compensate for reduced surface water diversions.

The results shown in Figure 34 provide a range of potential impacts that could be encountered if surface water diversions are changed. Even though surface water diversions only represent about 8 percent of the total factors that increase the amount of water to the system, reductions to surface water diversions have an impact on the volume of the groundwater mound volume. For example, the results suggest that if surface water diversions were eliminated in 1985 and remaining factors remained unchanged, the entire volume of the groundwater mound would have been depleted by 2003 (less than 20 years). Alternately, if surface water diversions were reduced by 50 percent for all years since 1985, the volume of the groundwater mound would have been reduced to about 38 percent of its current estimated volume in 2013.

7. SUMMARY AND CONCLUSIONS RESULTS AND DISCUSSION

The overall objective of this study was to provide a more thorough understanding of groundwater levels within the vicinity of the groundwater mound in the vicinity of lands irrigated by CNPPID facilities. This information will allow CNPPID to make informed water resources management decisions.

The purpose of the report is to summarize the methods, results, and conclusions from the groundwater mound evaluation. The evaluation includes temporal and spatial changes of the groundwater mound, factors affecting the groundwater mound, and a water balance analysis within the study area.

7.1 GENERAL

Based on the information provided in this report, the following general conclusions are presented:

- Seven subareas were identified to represent areas of interest or key features. The subareas are as follows: Johnson Lake, Elwood Reservoir, E76 Canal, E65 Canal, Phelps Canal Upper, Phelps Canal Middle, and Phelps Canal East.

- The time period included in the evaluation includes years 1954-2013 for long-term analysis and a more detailed evaluation for recent years (2000-2013). This study period corresponds with the time period where CSD has published groundwater level change maps in Nebraska.

- Pre-development water levels were defined by CSD as the estimated water levels that generally occurred before 1930s, 1940s, or early in the mid-1950s. CSD’s pre-development conditions were used as a common basis of comparison throughout this evaluation.

- The study area boundary includes a 1,620-square mile area that extends beyond the edges of the historic groundwater mound.

- The hydrogeologic conditions of the area are described in COHYST HUs and Aquifer Characterization Report (2006). The geologic units of interest are Hydrostrographic Unit 1 (Upper Quaternary Fines) and HU 2 (Quaternary Alluvial/Valley Fill Deposits). The rise of groundwater levels has occurred in these two geologic units.

- Specific yield is the primary aquifer parameter of interest and is used to estimate the volume of groundwater present within a volume of saturated aquifer. An average specific yield of 0.14 was used for this evaluation.

7.1.1 Groundwater Mound Volume

The following conclusions are presented related to temporal changes of the groundwater mound volume:

- Two approaches were used to estimate the size and the shape of the groundwater mound: digitizing the contours prepared and published by CSD, and recreating the contours from raw water level data used by CSD for each year. It was found that using the raw water level data was more accurate and this approach was used throughout the evaluation.

- The volume of the groundwater mound was estimated for each year from 1954 through 2013. The general long-term trend through 2000 has been increasing total volume of the groundwater mound, with occasional periods of decline. The size of the groundwater mound was the maximum in 2000. After the decline through 2006, groundwater water levels continued to steadily increase through 2012, to levels slightly less than the maximum in 2000.

- The first year included in the study is 1954. The volume of the groundwater mound was already significant in 1954; indicating the groundwater mound was already forming. This is reasonable, since Johnson Lake, Phelps Canal, and E65 Canal were constructed in the early 1940s.

- The western subareas (E67 Canal, Elwood Reservoir, E65 Canal, Johnson Lake, and Phelps Canal Upper Subareas) only comprise 48 percent of this study's area, but contain approximately 75 percent of the groundwater mound volume. Table 5 shows the groundwater mound volume and the groundwater mound volume per unit area for each subarea.

7.1.2 Groundwater Mound Shape

The following conclusions are presented related to spatial and temporal changes of the groundwater mound shape:

- A large increase in the groundwater mound was observed from 1960 to 1970 across most of the study area.

- In general, groundwater mound has increased in size from 1960 through 2000. The groundwater mound growth has been somewhat symmetrical vertically and horizontally, with more growth to the south than to the north.

- In general, the groundwater mound decreased in size slightly from 2000 to 2010. The groundwater mound decline has also been somewhat symmetrical vertically and horizontally.

- The groundwater mound has had some decline in the extreme eastern and southern edges of the study area from 1960 to 2010 compared to pre-development.

- From 2000 to 2006, the groundwater mound size generally decreased across the entire study area, with the largest declines across the middle and far eastern portions of the study area.

- From 2007 to 2012, the groundwater mound size generally increased across the entire study area, but with pockets of areas where the increase was less consistent. The groundwater mound size was variable in 2013, increasing in some areas and noticeable decreases with other areas.

7.1.3 Investigating Factors Influencing the Groundwater Mound

The following conclusions are presented related to factors that have an influence on the groundwater mound:

- Annual precipitation ranged from about 13 inches per year to about 37 inches per year. During years 1954 through 1970, the volume of the groundwater mound appears to only have a minimal response to precipitation. In some years of unusually high precipitation, such as 1993 and 1996, the groundwater mound volume has a noticeable increase the following year. Similarly, in some unusually dry years, such as 2002 and 2012, the groundwater mound volume has a noticeable decrease the following year. However, there are many instances where the response is minimal or non-existent, such as from 1998 to 1992 and 2006.

- Total diversions have had a general downward trend, opposite of the general increasing trend of the groundwater mound volume. The groundwater mound volume increased in 1993 and 1994 despite a significant decrease of overall diversions and deliveries in 1993, a year of record rainfall. Overall deliveries and diversions are less than average from 2005 to 2011. The decrease in deliveries and diversions corresponds with the decrease in the groundwater mound volume during the same period; however, it appears that the groundwater mound volume decrease begins before the reduction in diversions began. Similarly, it appears that the groundwater mound volumes began to rise in 2007 while diversions were decreasing.

- Seepage from Elwood Reservoir has a generally decreasing trend from 1985 to 2004. During the same period, the groundwater mound volume is increasing. The impact of the reservoir seepage is not evident in the overall groundwater mound volume or the Elwood Reservoir Subarea groundwater mound volume.

- The number of registered irrigation wells within the study area has generally increased since 1954. The steepest increase was from 1954 through 1977. The number of wells continued to increase gradually from 1978 to 2001, with a sharp increase from 2002 to

2005. Since 2005, the number of irrigation wells has remained steady. In general, the continued increase in the number of registered irrigation wells coincides with the reduced steepness of growth of the groundwater mound volume.

7.1.4 Water Balance

The following conclusions are presented related to the water balance analysis conducted with the study area:

- A comprehensive approach water balance was used for the evaluation. The domain included the entire study from the land surface to the bottom of the aquifer, including the root zone, vadose zone, and groundwater in the saturated zone.

- Data for the water balance were obtained through several sources, but primarily CNPPID, COHYST, and CSD. One limitation of the COHYST data was that it was typically from the period of 1985-2005.

- The time period for the water balance was extended to include years back to 1985 instead of only 2000-2012 because the data were available through COHYST and the results provided additional perspective.

- The data for several factors was estimated for years 2006-2012 based on regression analysis using data for years 1985-2005.

- The volume of the groundwater mound (groundwater storage) was used as the basis of comparison between the groundwater mound volume calculated using the CSD raw well data and groundwater mound volume calculated using the water balance. The CSD groundwater mound volume for 1985 was used as the starting point for the water balance groundwater mound volume. After 1985, the water balance groundwater mound volume was calculated using the previous year’s water balance.

- Precipitation and diversions are the prominent factors for adding water to the system. Groundwater flux in, reservoir seepage, and surface water in are additional factors.

- ET and surface water out are the prominent factors for removing water from the system. Groundwater flux out and evaporation are additional factors.

- The water balance groundwater mound and CSD groundwater mound were found to have several similarities. Both volumes have similar response patterns to different periods of time. For example, both volumes increase from 1985 through 1988, then decrease through 1992. Both rise sharply in 1994 and decline sharply from 2002 through 2006. Both increase from 2006 through 2012 before declining sharply in 2013. One noticeable difference in the fluctuations is that the amplitude of the highs and lows are larger for the water balance groundwater mound volume than the CSD groundwater mound volume. It appears that the years that are exceptionally dry or exceptionally wet are the years that the differences between the CSD groundwater mound volume and the water balance groundwater mound volume are most exaggerated.

- Several potential adjustments were evaluated including adjustment of time of travel through the vadose zone, increased runoff for years with high precipitation, and sensitivity analysis for specific yield values. The adjustments did not provide water balance groundwater mound volumes that significantly matched the CSD groundwater mound water volume.

- The amount of ET in the study area is the largest factor for reducing water within the system. To evaluate the effects that changes to ET would have on the groundwater mound, the water balance groundwater mound volumes were recalculated with a range of adjusted ET volumes. Figure 33 shows the groundwater mound volumes as determined by the water balance adjusted by altering the ET to 105, 102, 98, and 95 percent of the historic ET estimates compared to groundwater mound volumes as determined by an un-adjusted water balance and un-adjusted ET. The results provide a range of potential impacts that could be encountered if ET is altered. Because the annual ET volume comprises nearly 90 percent of the factors that reduce water within the system, even a small change can have a large effect on the groundwater mound over time.

- The amount of water imported in the study area boundary through surface water diversions is the second largest factor for adding water to the system following precipitation. To evaluate the effects that changes to diversions would have on the groundwater mound, the water balance groundwater mound volume was recalculated with a range of adjustments to the amount of water diverted. The water balance was adjusted by adjusting the diversions to 125, 75, 50, 25, and 0 percent of the actual diversions and compared to un-adjusted results. The results provided a range of potential impacts that could be encountered if management practices related to surface water diversions are significantly changed. Even though surface water diversions only represent about 8 percent of the total factors that increase the amount of water to the system, reductions to surface water diversions have an impact on the volume of the groundwater mound volume.

7.1.5 Conclusions

The following conclusions are presented related to the growth and decline of the groundwater mound:

- The groundwater mound has been increasing in size and volume for the last 60 years, but appears to be at a critical point where the general trend is no longer rising. The groundwater mound has not grown from 2000 to 2012 despite the average precipitation being slightly higher than the average precipitation for 1954-1999 for the study area.

- The groundwater mound is growing the most in the western half of the study area. Groundwater mound growth has been somewhat symmetrical horizontally and vertically, with more growth to the south than to the north.

- Precipitation is a significant factor in the water balance, but the effects of both extremely low and high precipitation are dampened in the CSD groundwater mound volumes compared to the water balance groundwater mound volumes. A comparison of the water balance groundwater mound and the CSD groundwater mound is shown on Figure 30. In extremely wet years, such as 1993, 2007, and 2008 the groundwater mound volume as calculated by the water balance increases much more than the groundwater mound volume determined by the CSD well data. In extremely dry years, such as 2002 and 2012, the CSD groundwater mound volume does not decrease near as much as calculated by the water balance.

- The groundwater mound grew more rapidly prior to the 1970s, before the greatest rate of increase in registered wells and the wide use of center pivots for irrigation. Beginning in the mid-1970s, the groundwater mound's consistent growth pattern that started in the 1950s ends. This is shown in Figure 23.

- Small alterations to ET across this study's area would have a significant impact on the groundwater mound. The estimated effect of adjusting the ET is shown in Figure 33.

- If diversions were eliminated or significantly reduced, the groundwater mound would significantly decrease. It also appears that even small reductions to current surface water diversions would lead to slow declines in the groundwater mound. The estimated effect of adjusting the diversions is shown in Figure 34.

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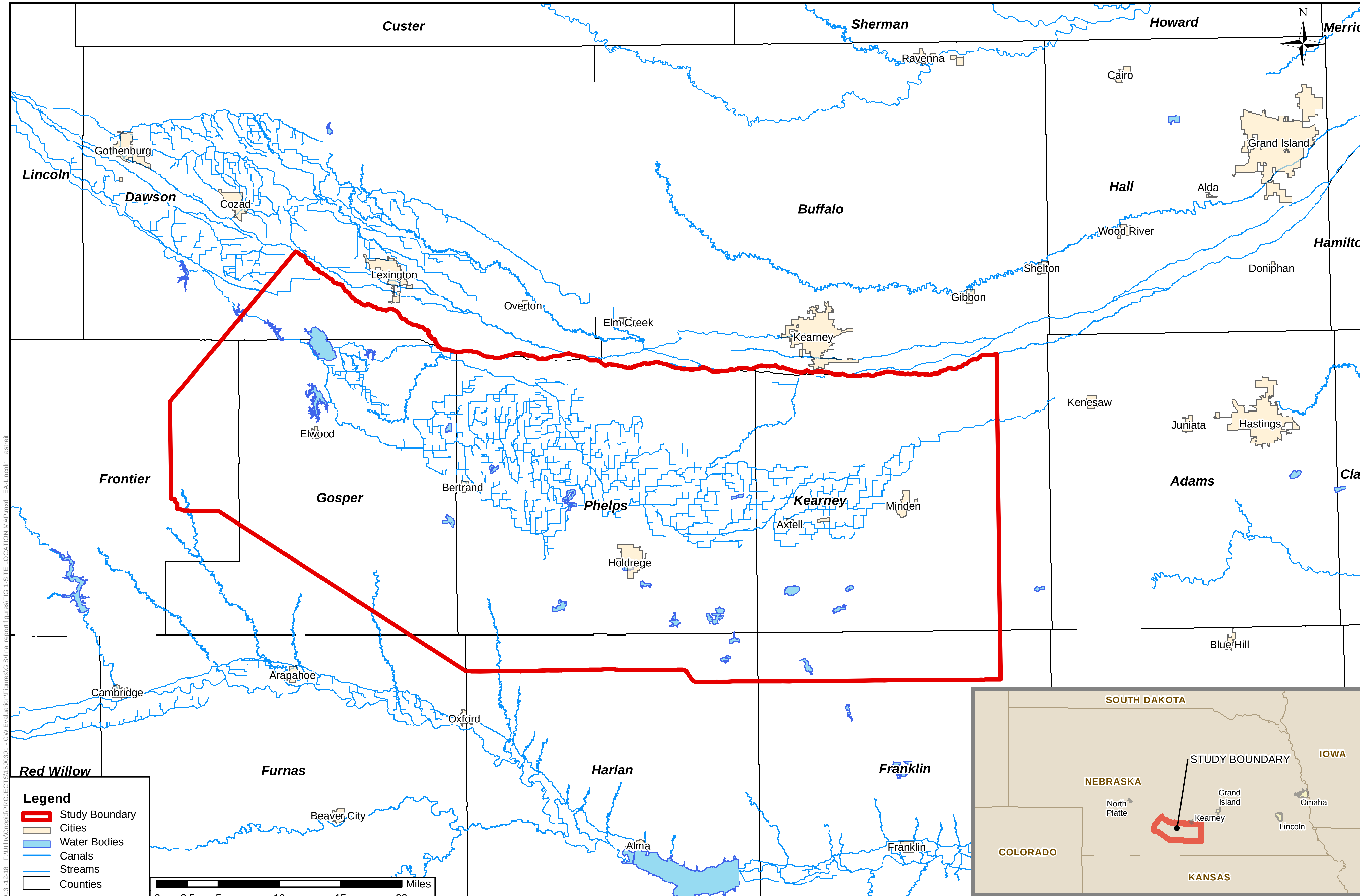
Figures



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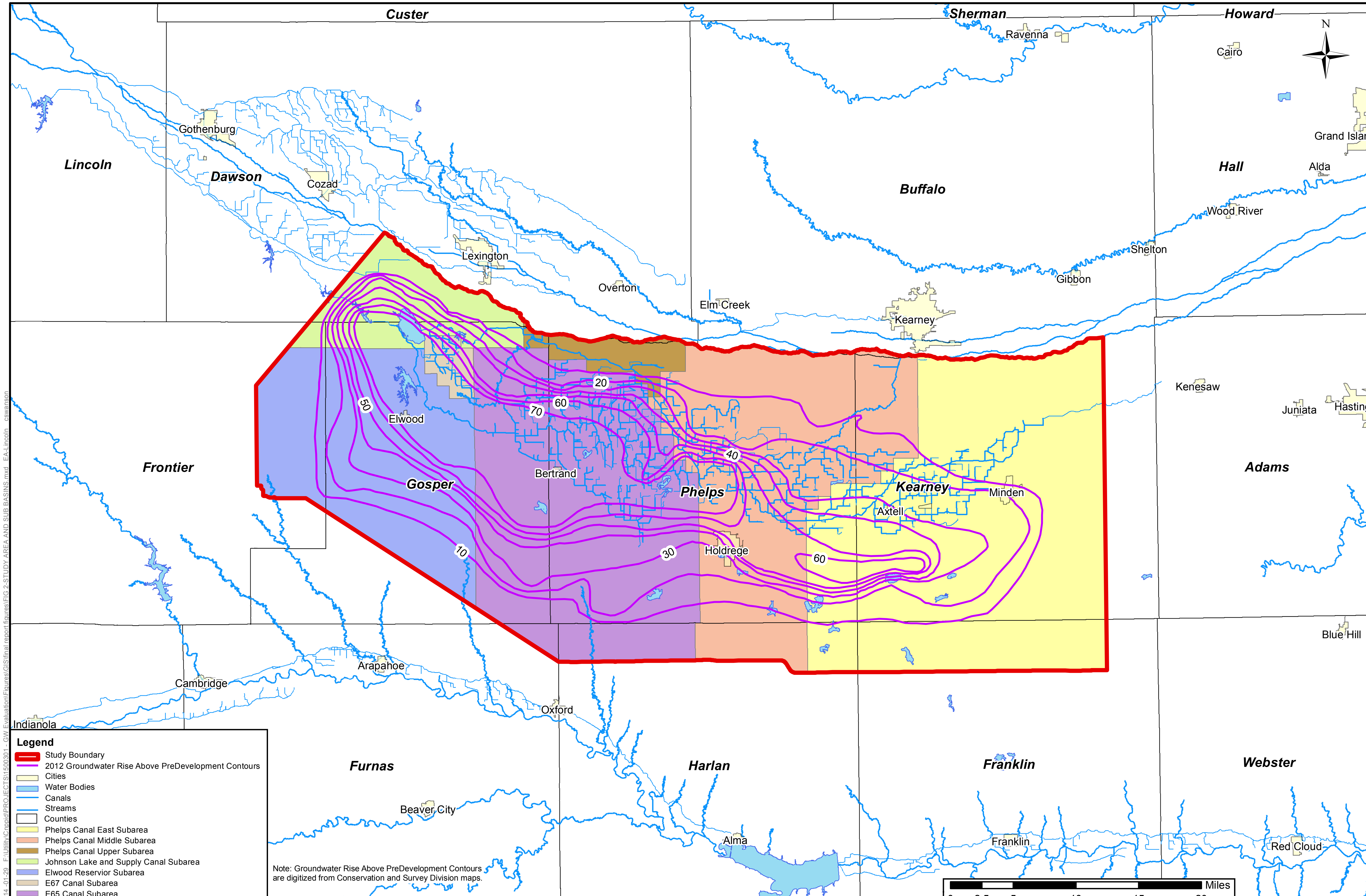
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

SITE LOCATION MAP

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	CNS	RJL	DEC 2013	AS SHOWN	1500301	–	–	1

2013-12-18 F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\GIS\final report figures\FIG 1-SITE LOCATION MAP.mxd EA-Lincoln astreit



SUBAREAS WITH 2012 DIGITIZED GROUNDWATER MOUND CONTOURS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

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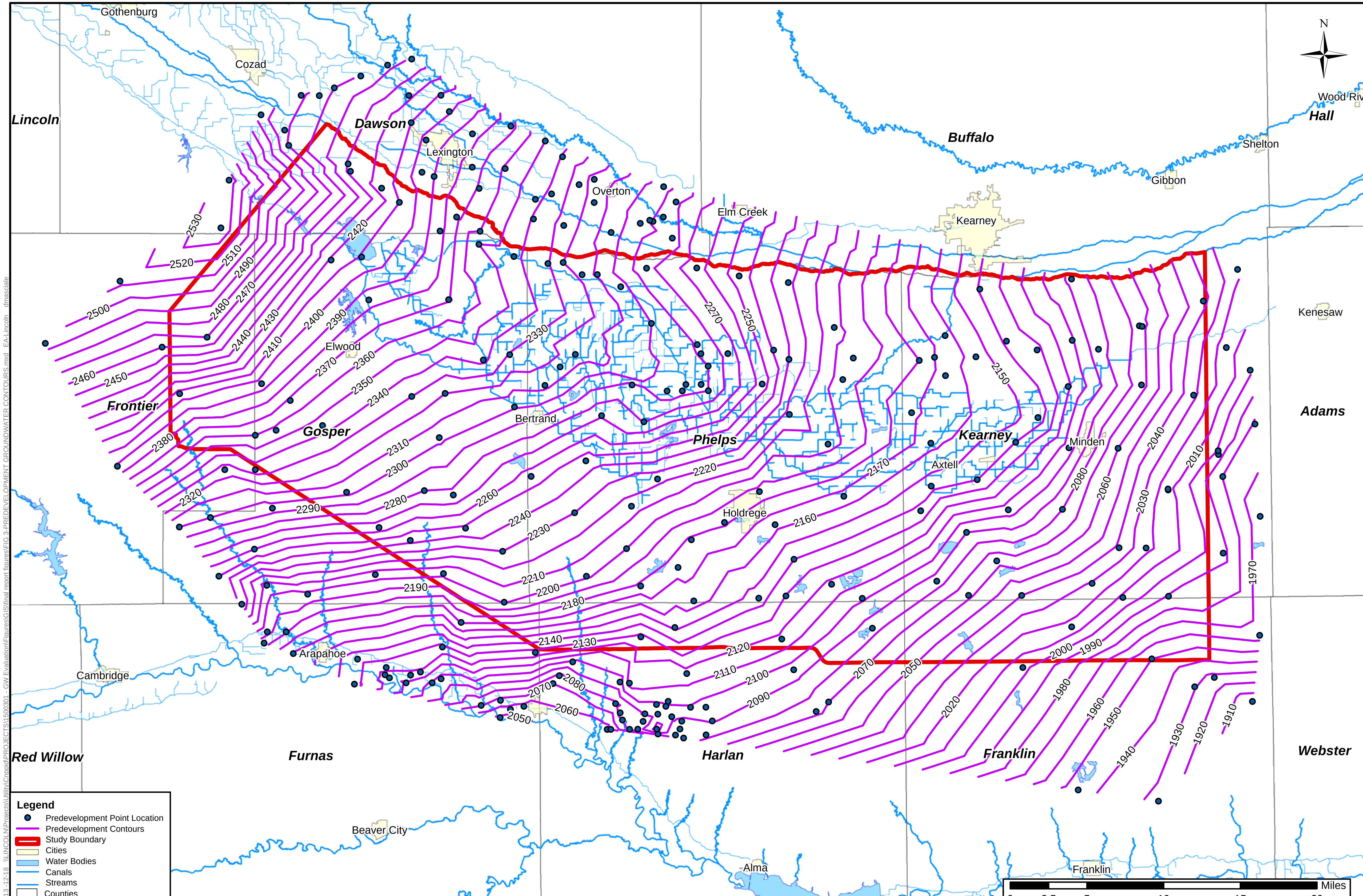
FIGURE	2
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	CNS
DESIGNED BY	CNS
PROJECT MGR.	DJS



PREDEVELOPMENT GROUNDWATER CONTOURS AND POINTS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	CNS	DJS	DEC 2013	AS SHOWN	1500301	–	–	3

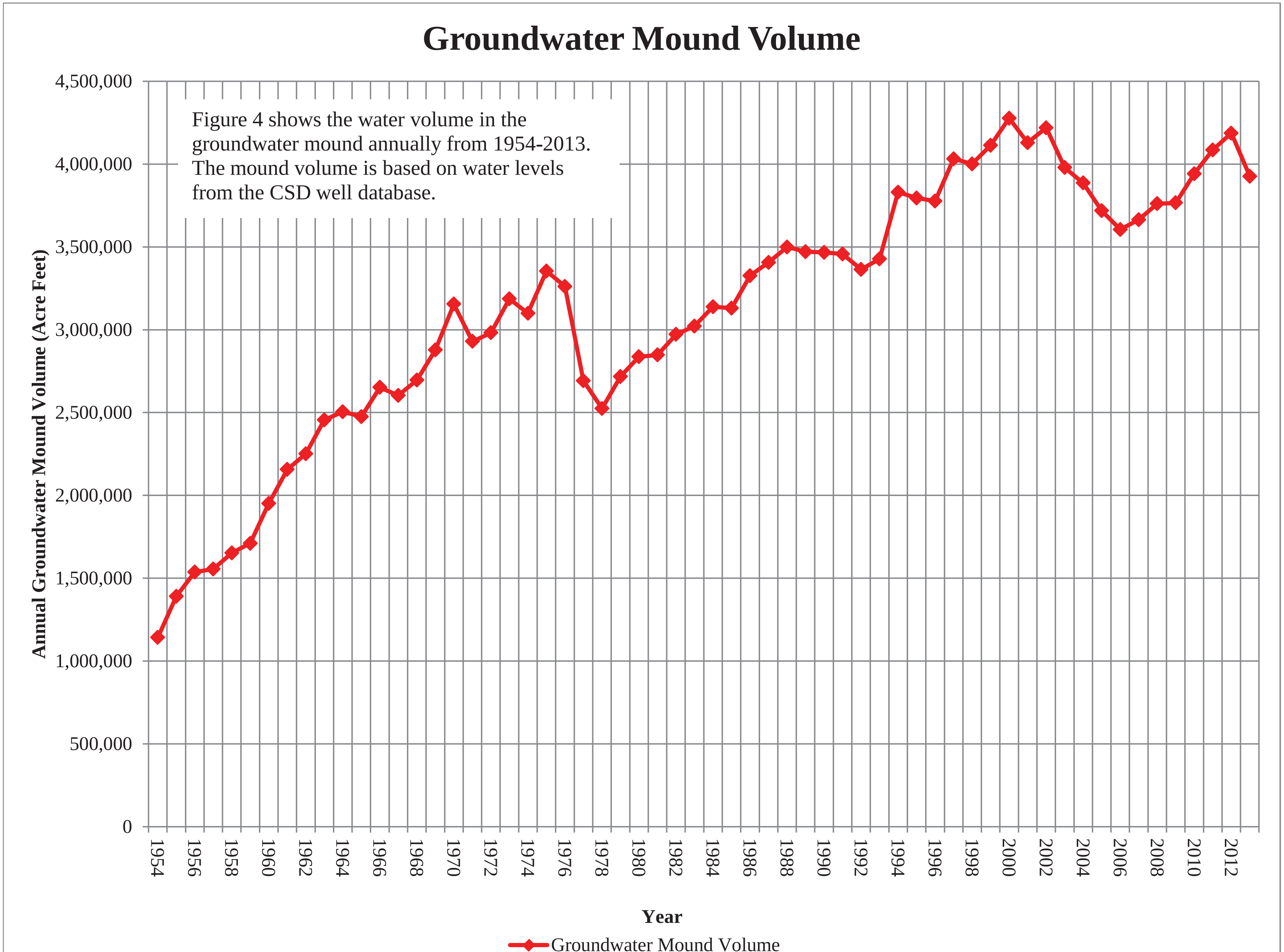


Figure 4. Calculated volume of the groundwater mound.

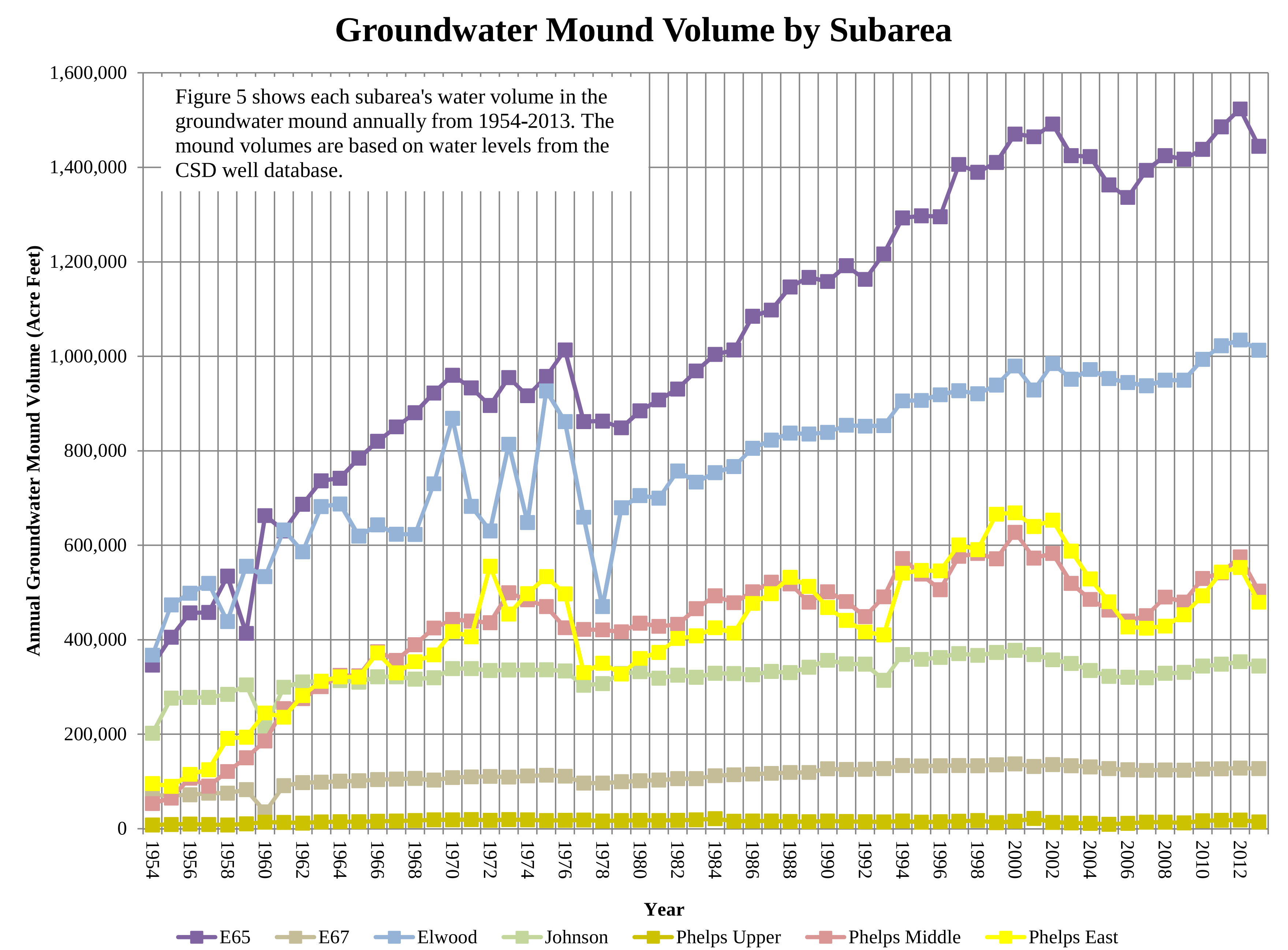
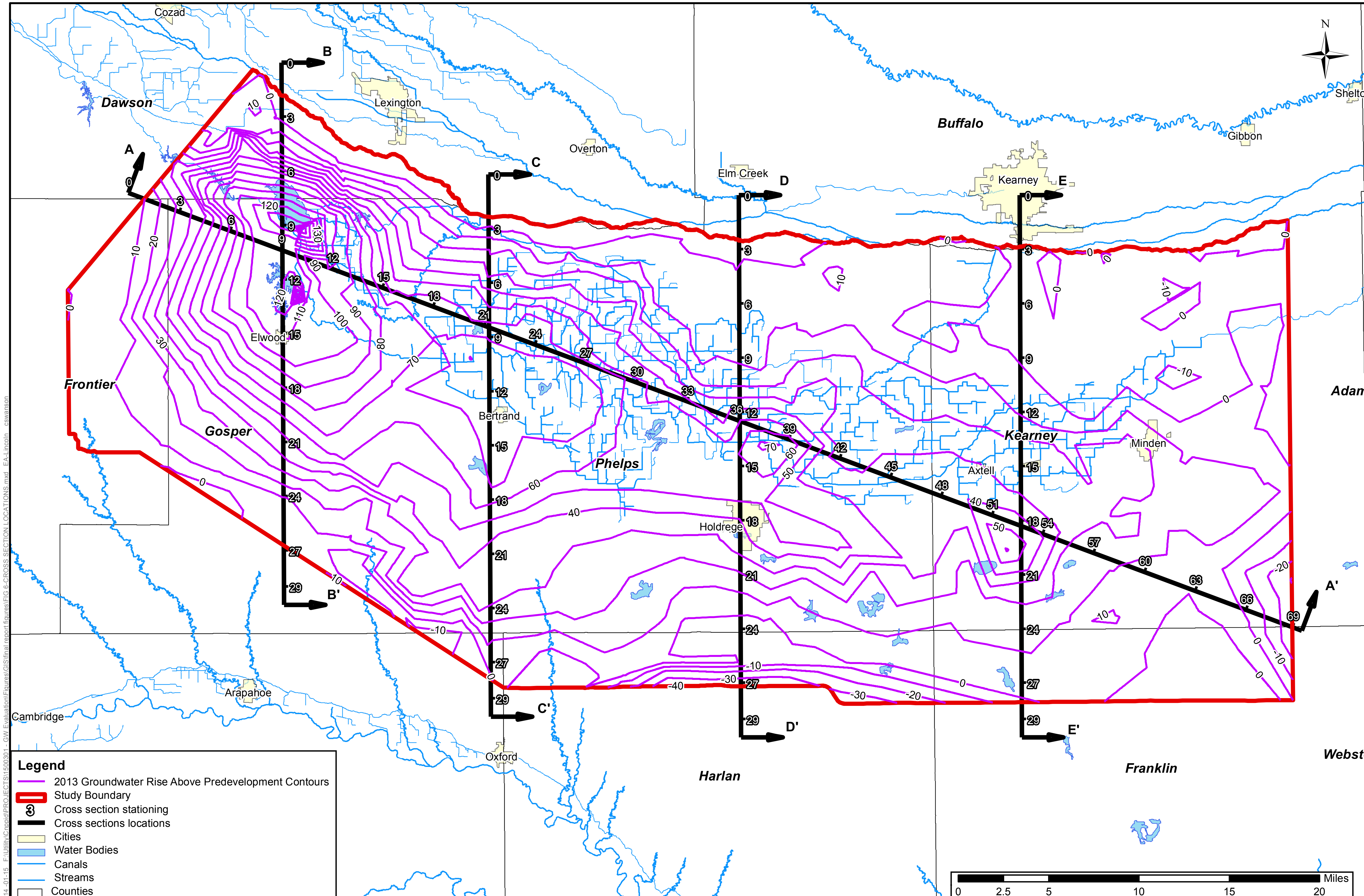


Figure 5. Calculated volume of the groundwater mound in each subarea.



CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

CROSS SECTION LOCATIONS

EA Engineering, Science, and Technology, Inc.

FIGURE	6
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
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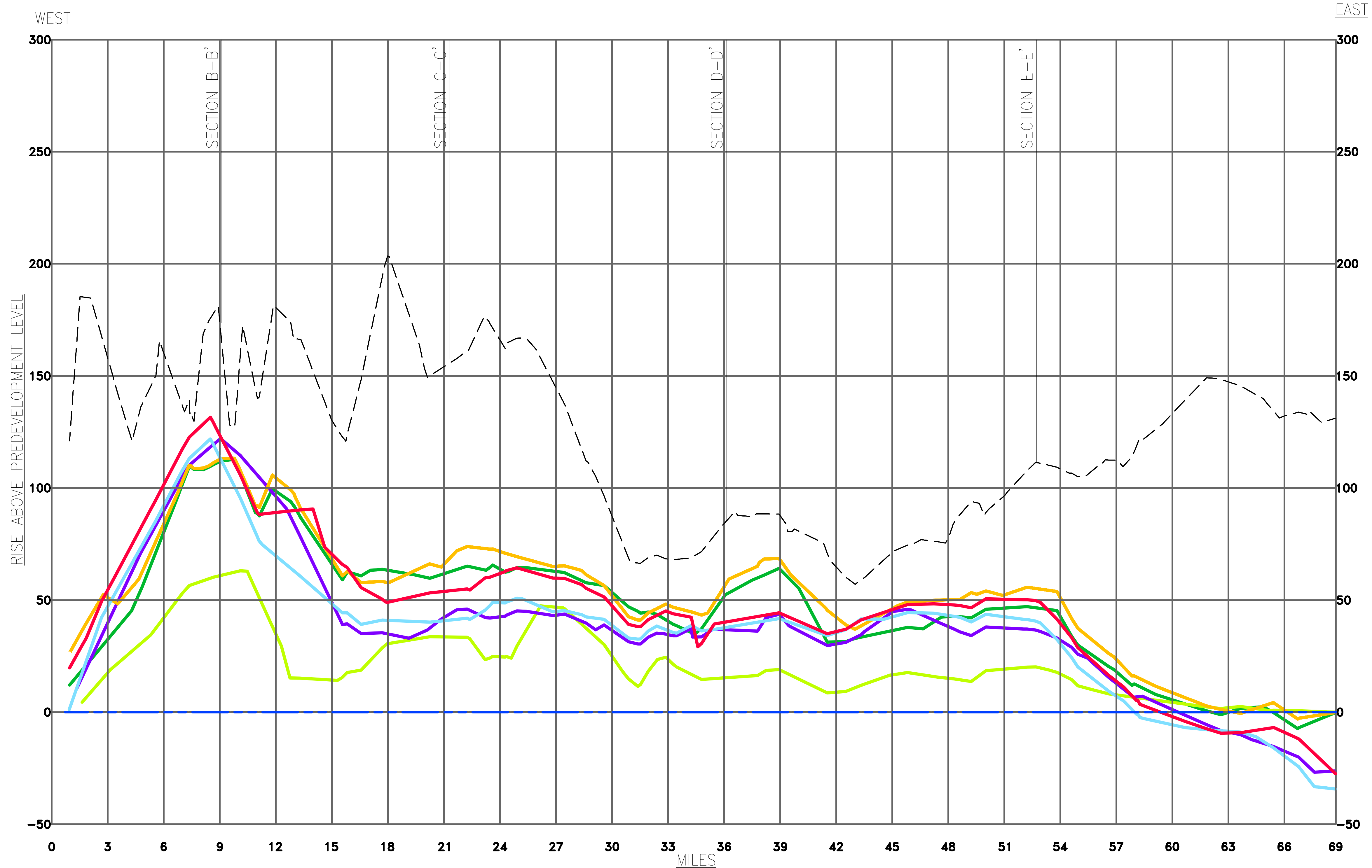
DESIGNED BY	CNS
PROJECT MGR.	DJS



SECTION A–A'

HORIZONTAL SCALE: 1"=6 MILES

VERTICAL SCALE: 1"=50'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- APPROXIMATE GROUND SURFACE
- 1960 GROUNDWATER RISE
- 1970 GROUNDWATER RISE
- 1980 GROUNDWATER RISE
- 1990 GROUNDWATER RISE
- 2000 GROUNDWATER RISE
- 2010 GROUNDWATER RISE

GROUNDWATER LEVELS
MULTIPLE YEAR CROSS SECTIONS
1960, 1970, 1980, 1990, 2000, AND 2010

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	7
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	CNS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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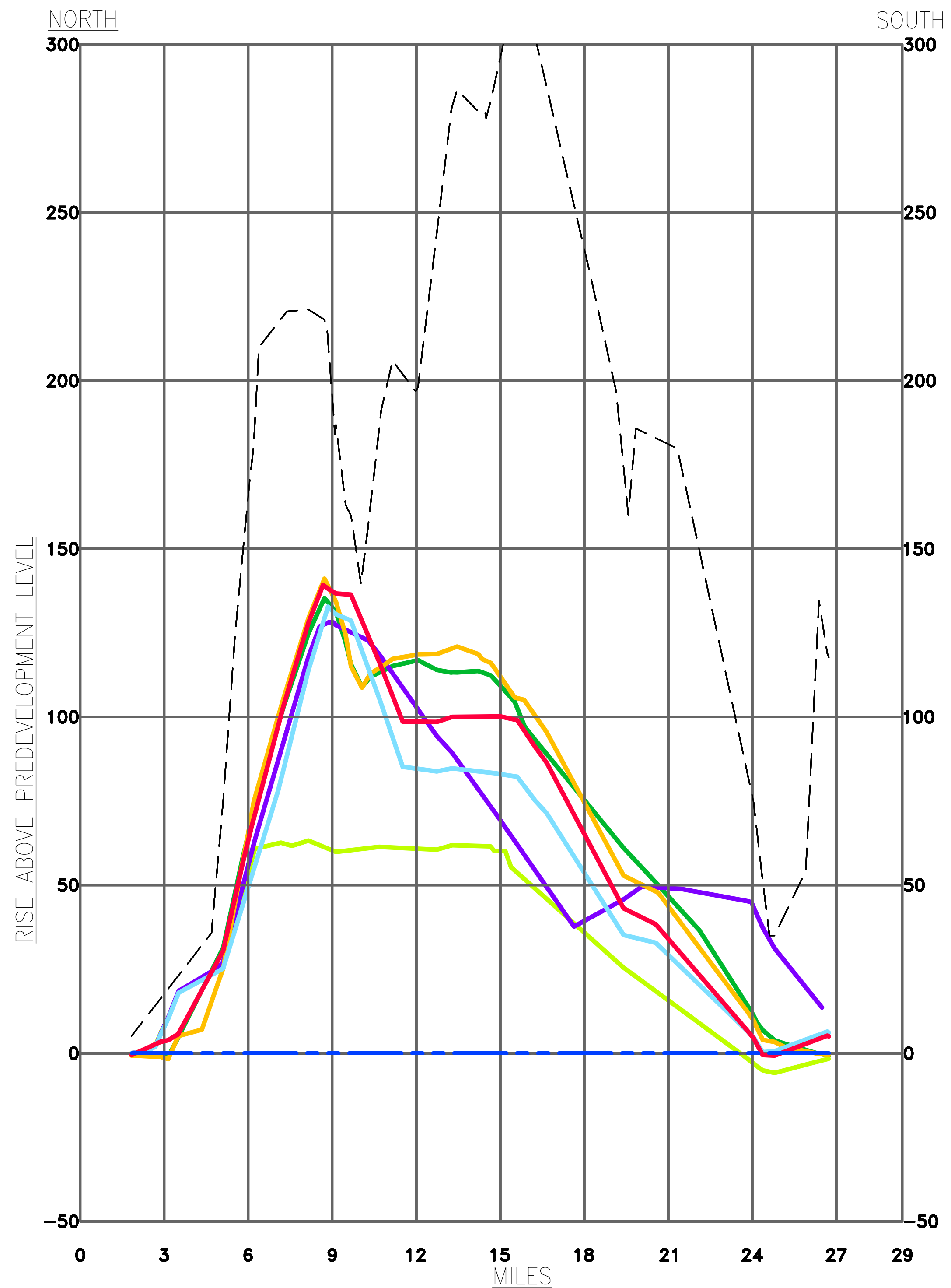
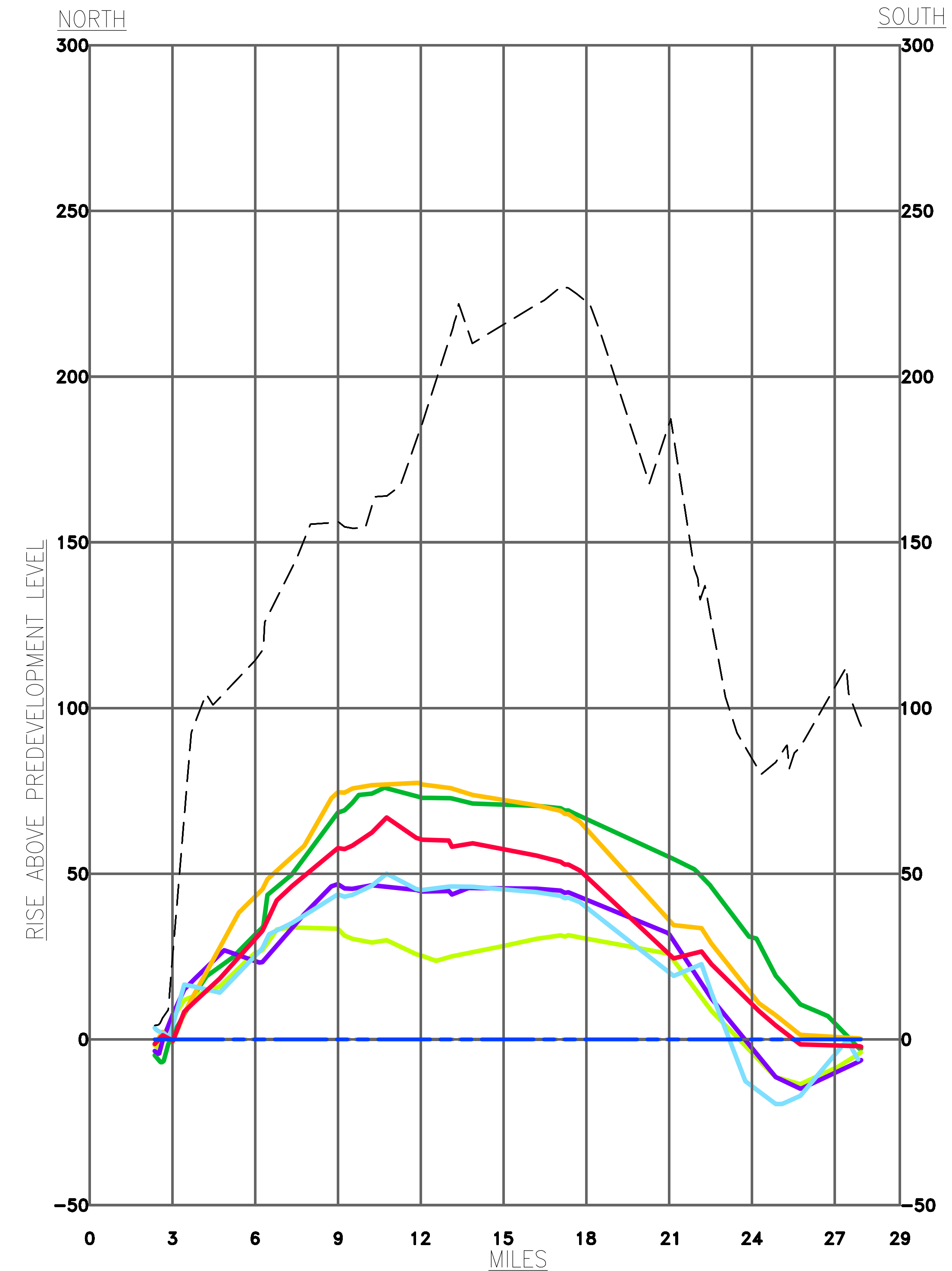


SECTION B-B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL
APPROXIMATE GROUND SURFACE
1960 GROUNDWATER RISE
1970 GROUNDWATER RISE
1980 GROUNDWATER RISE
1990 GROUNDWATER RISE
2000 GROUNDWATER RISE
2010 GROUNDWATER RISE

GROUNDWATER LEVELS
MULTIPLE YEAR CROSS SECTIONS
1960, 1970, 1980, 1990, 2000, AND 2010

CENTRAL NEBRASKA PUBLIC POWER
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GROUNDWATER EVALUATION

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FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
8	-	-	1500301	AS SHOWN	DEC 2013	DJS	CNS	CNS	DJS

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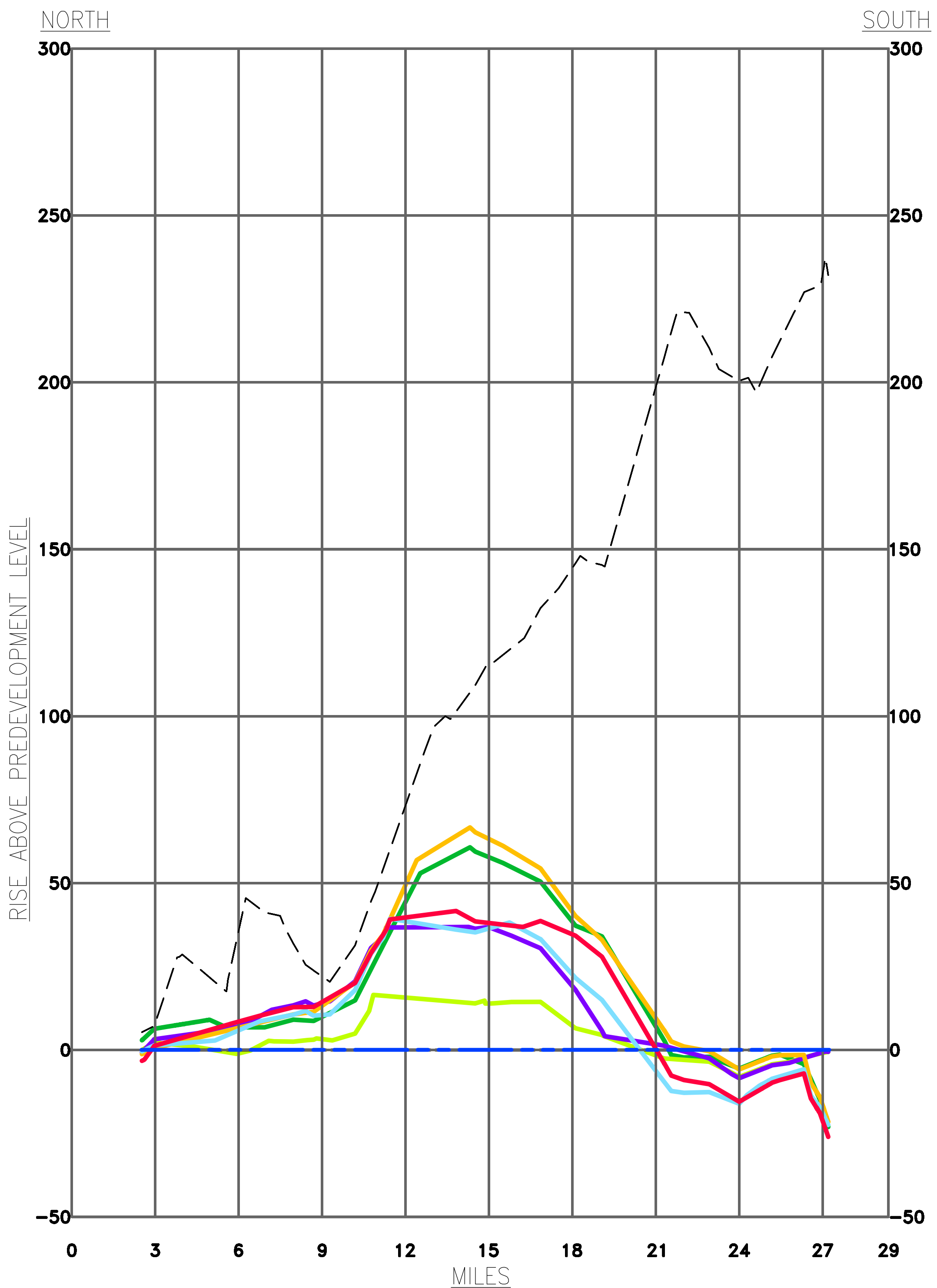
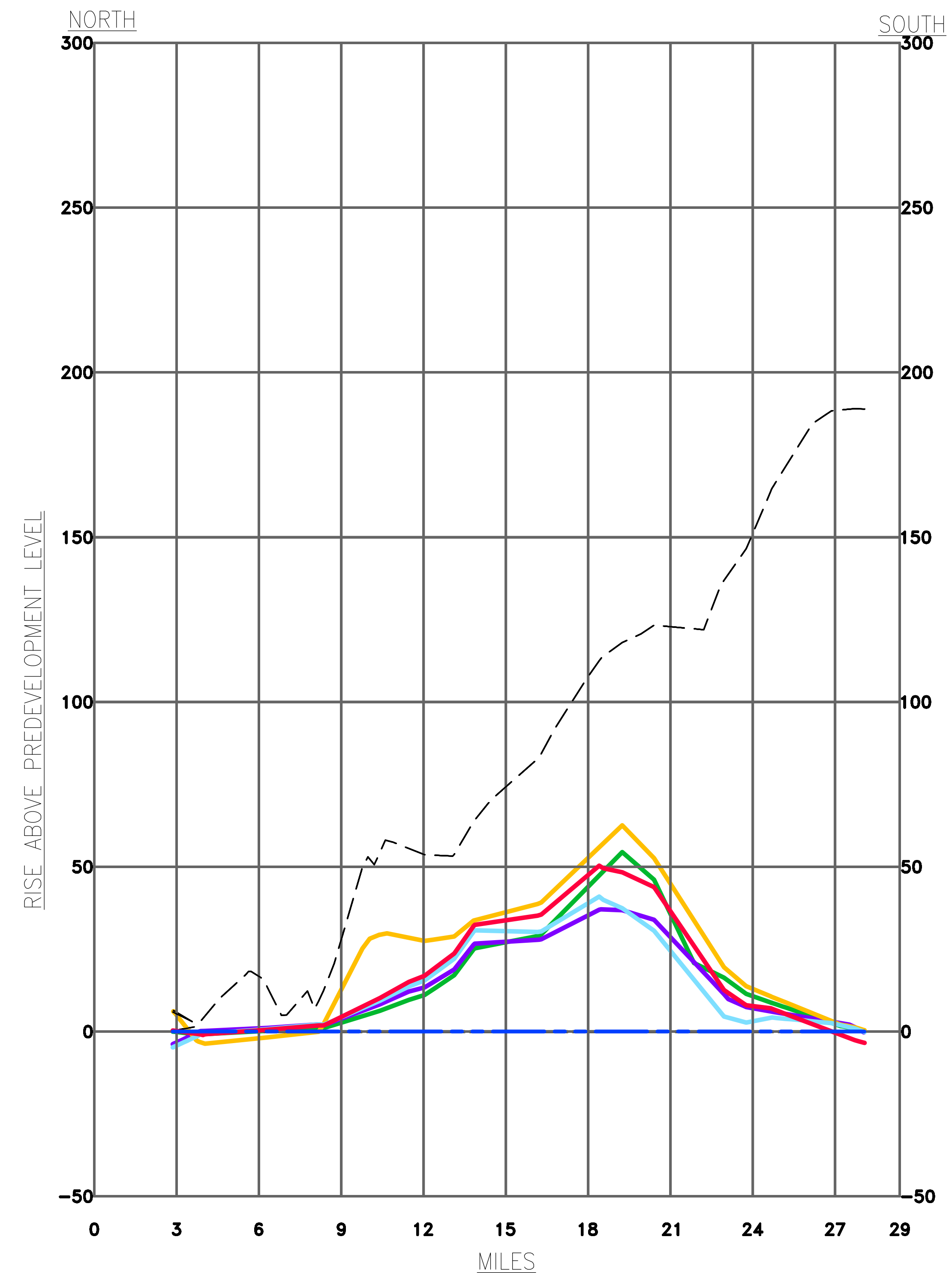


SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'



SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- APPROXIMATE GROUND SURFACE
- 1960 GROUNDWATER RISE
- 1970 GROUNDWATER RISE
- 1980 GROUNDWATER RISE
- 1990 GROUNDWATER RISE
- 2000 GROUNDWATER RISE
- 2010 GROUNDWATER RISE

GROUNDWATER LEVELS
MULTIPLE YEAR CROSS SECTIONS
1960, 1970, 1980, 1990, 2000, AND 2010

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	9
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	CNS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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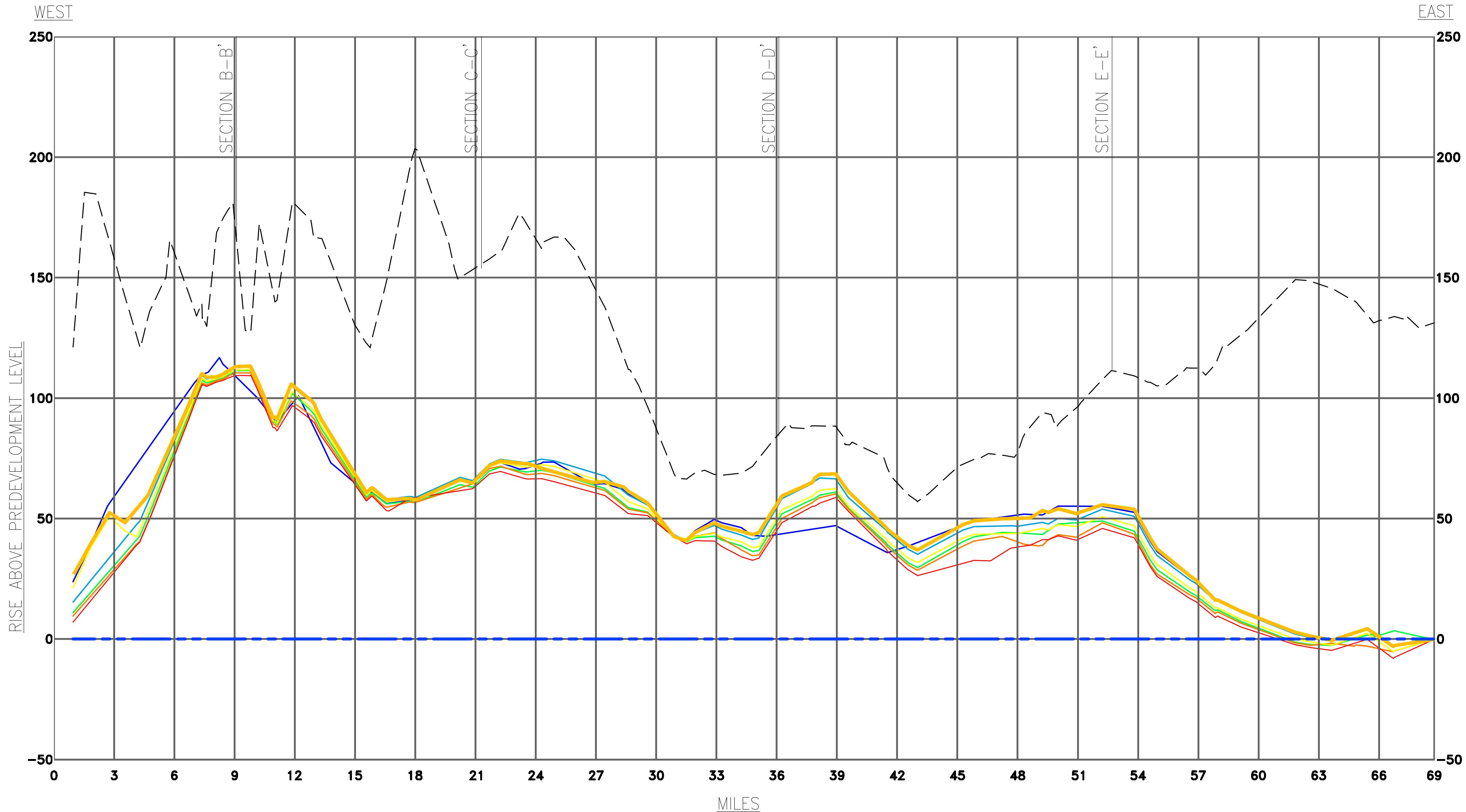

SECTION A-A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

2000 GROUNDWATER RISE
2001 GROUNDWATER RISE
2002 GROUNDWATER RISE
2003 GROUNDWATER RISE
2004 GROUNDWATER RISE
2005 GROUNDWATER RISE
2006 GROUNDWATER RISE
PREDEVELOPMENT GROUNDWATER LEVEL
APPROXIMATE GROUND SURFACE

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2000-2006 2X SCALE sections.dwg
DATE:11/22/2013 TIME:09:17 DRAWN BY: cswanson

GROUNDWATER LEVELS
2000-2006 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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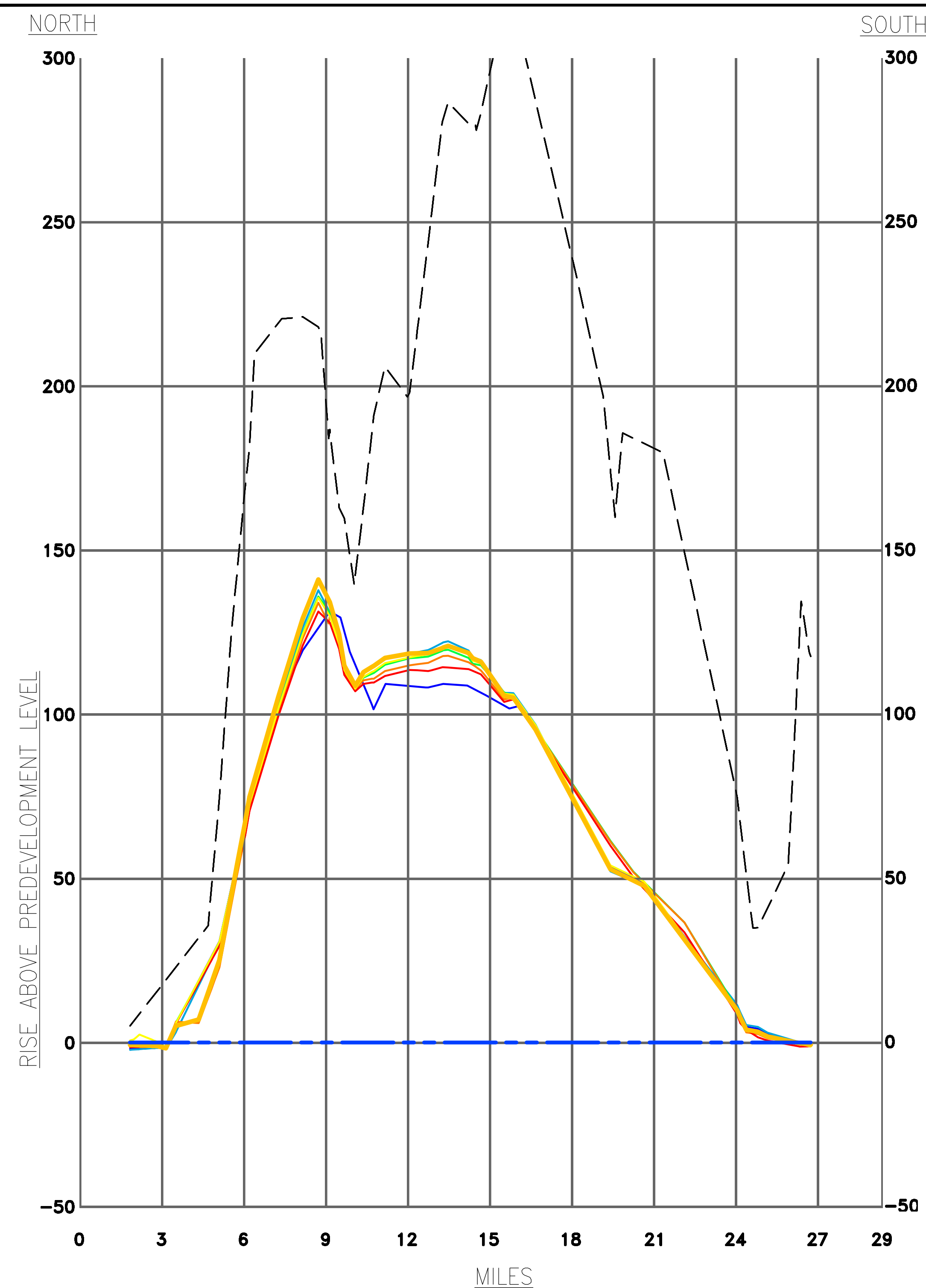
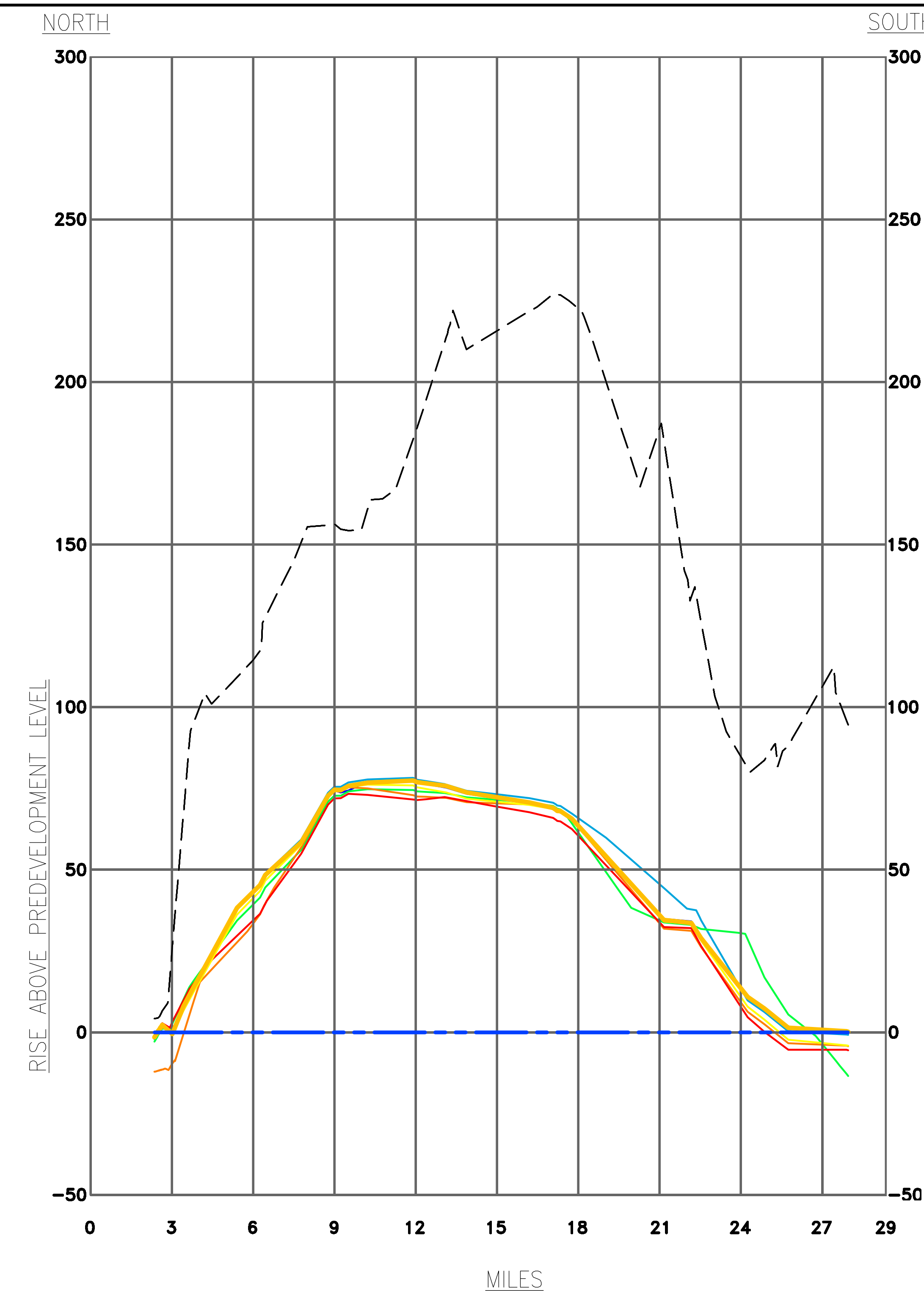
FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
10	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

2000 GROUNDWATER RISE
2001 GROUNDWATER RISE
2002 GROUNDWATER RISE
2003 GROUNDWATER RISE
2004 GROUNDWATER RISE
2005 GROUNDWATER RISE
2006 GROUNDWATER RISE
PREDEVELOPMENT GROUNDWATER LEVEL
APPROXIMATE GROUND SURFACE

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CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

GROUNDWATER LEVELS
2000-2006 CROSS SECTIONS

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	PLS	DJS	DEC 2013	AS SHOWN	1500301	-	-	11

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2000-2006 2X SCALE sections.dwg
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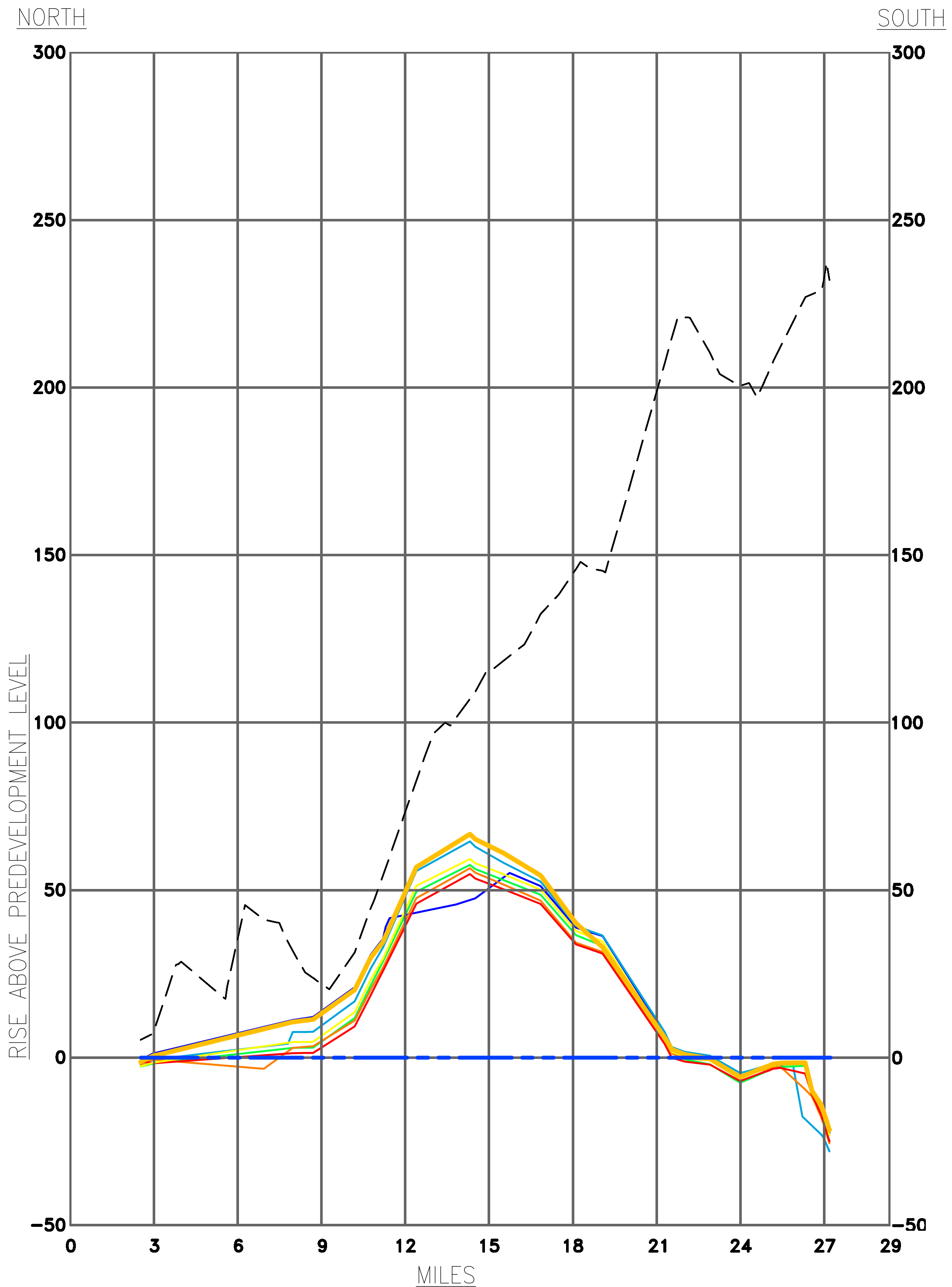
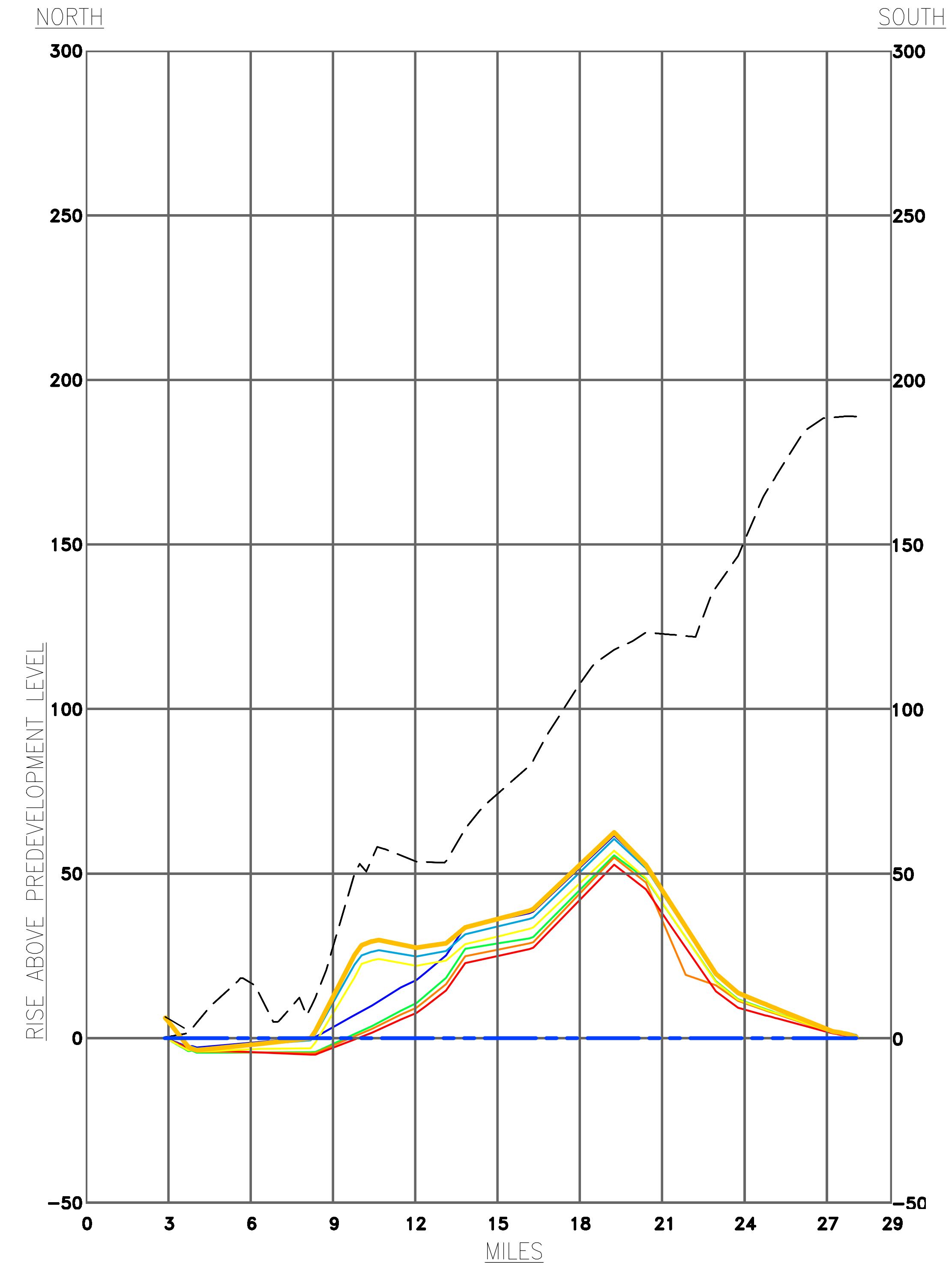


SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

- 2000 GROUNDWATER RISE
- 2001 GROUNDWATER RISE
- 2002 GROUNDWATER RISE
- 2003 GROUNDWATER RISE
- 2004 GROUNDWATER RISE
- 2005 GROUNDWATER RISE
- 2006 GROUNDWATER RISE
- PREDEVELOPMENT GROUNDWATER LEVEL
- APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2000-2006 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
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GROUNDWATER EVALUATION

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FIGURE	12
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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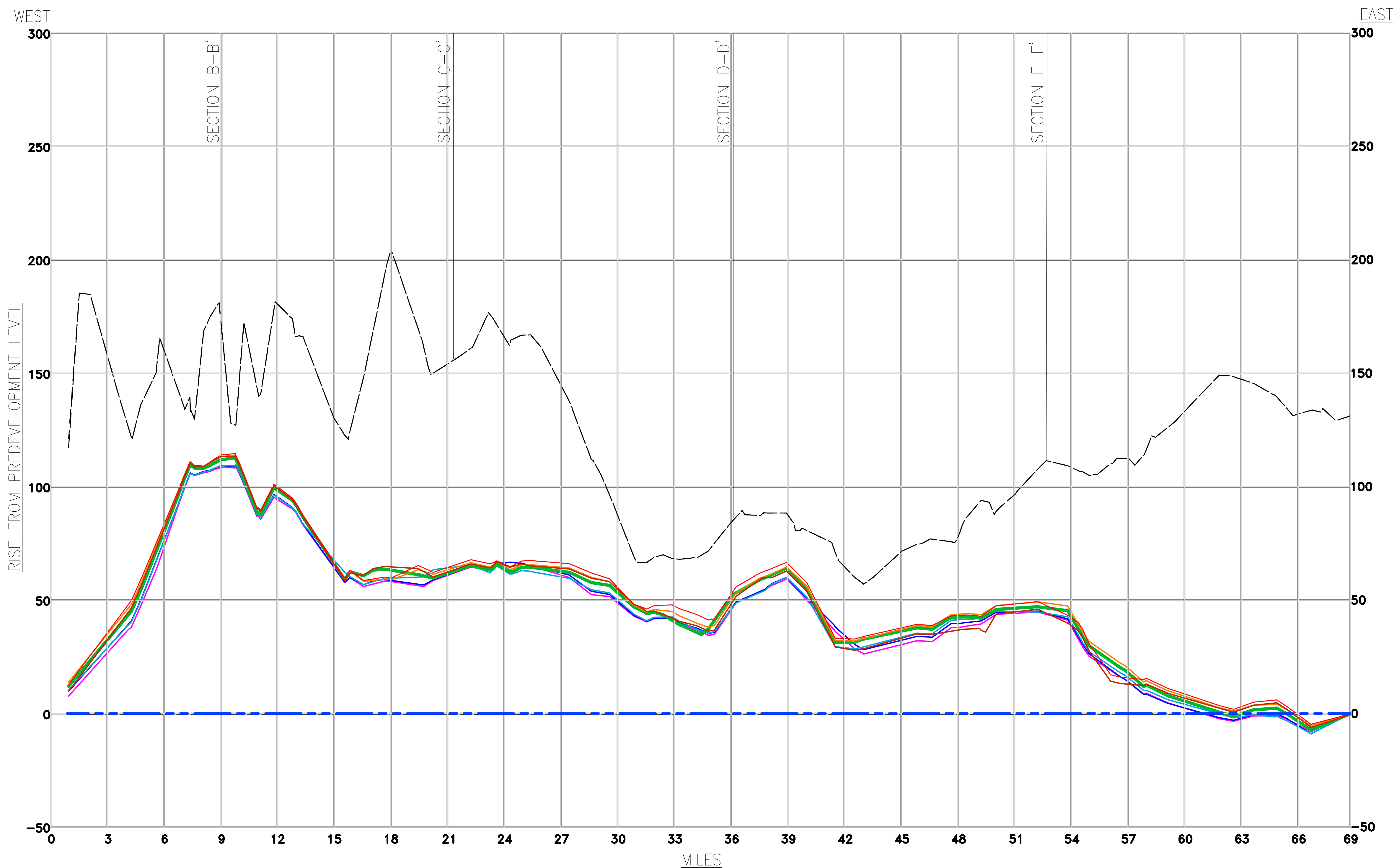

SECTION A–A'

HORIZONTAL SCALE: 1"=6 MILES

VERTICAL SCALE: 1"=50'

LEGEND:

- 2007 GROUNDWATER RISE
- 2008 GROUNDWATER RISE
- 2009 GROUNDWATER RISE
- 2010 GROUNDWATER RISE
- 2011 GROUNDWATER RISE
- 2012 GROUNDWATER RISE
- 2013 GROUNDWATER RISE
- PREDEVELOPMENT GROUNDWATER LEVEL
- APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2007-2013 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

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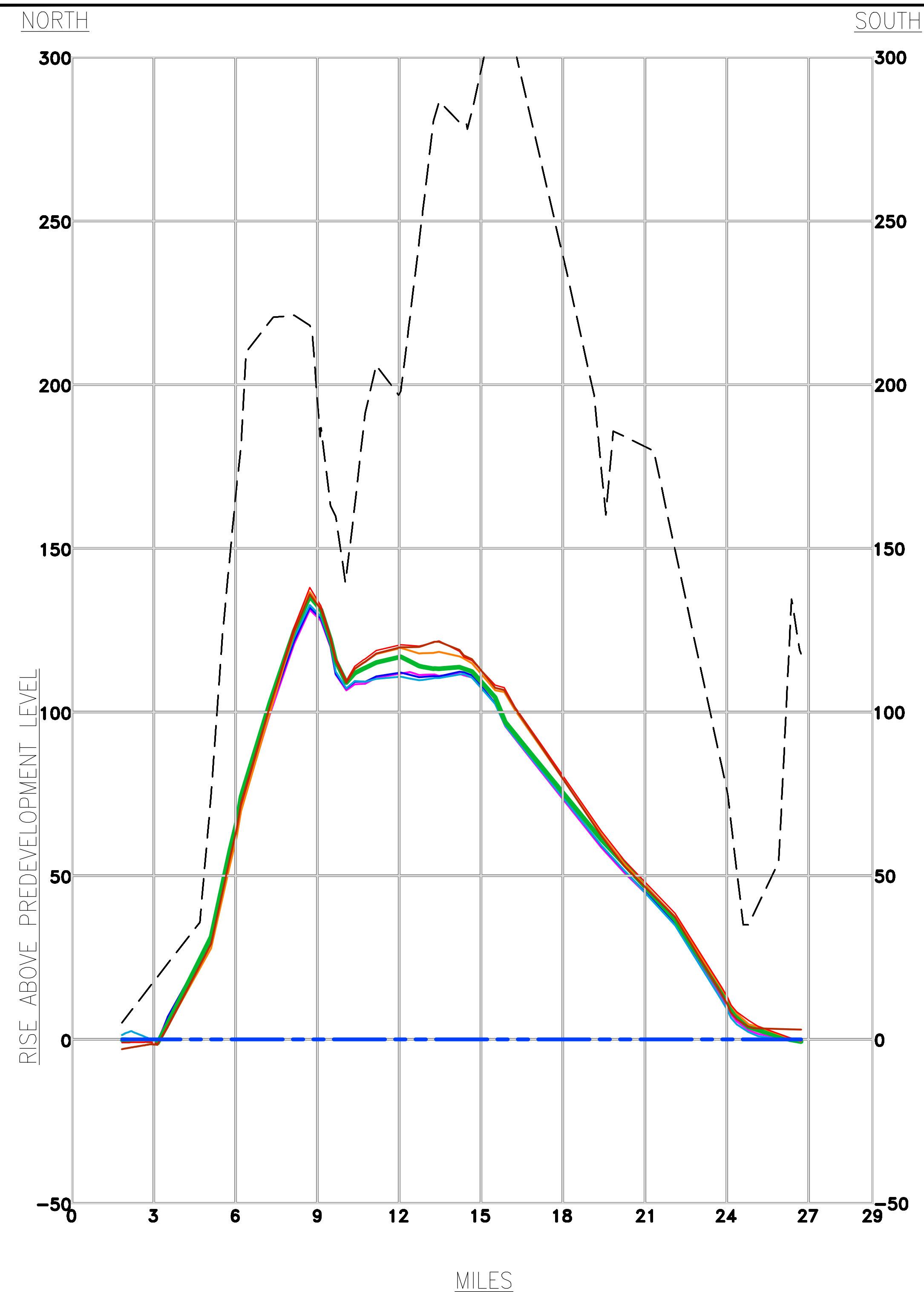
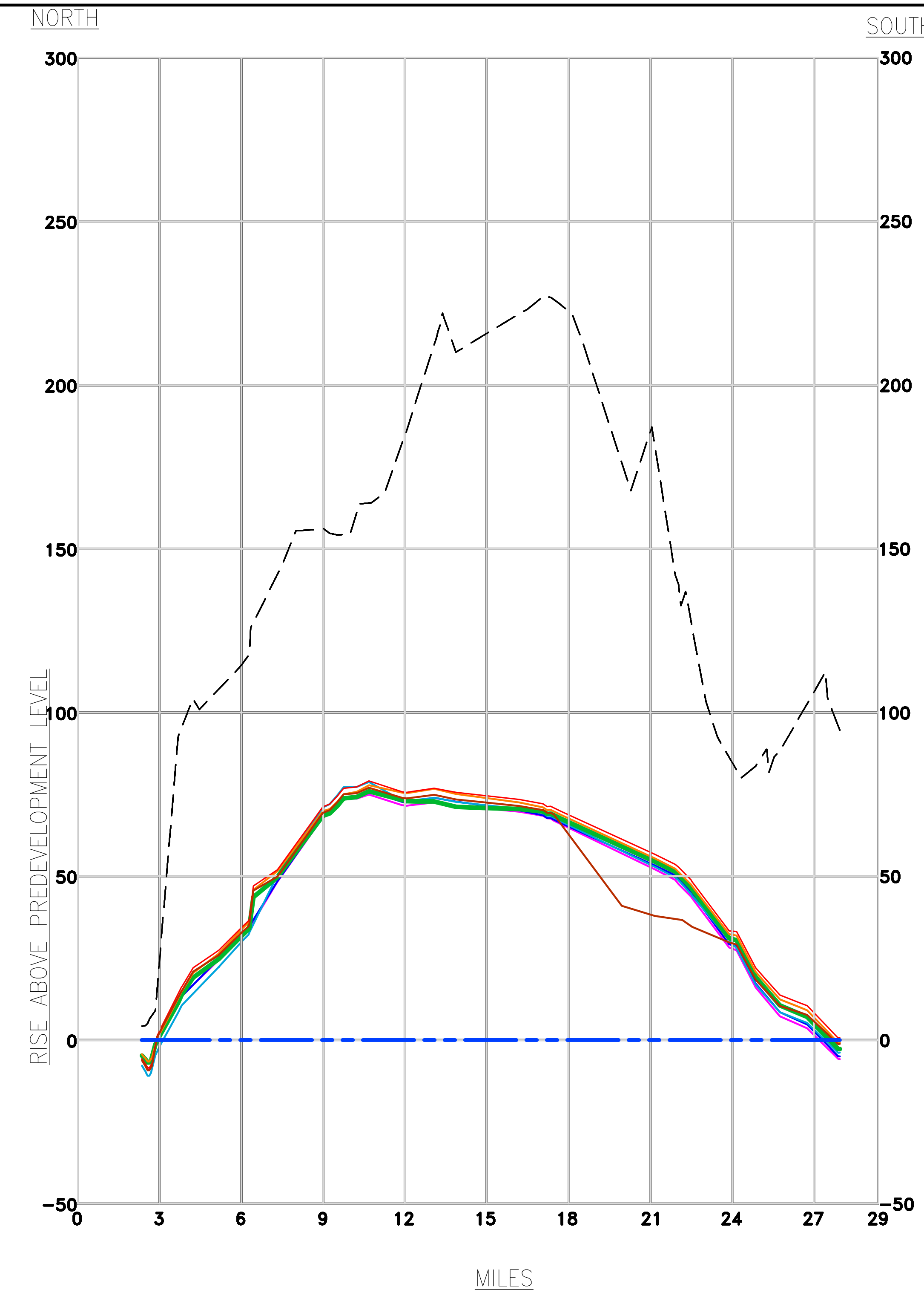
FIGURE	13
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: \\LINCOLN\Projects\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\OCT 2013\2007–2012 2X SCALE sections.dwg
DATE:11/11/2013 TIME:15:43 DRAWN BY: psmith



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

- 2007 GROUNDWATER RISE
- 2008 GROUNDWATER RISE
- 2009 GROUNDWATER RISE
- 2010 GROUNDWATER RISE
- 2011 GROUNDWATER RISE
- 2012 GROUNDWATER RISE
- 2013 GROUNDWATER RISE
- PREDEVELOPMENT GROUNDWATER LEVEL
- APPROXIMATE GROUND SURFACE

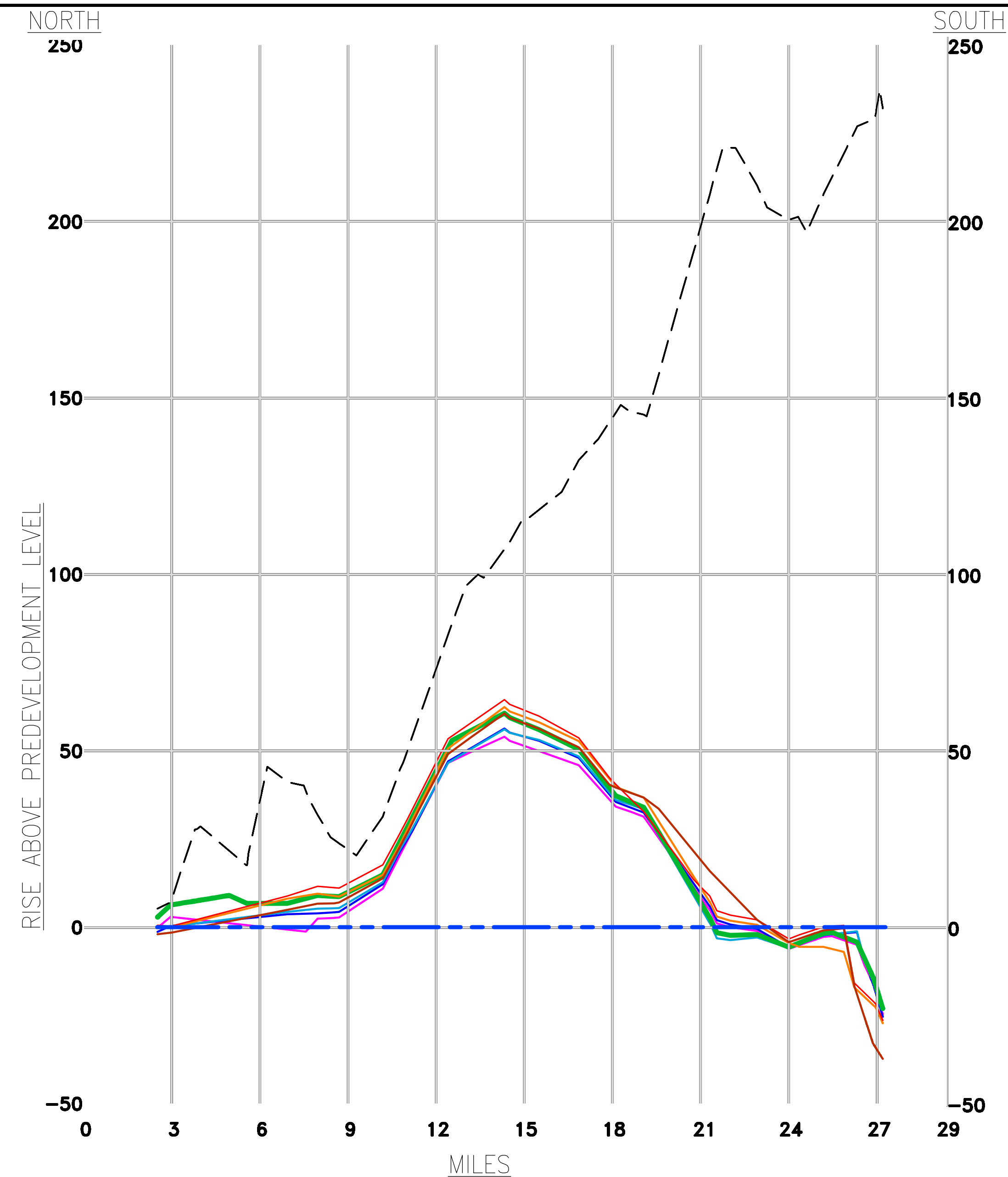
GROUNDWATER LEVELS
2007-2013 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

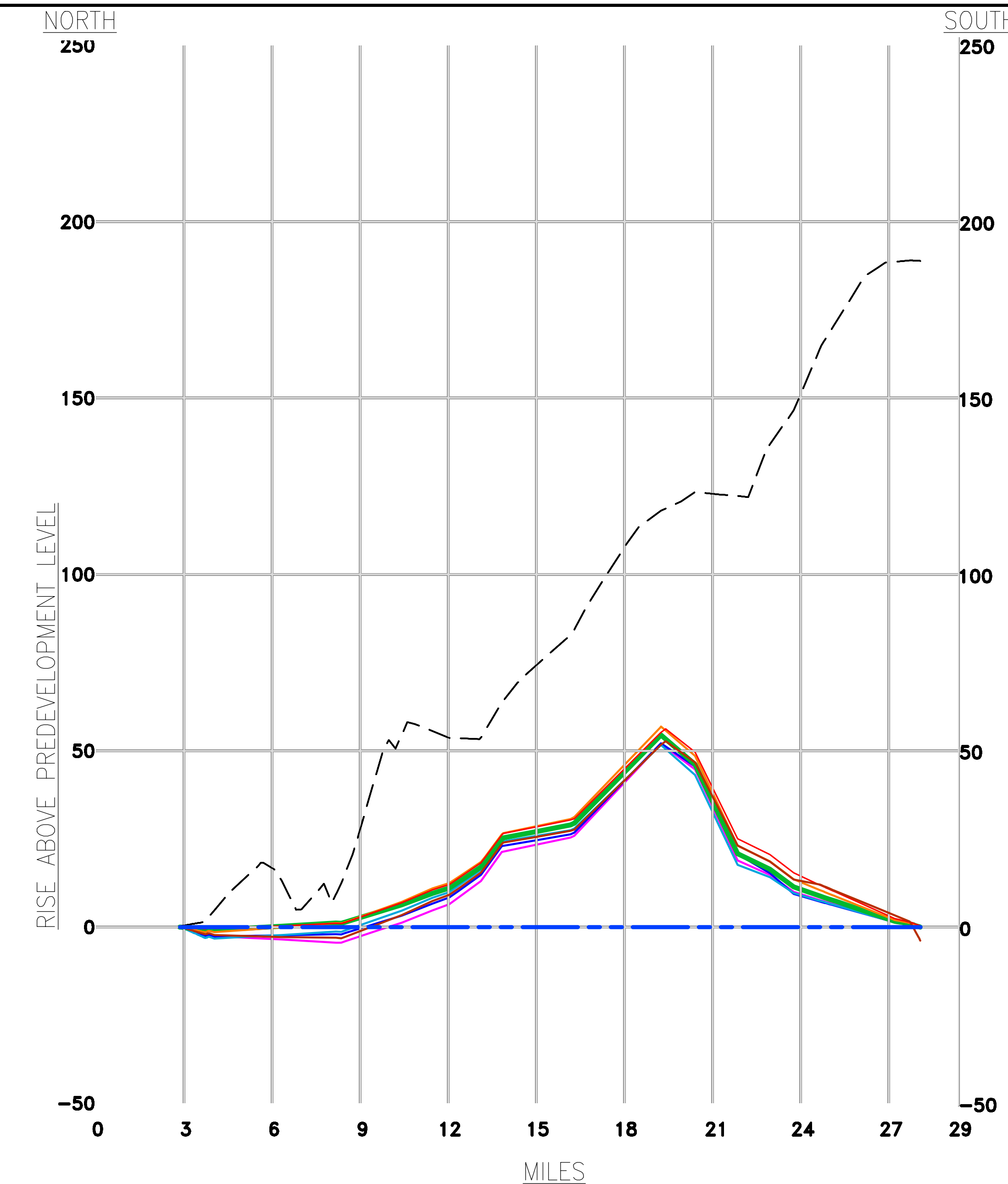
EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

FIGURE	14
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: \\LINCOLN\Projects\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\OCT 2013\2007–2012 2X SCALE sections.dwg
DATE:11/11/2013 TIME:15:43 DRAWN BY: psmith



SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'



SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=50'

LEGEND:

- 2007 GROUNDWATER RISE
- 2008 GROUNDWATER RISE
- 2009 GROUNDWATER RISE
- 2010 GROUNDWATER RISE
- 2011 GROUNDWATER RISE
- 2012 GROUNDWATER RISE
- 2013 GROUNDWATER RISE
- PREDEVELOPMENT GROUNDWATER LEVEL
- APPROXIMATE GROUND SURFACE

DRAWING NAME: \\LINCOLN\Projects\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\OCT 2013\2007-2012 2X SCALE sections.dwg
DATE:11/11/2013 TIME:15:43 DRAWN BY: psmith

GROUNDWATER LEVELS
2007-2013 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

FIGURE	15
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

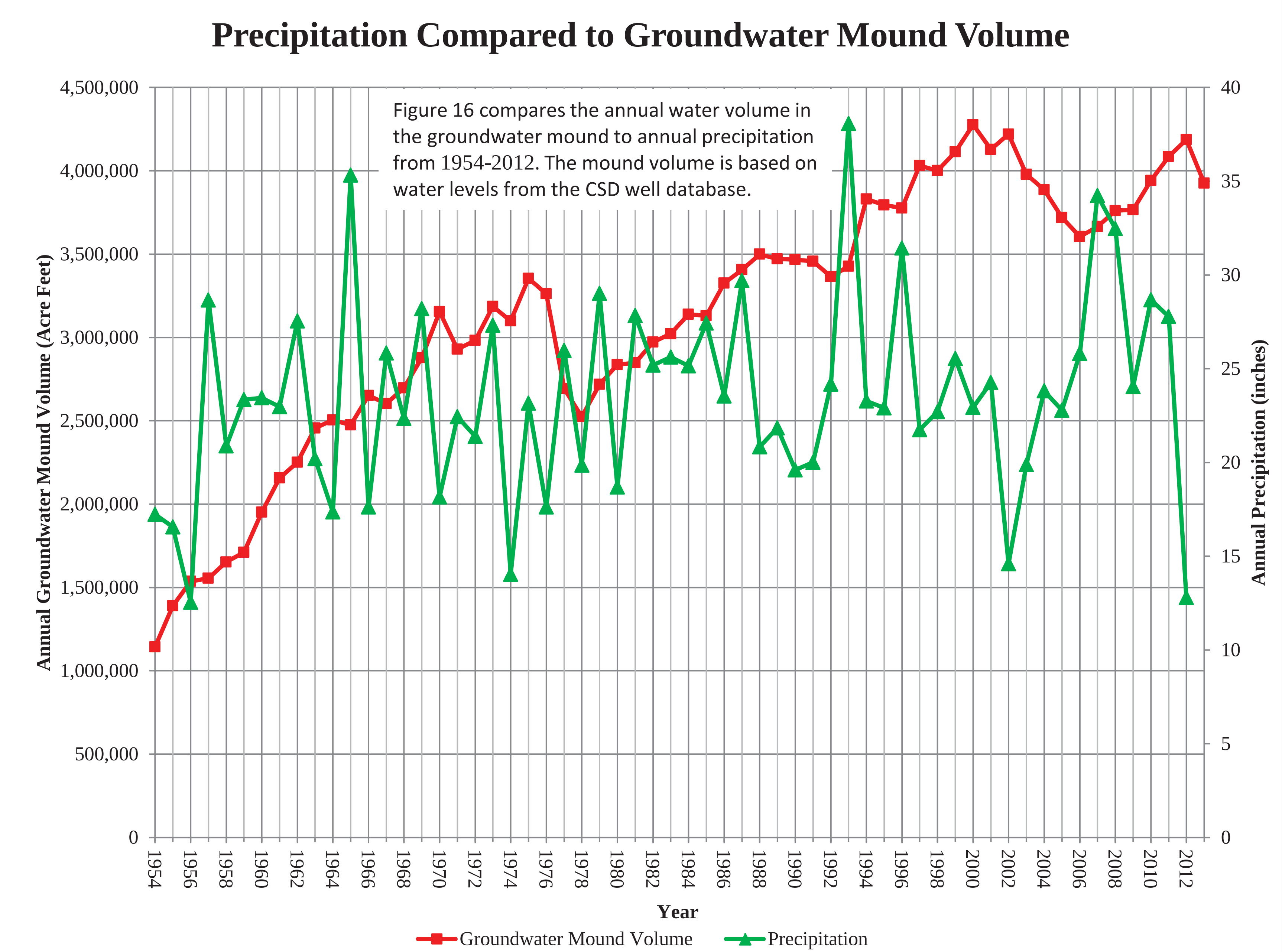


Figure 16. Calculated precipitation of the study area.

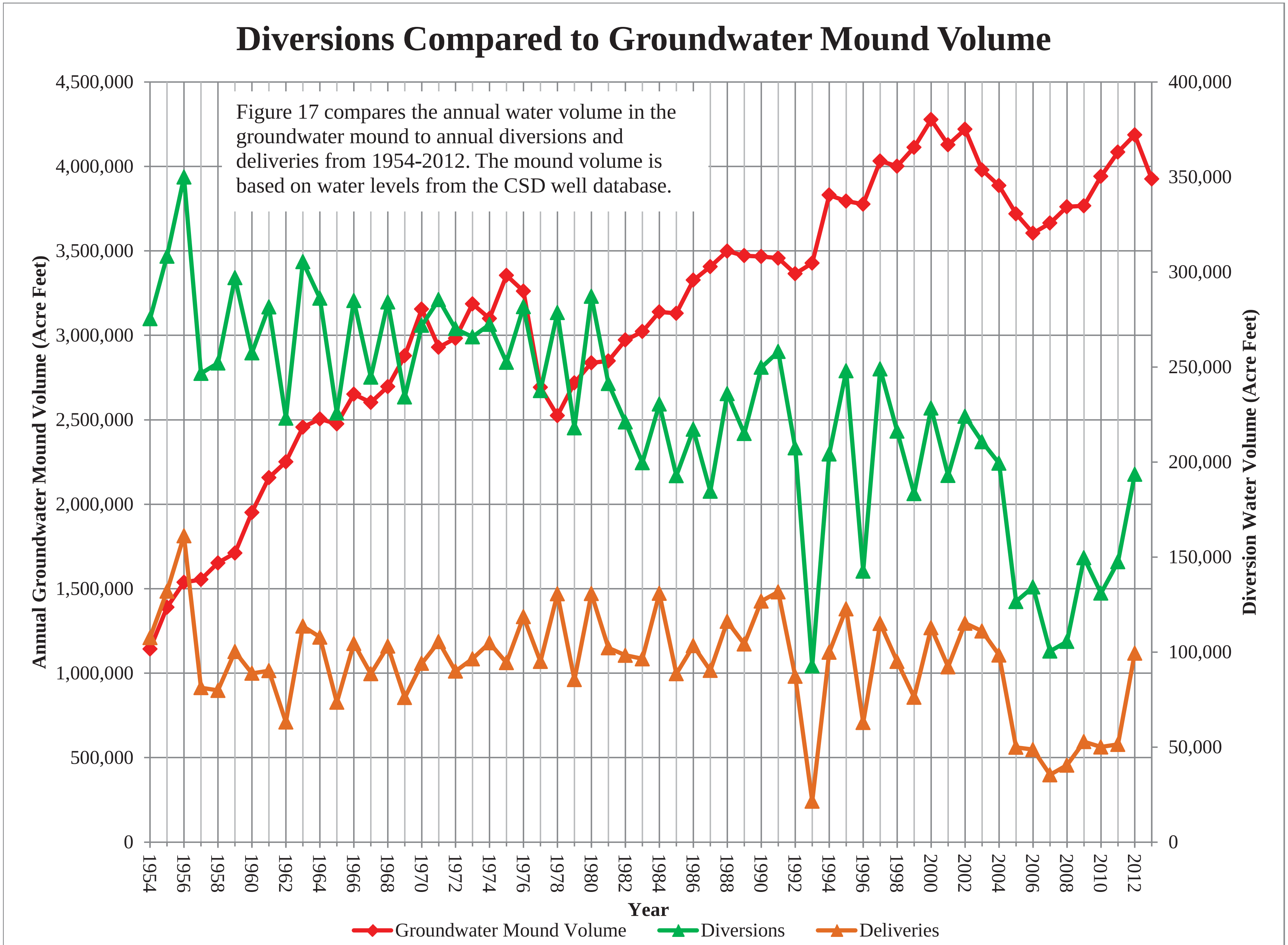


Figure 17. Diversions and deliveries for the study area.

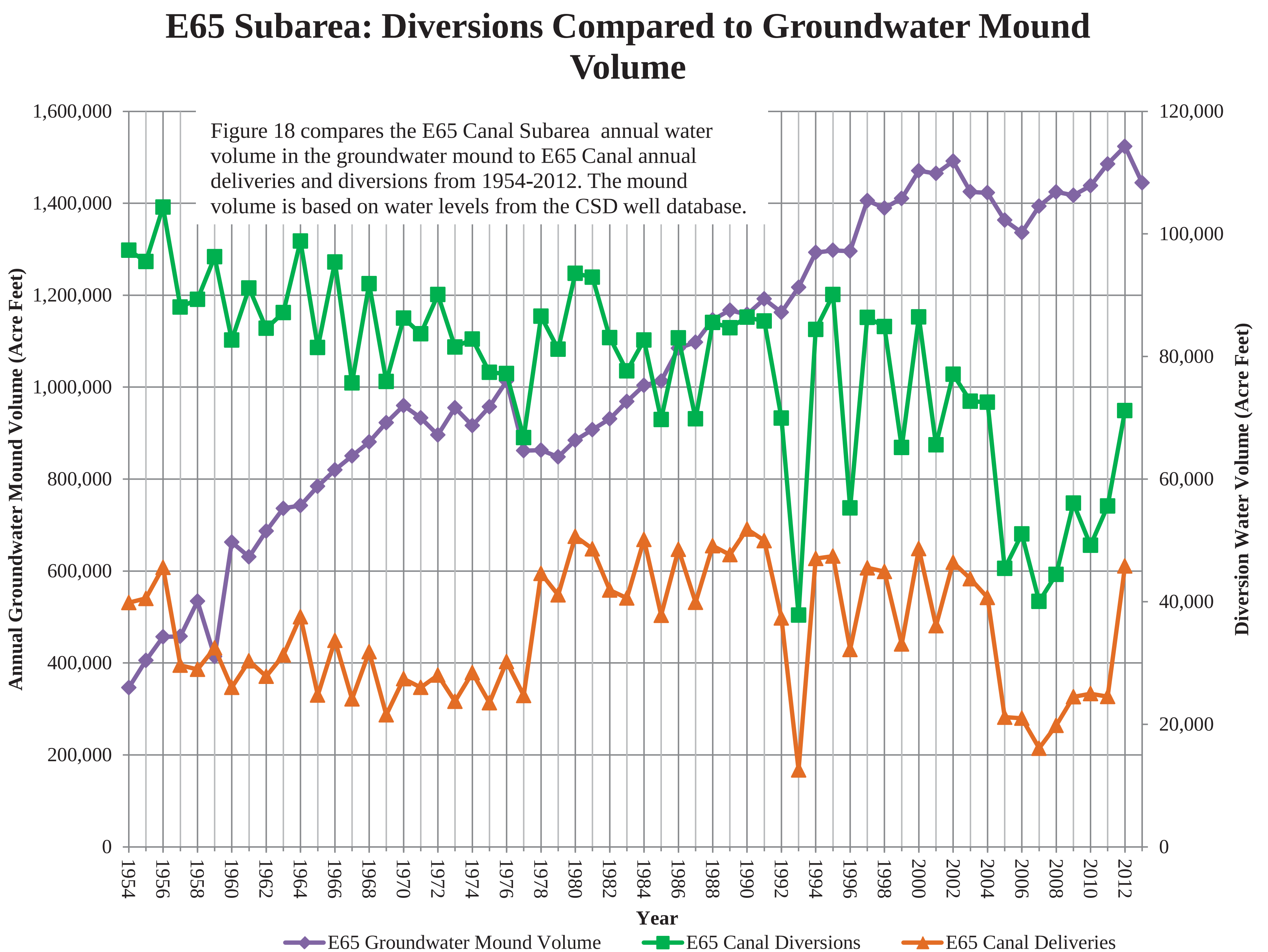


Figure 18. Diversions and deliveries for the E65 subarea.

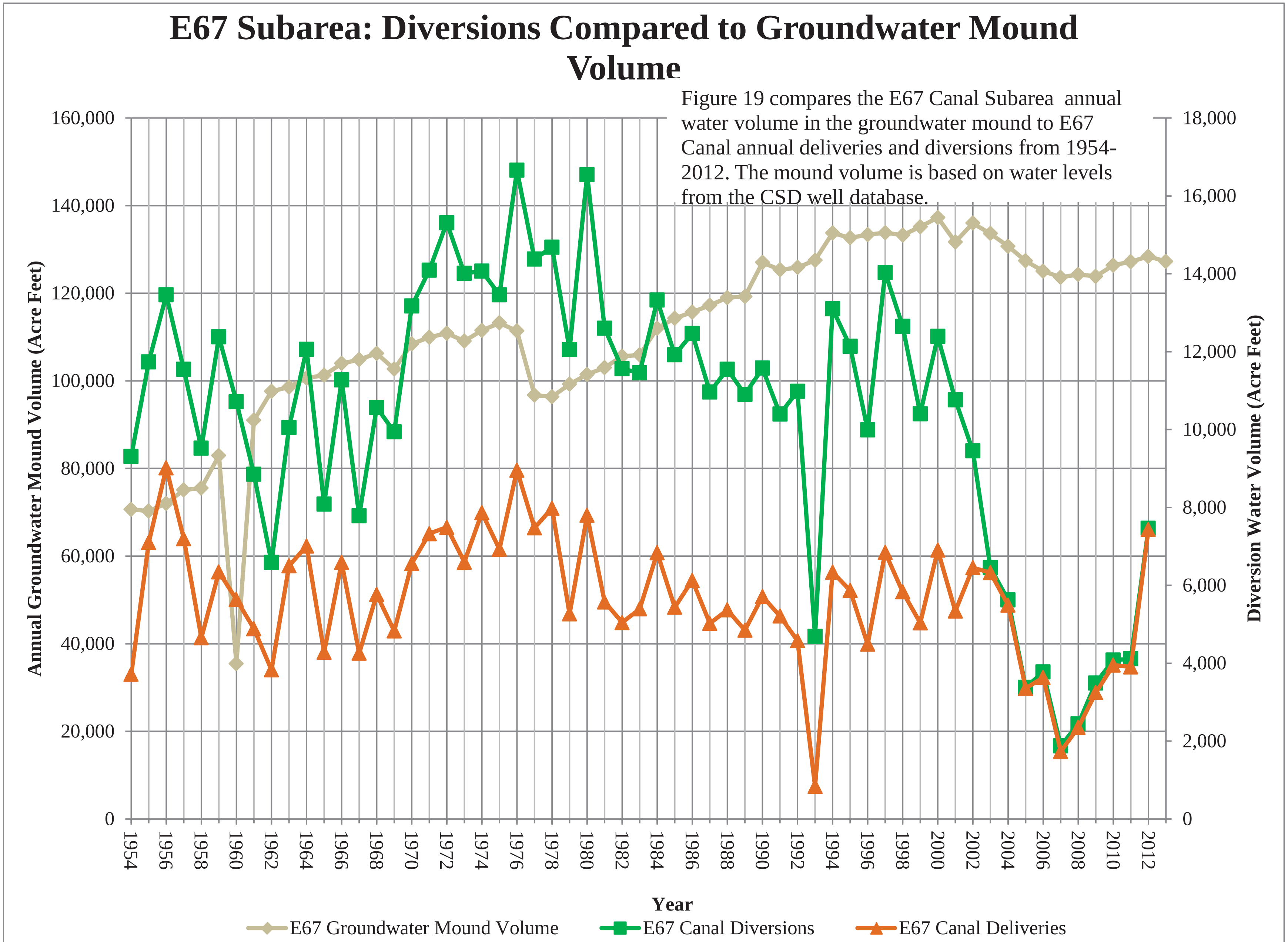


Figure 19. Diversions and deliveries for the E67 subarea.

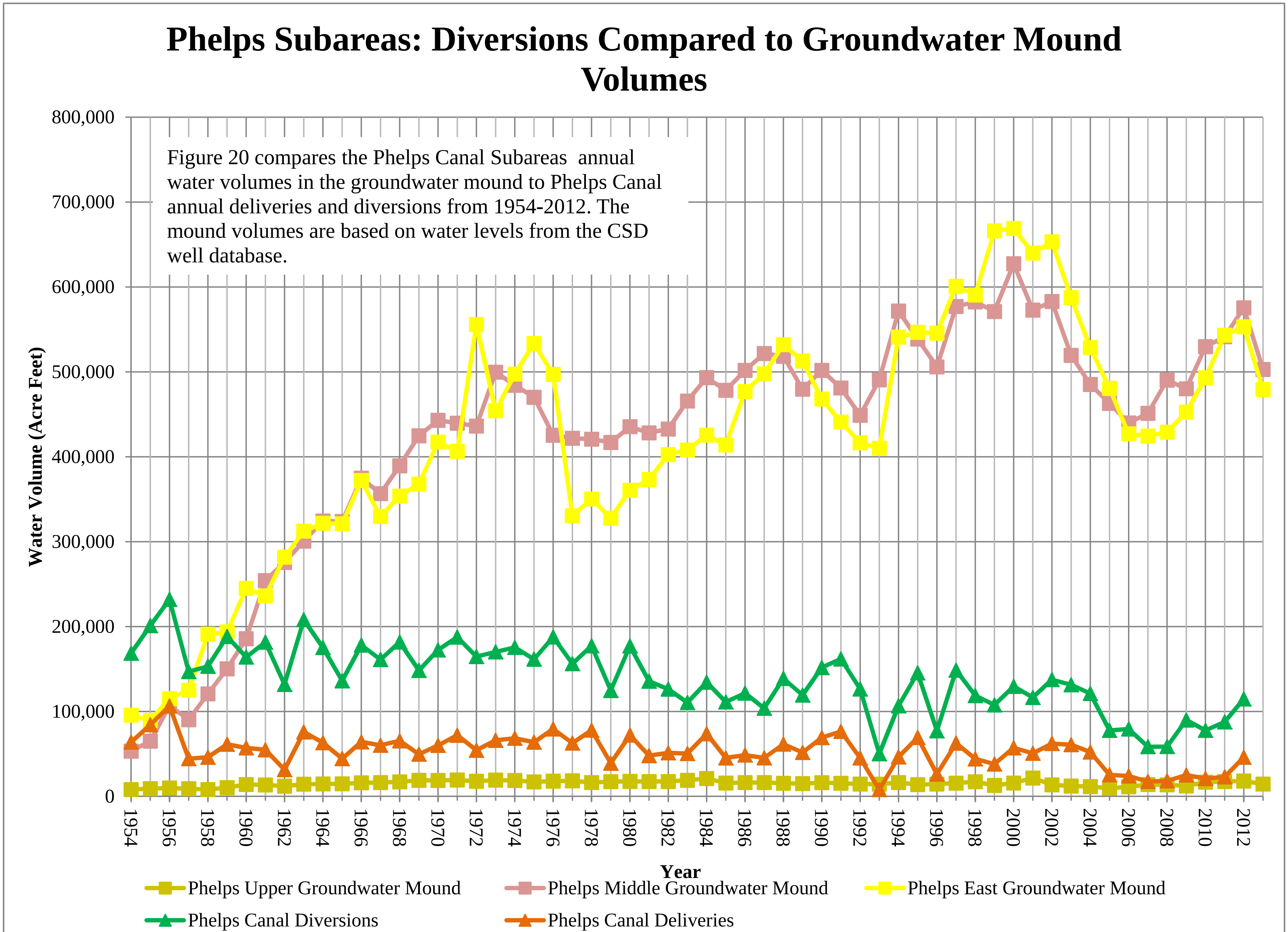


Figure 20. Diversions and deliveries for the three Phelps subareas.

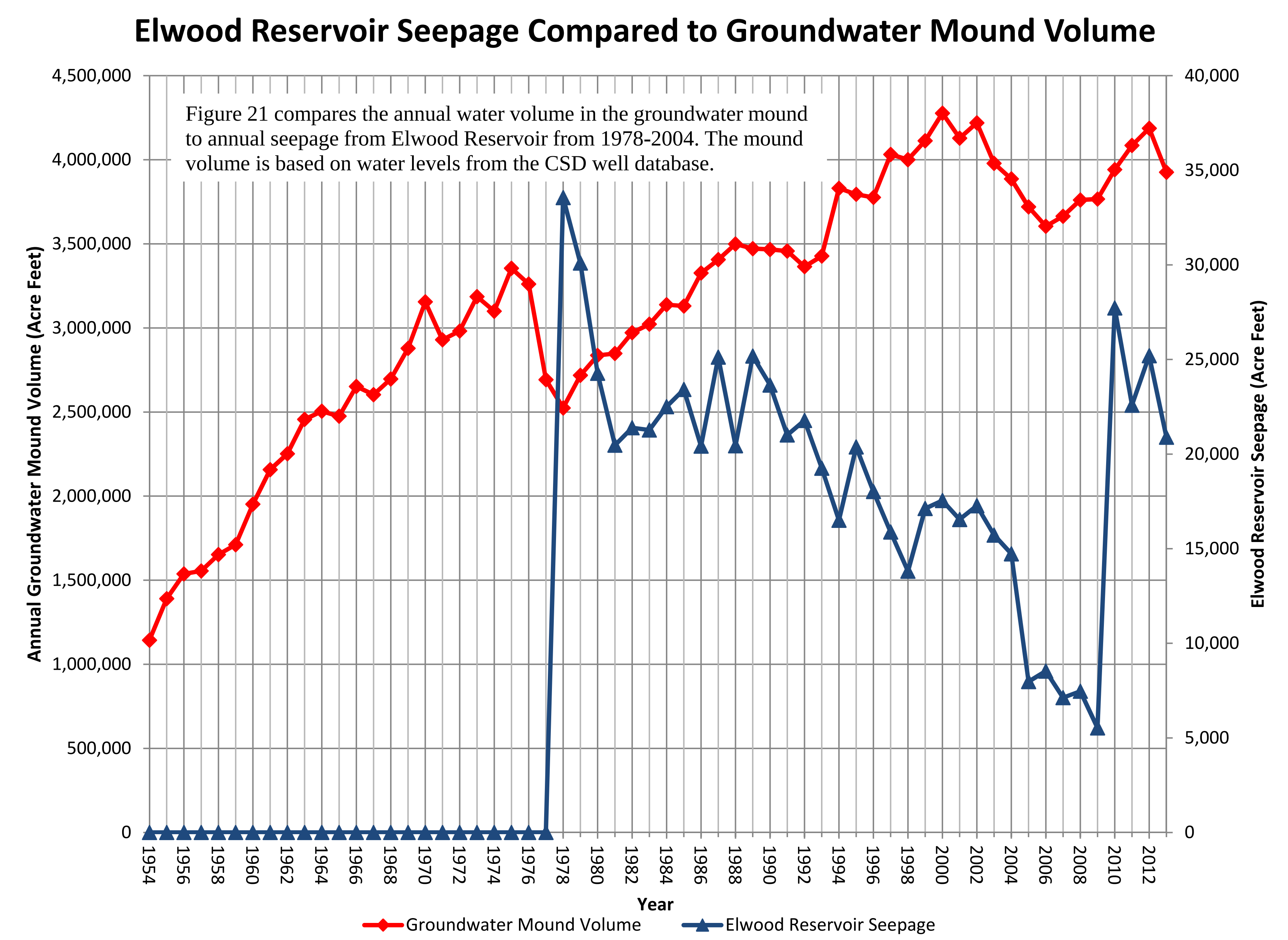


Figure 21. Seepage for the Elwood Reservoir.

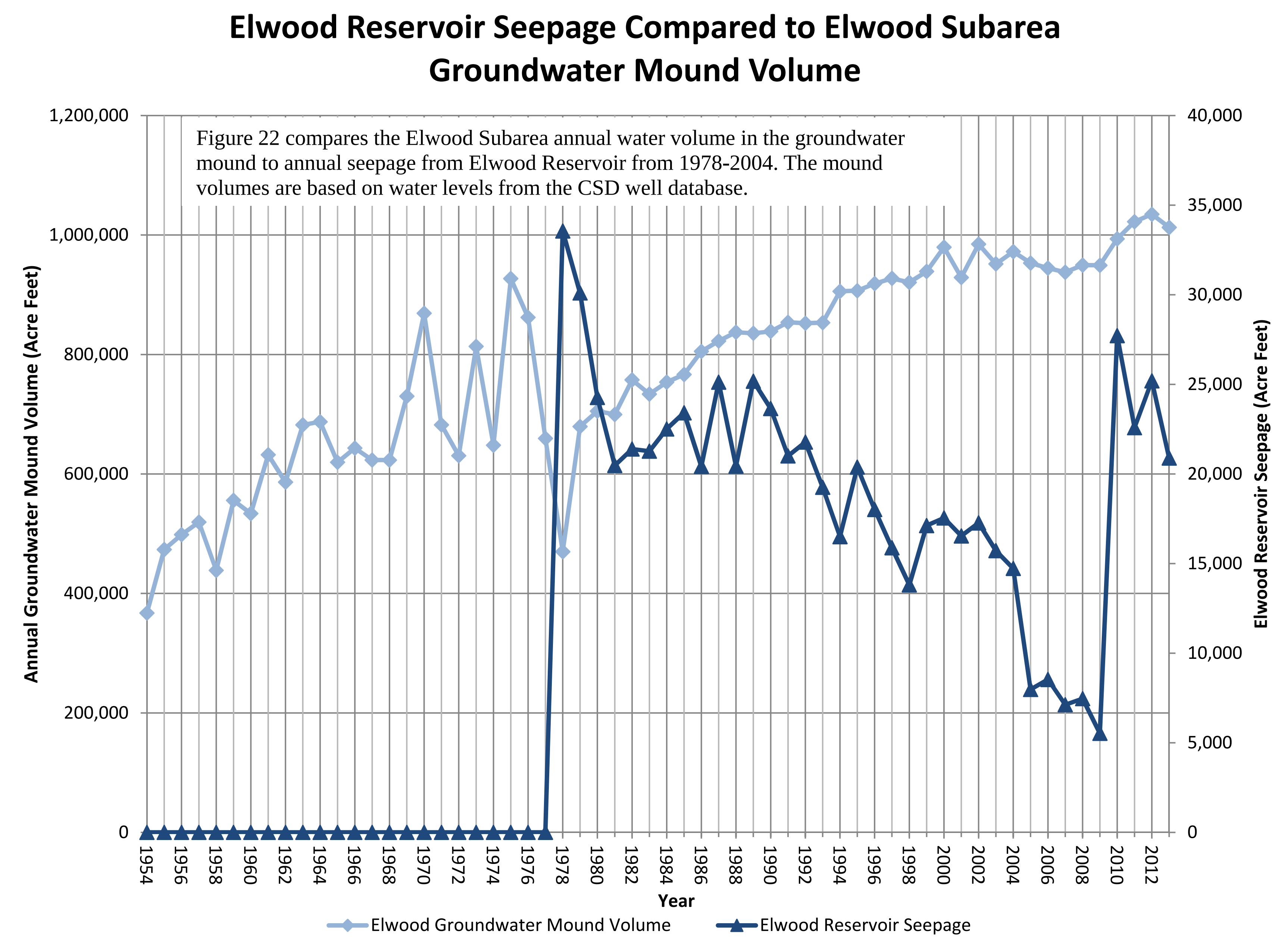


Figure 22. Seepage for the Elwood Reservoir.

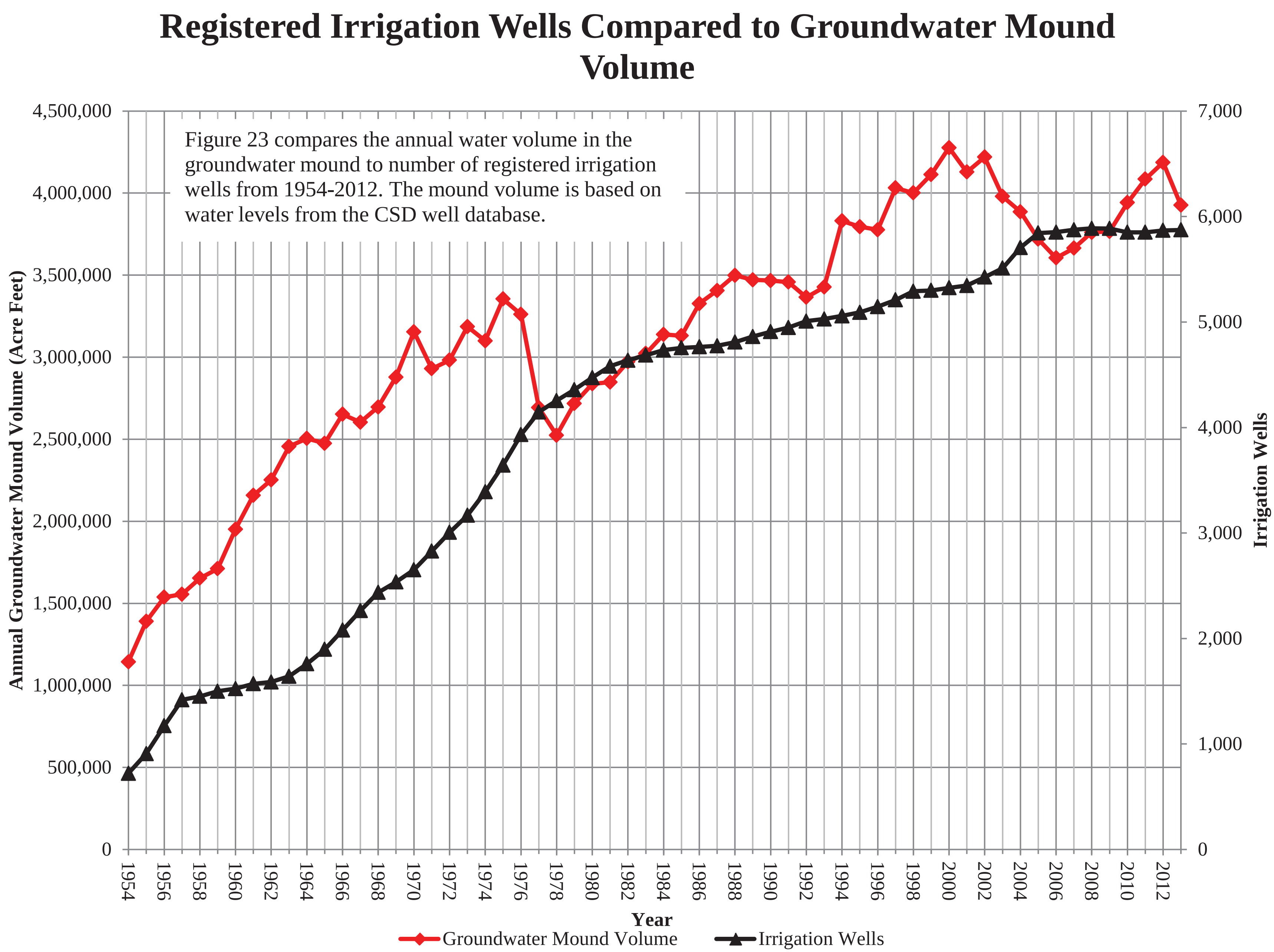


Figure 23. Registered irrigation wells in the study area.

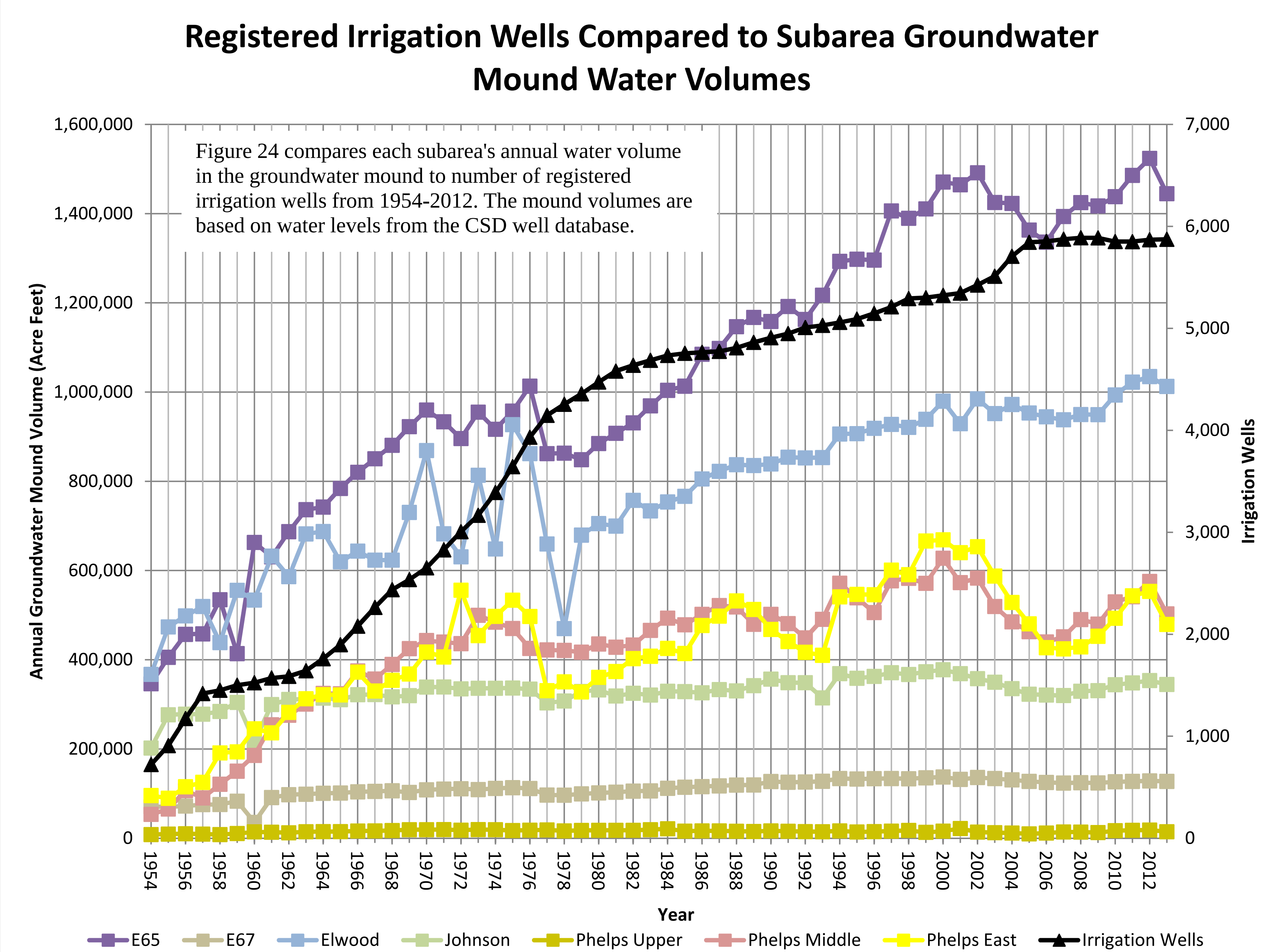
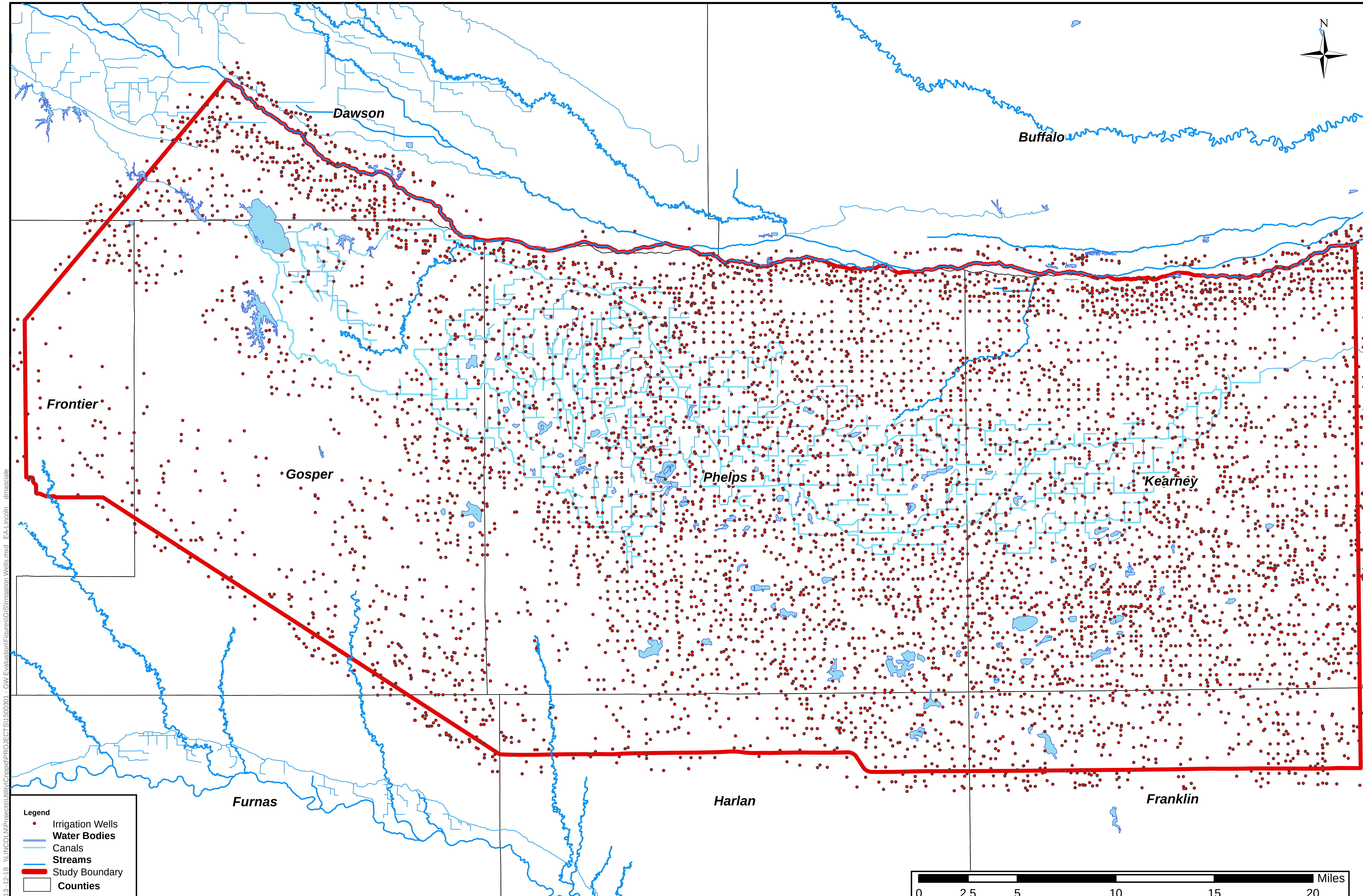


Figure 24. Registered irrigation wells in the study area.



LOCATION OF REGISTERED IRRIGATION WELLS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

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FIGURE	25
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	RJL
DRAWN BY	CNS
DESIGNED BY	JMD
PROJECT MGR.	DJS

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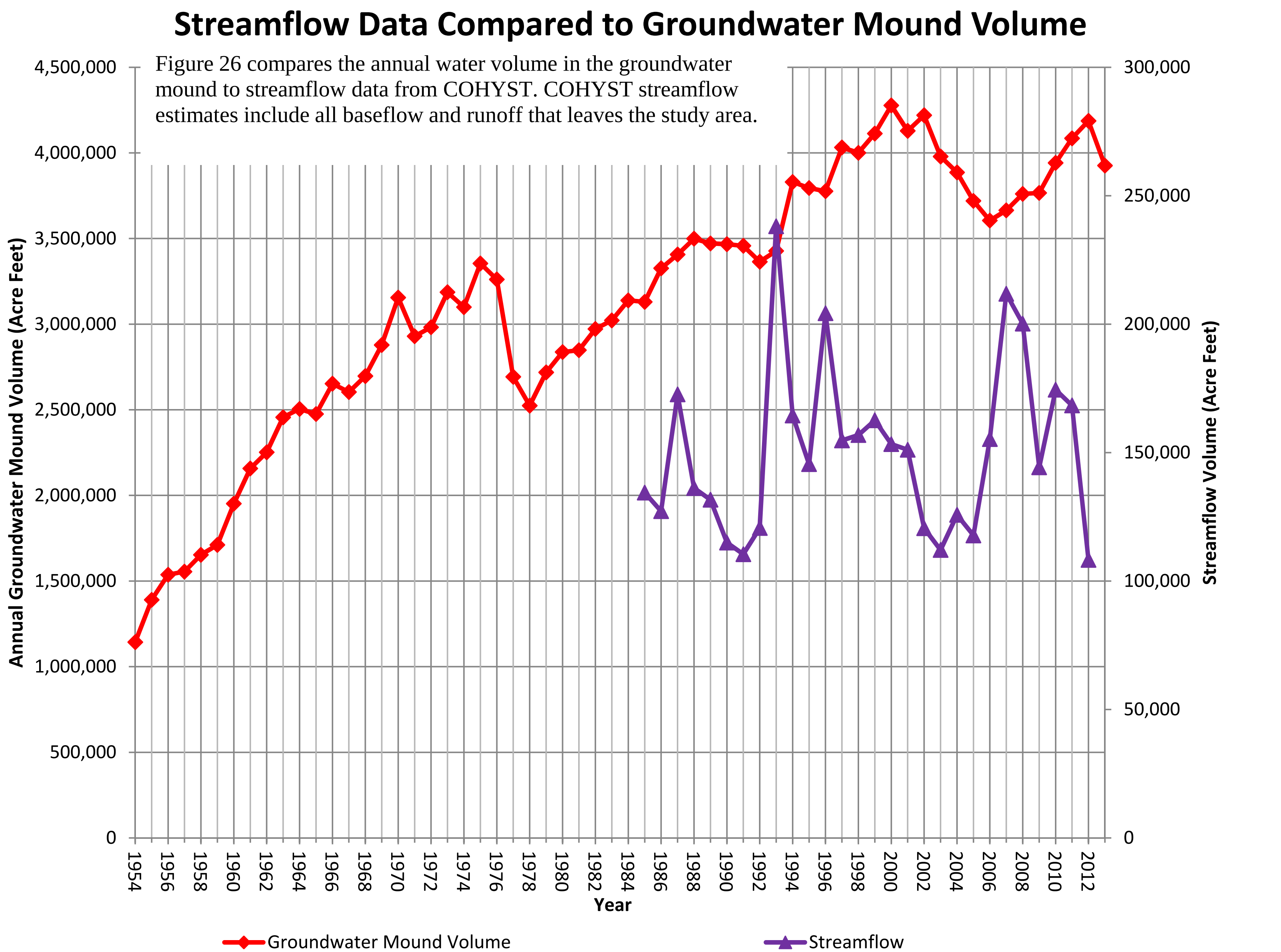
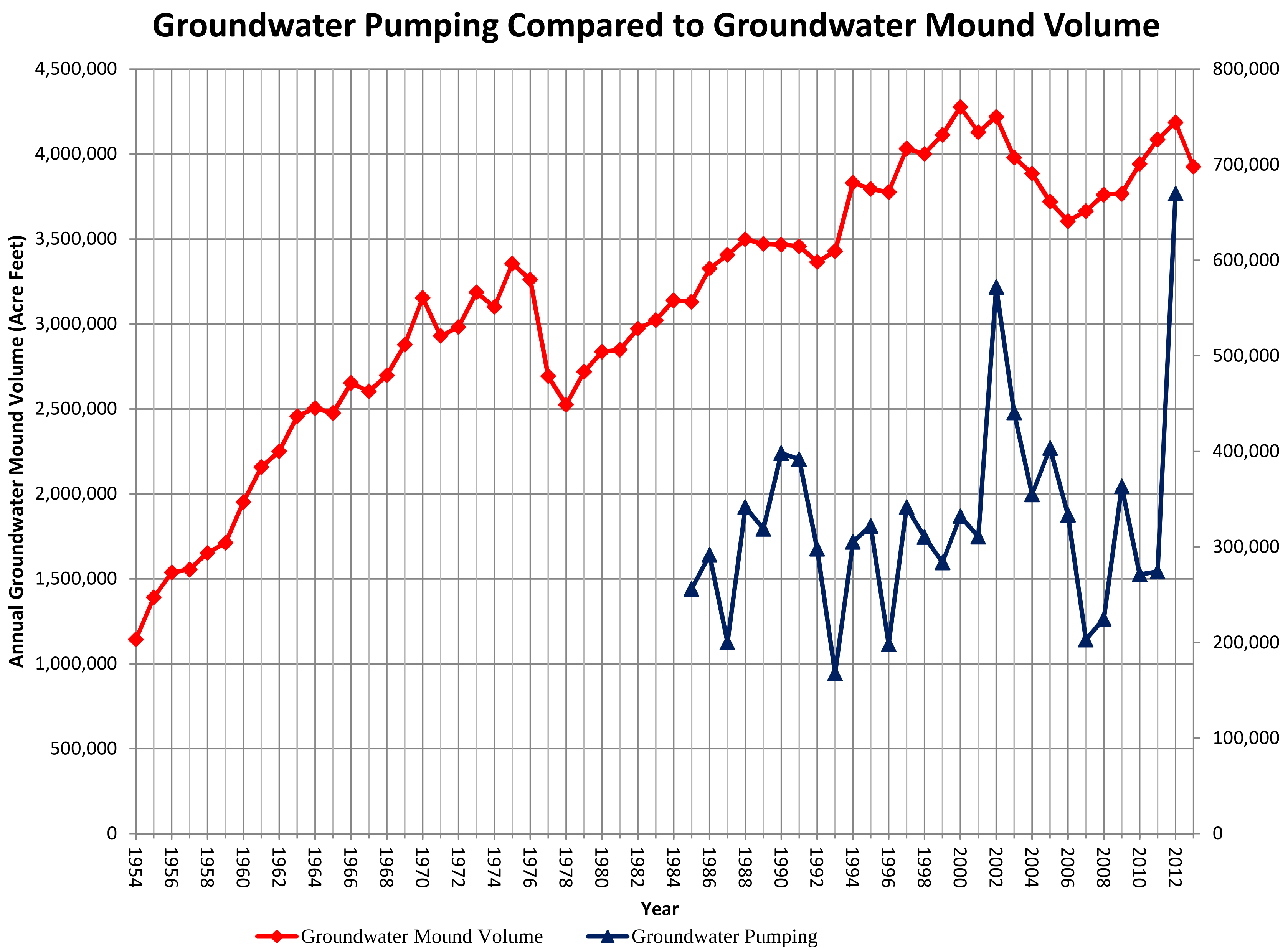


Note: Streamflow data from 1985-2005 is from COHYST's CROPSIM and MODFLOW models and streamflow data from 2006-2012 is estimated as described in Appendix G.

Figure 26. Streamflow in the study area.

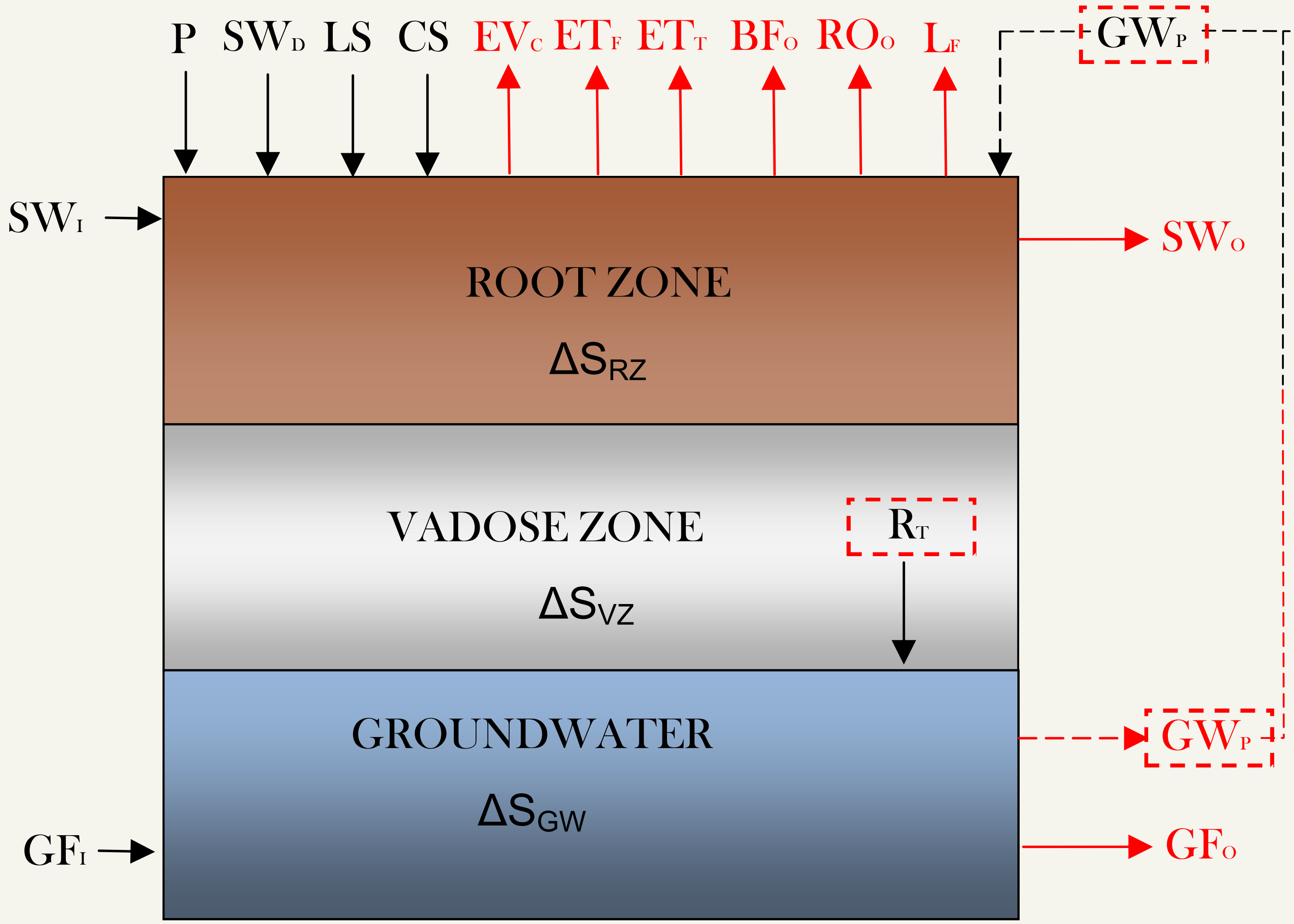


Note: Groundwater pumping data from 1985-2005 is from COHYST's CROPSIM model and groundwater pumping data from 2006-2012 is estimated as described in Appendix G.

Figure 27. Groundwater pumping in the study area.

WATER BALANCE DIAGRAM

FIGURE 28



SW_I = Surface Water Streamflow In (not canals)

P = Precipitation

SW_D = Surface Water Diversions (canal flow)

LS = Lake Seepage

CS = Canal Seepage

EV_C = Canal and Lateral Evaporation

ET_F = Field Evapotranspiration

ET_T = Trans Evapotranspiration

BF_O = Baseflow Out

RO_O = Runoff Out

LF = Field Losses

GW_P = Groundwater Pumping

SW_O = Surface Water Out

GF_I = Groundwater Flux In

GF_O = Groundwater Flux Out

ΔS_{RZ} = Change in Storage in the Root Zone

ΔS_{VZ} = Change in Storage in the Vadose Zone

R_T = Total Recharge

ΔS_{GW} = Change in Groundwater Storage

- - - - - Factors that are internal and therefore not included in the water balance calculations

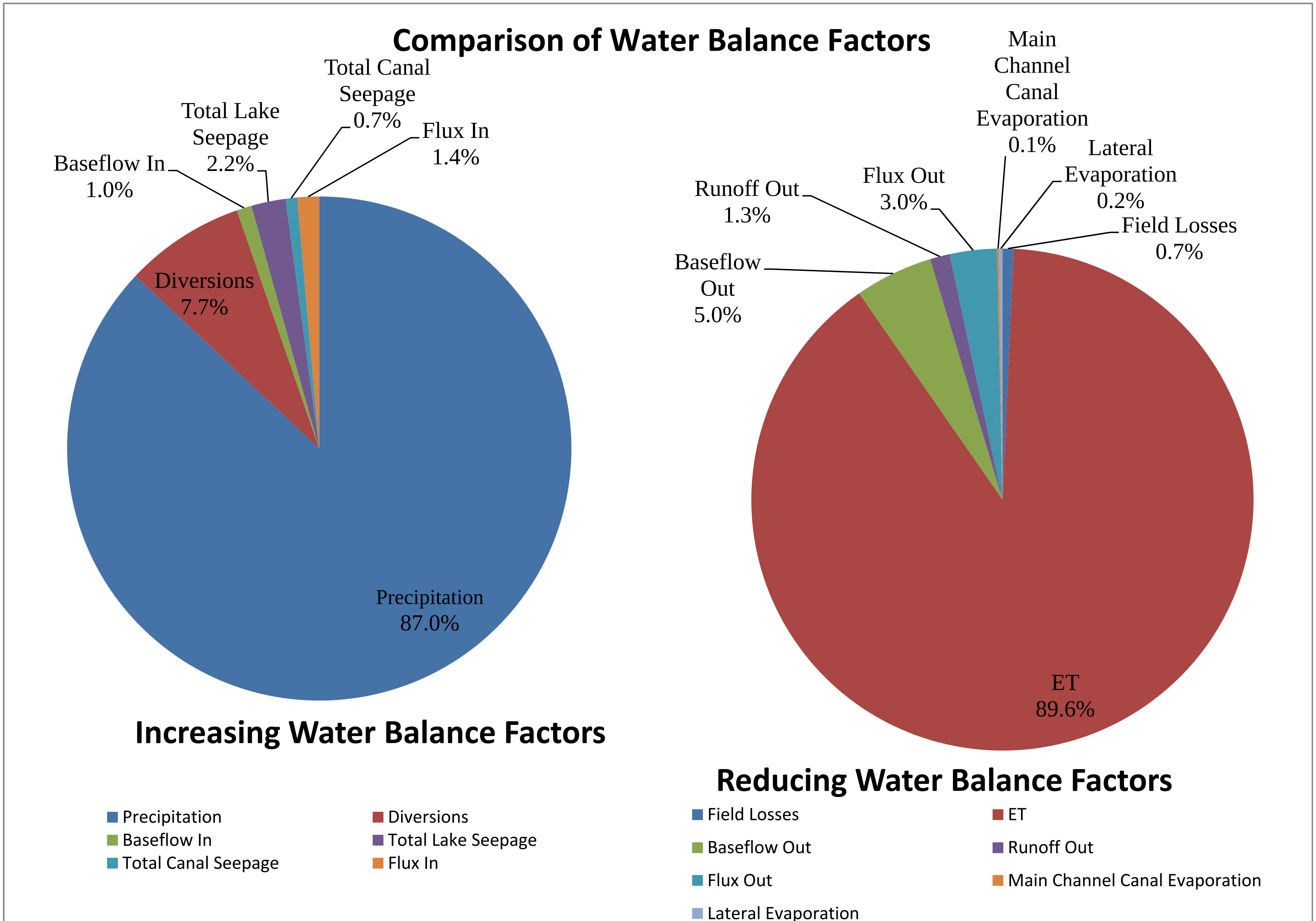


Figure 29. Comparison of Average Water Balance Factors Contribution by Percentages

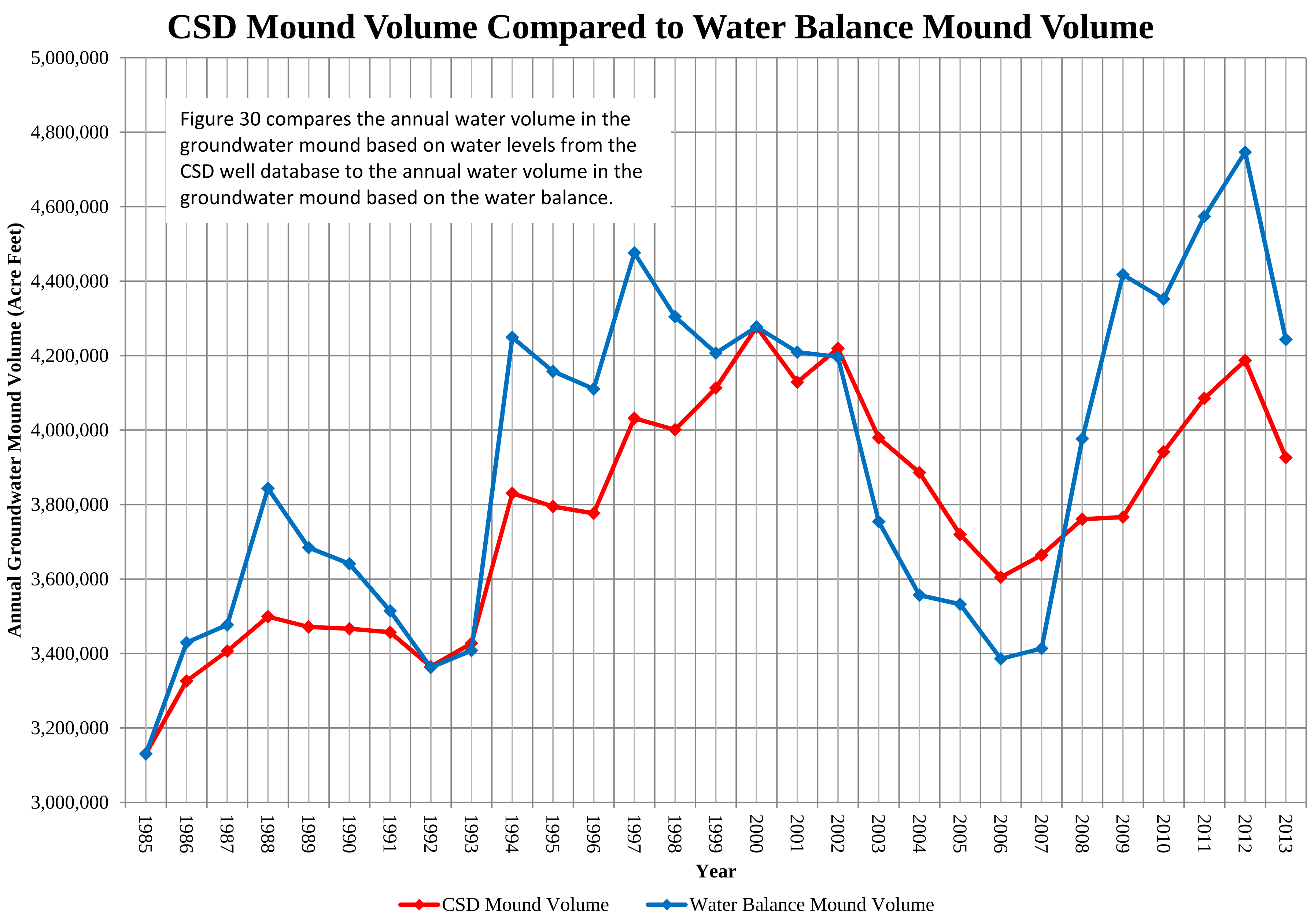


Figure 30. Comparison of the calculated water balance mound volume and the CSD mound volume.

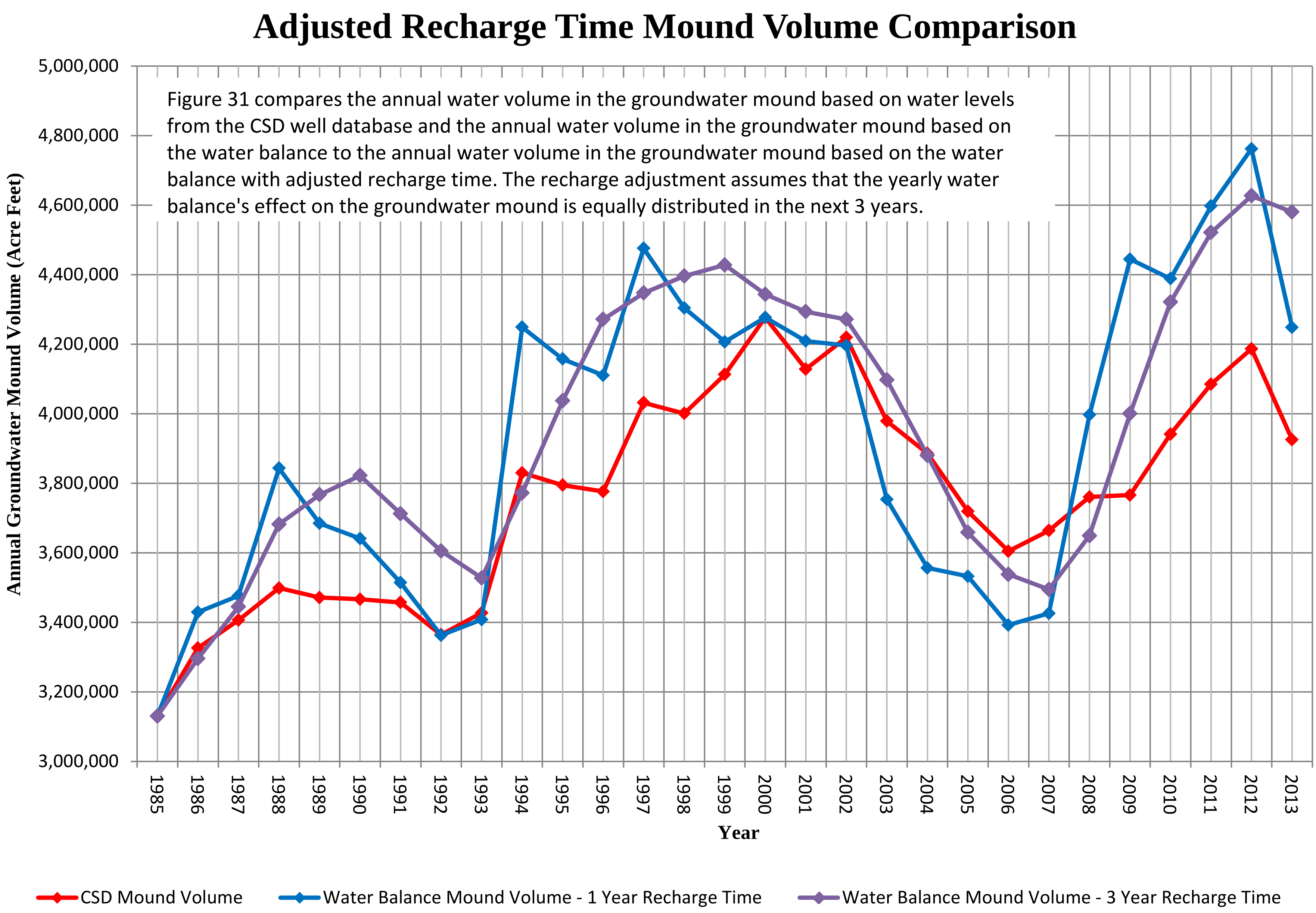


Figure 31. Comparison of the water balance mound volume with adjusted recharge time to the un-adjusted water balance mound volume and the CSD mound

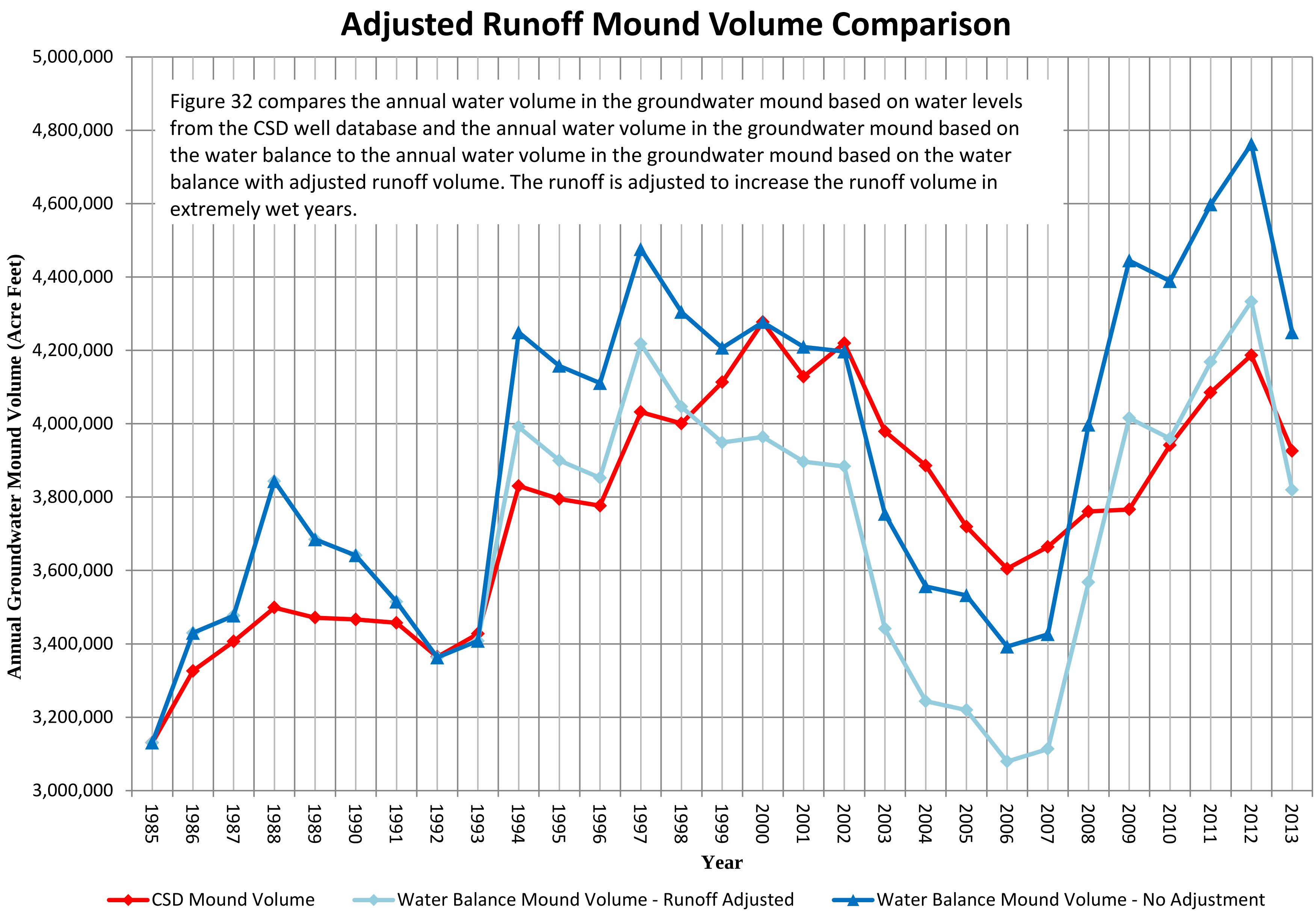


Figure 32. Comparison of the water balance mound volume with runoff volumes time to the un-adjusted water balance mound volume and the CSD mound volume.

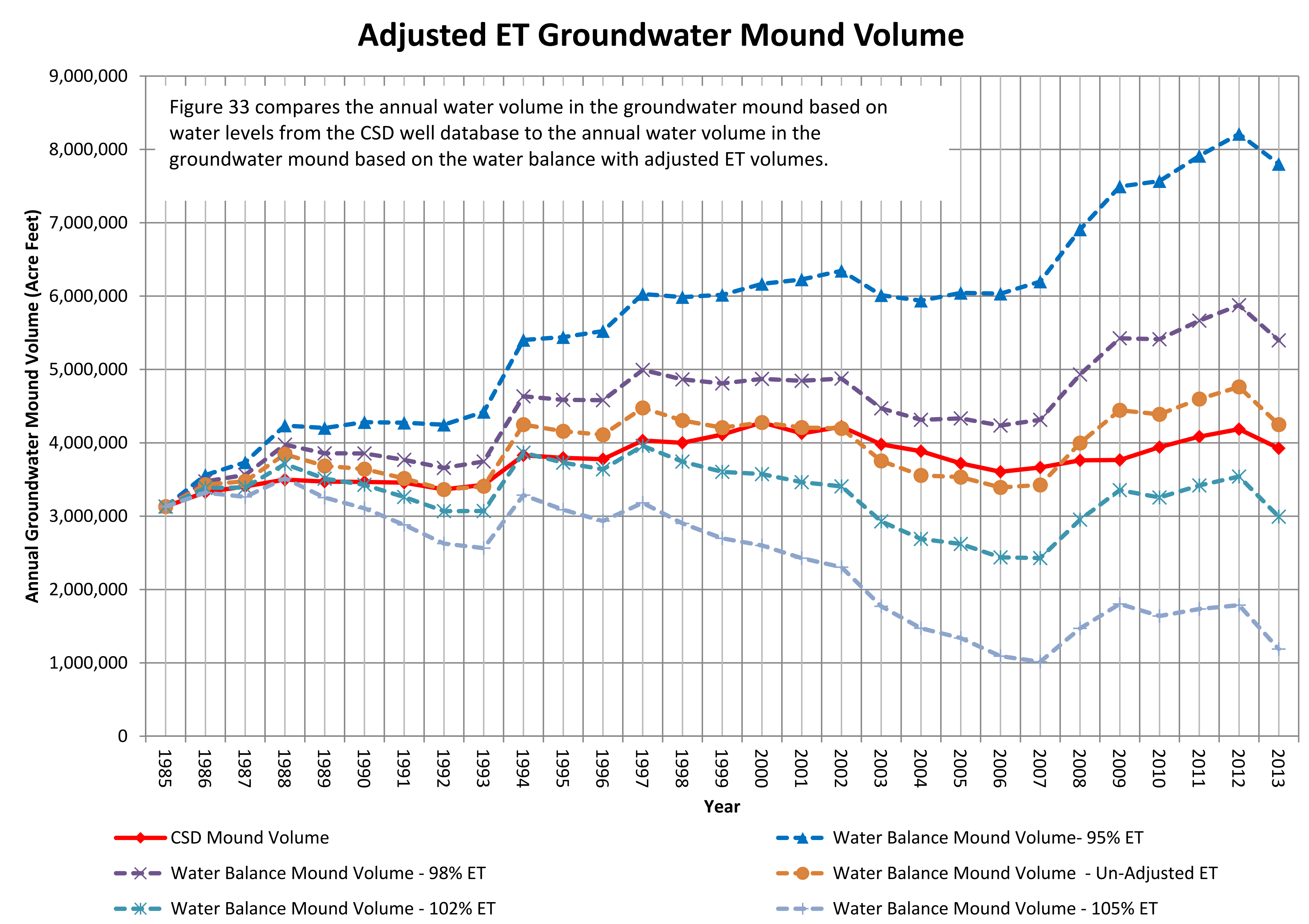


Figure 33. Comparison of the water balance mound volume with adjusted ET volumes.

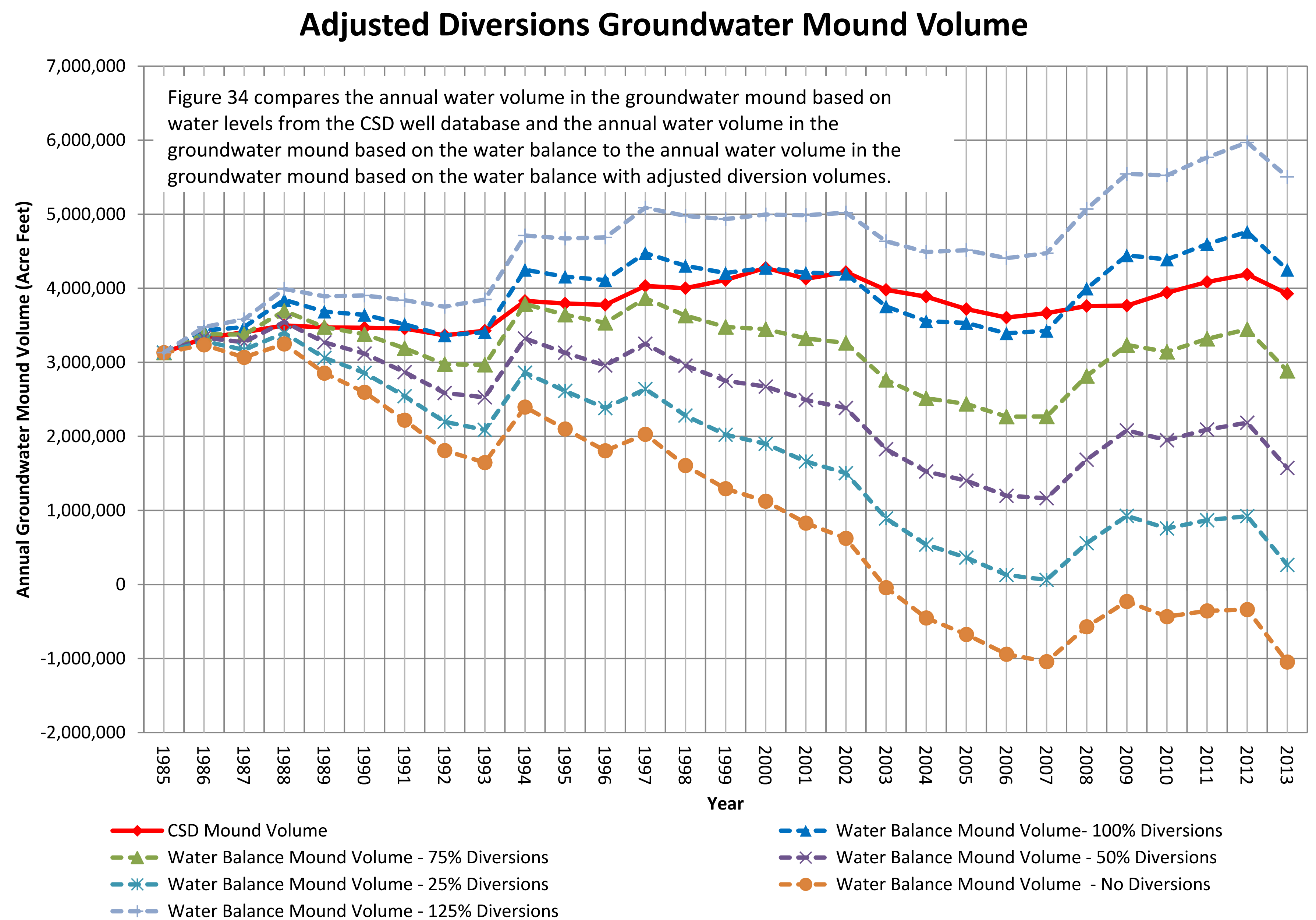


Figure 34. Comparison of the water balance mound volume with adjusted diversion volumes.

Appendix A

Data Evaluation Memorandum – Groundwater Mound Evaluation Project

Engineering, Science, and Technology, Inc.
221 Sun Valley Blvd., Suite D
Lincoln, NE 68528

MEMORANDUM

DATE: 29 January 2013

TO: **Cory Steinke, P.E., CNPPID**

FROM: Dale Schlautman, P.E., EA

SUBJECT: Data Evaluation Memo
Groundwater Mound Evaluation Project

The purpose of this memorandum is to provide an overview of the planned approach for data evaluation related to the groundwater mound in the vicinity of the CNPPID irrigation facilities, provide an understanding of the changes in the groundwater mound that have occurred over time, and the factors effecting the mound. Attached to this memorandum is a scope of work and a budgetary cost for completing the data evaluation.

GENERAL APPROACH

EA's general approach to evaluation and reporting includes the following steps:

- Step 1 – Prepare Data Evaluation Memorandum (this document)
  - Provide a list of preliminary factors that could impact the groundwater mound.
  - Provide an overview of the planned approach to data evaluation.

- Step 2 – Conduct Data Evaluation (Phase II)
  - The data evaluation activities will be conducted as described later in this memorandum.
  - If new opportunities for analysis or unexpected results are found, CNPPID will be notified to determine if changes to the evaluation approach are needed.

- Step 3 – Reporting
  - The resulting data and evaluation results will be compiled into a Draft Report submitted for review and comment.
  - The comments will be addressed and incorporated into a Final Report.

- Step 4 – Follow-up Evaluation (Phase III)
  - Based on the results from Phase II, some follow-up evaluation may be conducted, if desired by CNPPID.
  - Results from Phase III evaluation will be compiled and submitted as an Addendum to the Report.

PRELIMINARY FACTORS

The following is a list of preliminary factors that may be related to changes in the groundwater mound.

Factor	Description	Anticipated Impact
Precipitation	Infiltration due to rainfall	↑ rainfall = ↑ GW levels
CNPPID Diversions	Diversions into the CNPPID canal system and within the system	↑ diversions = ↑ GW levels
CNPPID Deliveries	Deliveries to lands by the CNPPID canal system	↑ deliveries = ↑ GW levels
CNPPID Delivery Efficiency	Efficiency of system for delivering water diverted into system	↑ delivery efficiency = ↓ GW levels
CNPPID Delivery per Acre	Amount of water delivered per irrigated acre	↓ delivery/acre = ↓ GW levels
Reservoir Seepage	Seepage from Elwood Reservoir	↑ seepage = ↑ GW levels
Gate Irrigated Acres	Acres of irrigated using gated pipe or open ditch methods	↑ acres = ↑ GW levels
Pivot Irrigated Acres	Acres of irrigated using center pivots	↑ acres = ↓ GW levels
Irrigation Wells	Number of registered irrigation wells	↑ wells = ↓ GW levels
Water Pumped	The estimated volume of groundwater pumped for irrigation	↑ water pumped = ↓ GW levels
Streamflow	Flow in streams and drains within study area	↑ GW levels = ↑ streamflow
Canal Lining	Length of canal and laterals that have had liners installed	↑ liner length = ↓ GW levels
Farming Practices	Changes in crop type and conservation practices	changes in crop type = ? GW levels ↑ conservation practices = ↓ GW levels

SUBAREAS

The following is a list of preliminary Subareas within the study area that may have different trends in groundwater levels than the entire groundwater mound.

Subarea	Description	Characteristics
Johnson Lake and Supply Canal	Area in the vicinity of Johnson Lake and the Supply Canal from Johnson Lake to the Phelps Canal	Lake with stable water levels ~100% Open lateral
Elwood Reservoir	Area in the vicinity of Elwood Reservoir	Construction of the Elwood Reservoir increases groundwater recharge
Phelps Canal - West	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the Phelps County Canal, <u>upstream of Mile 13.3</u>	~86% Open lateral ~12% Pipeline ~2% Other
Phelps Canal - Mid	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the Phelps County Canal, <u>from Mile 13.3 to Mile 31.8</u>	~86% Open lateral ~12% Pipeline ~2% Other
Phelps Canal - East	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the Phelps County Canal, <u>downstream of Mile 31.8</u>	~86% Open lateral ~12% Pipeline ~2% Other
E65 Canal	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the E65 Canal	~58% Open lateral ~39% Pipeline ~3% Other
E67 Canal	Area in the vicinity of the canals/laterals, and surface irrigated land associated with the E67 Canal	~85% Pipeline ~13% Lined lateral ~2% Open lateral

GENERAL QUESTIONS

The following is a list of questions that are planned to be addressed through the groundwater evaluation project. The applicable data anticipated to be used to address the questions are briefly described. The questions are grouped by topic for clarity.

<u>Groundwater Mound Configuration and Trends</u>

1. What is the desired boundary for the study?

    Applicable Data:

- Discussion during meetings with CNPPID
- Natural and geographic boundaries (counties, District irrigated area, South boundary of Platte River, Basin, etc.)
- The boundary will not include the Supply Canal west and north of Johnson Lake.
- Boundary of the groundwater mound based on the increased water levels published in Nebraska Statewide Groundwater-Level Monitoring Report, 2011, UNL Conservation and Survey Division (NE GW Level Report, CSD)

2. How has the estimated volume of the entire groundwater mound changed over time?

   Applicable Data:
   - Water levels from UNL CSD Nebraska Groundwater Level Reports from 1954-2011
   - Hydrogeologic characteristics from COHYST Hydrostratigraphic Units and Aquifer Characteristic Report, 2006
   - Key dates for natural and operational events provide CNPPID
3. How has size and shape of the entire groundwater mound changed over time?

   Applicable Data:
   - Water levels from UNL CSD Nebraska Groundwater Level Reports
   - Results for the volume of the groundwater mound from Question 2.
4. How has the estimated volume of the groundwater mound changed over time within in different subareas? Are there trends within individual subareas that are different than the entire groundwater mound?

   Applicable Data:
   - Water levels from UNL CSD Nebraska Groundwater Level Reports
   - Past operation and management events and records from CNPPID.
   - Results for the volume of the groundwater mound from Question 2.

Precipitation

5. How does annual precipitation relate to changes in the volume of the groundwater mound?

   Applicable Data:
   - Rainfall data from select rain gauges provided by CNPPID within the study area.
   - Results for the volume of the groundwater mound from Question 2.

Diversion and Delivery

6. How do annual diversions, deliveries, efficiency, and delivery per acre relate to changes in the volume of the groundwater mound? Are there trends due to diversions, deliveries, efficiency, and delivery per acre within select subareas (Phelps, E65, and E67) that are different than the entire study area?

   Applicable Data:
   - CNPPID records for records for diversions, deliveries, efficiency, and deliveries per acre.
   - Results for the volume of the groundwater mound from Question 2.

<u>Elwood Reservoir</u>

7. How does the estimated annual seepage from Elwood Reservoir relate to changes in the volume of the groundwater mound?

   Applicable Data:
   - CNPPID records and estimated of reservoir seepage.
   - Results for the volume of the groundwater mound from Question 2.

<u>Irrigation</u>

8. How does surface water through gated pipe irrigated acres relate to changes in the volume of the groundwater mound? Are there trends within select subareas that are different than the entire study area? Consider for Phase III evaluation.

   Applicable Data:
   - CNPPID records for gated pipe irrigated acres.
   - Results for the volume of the groundwater mound from Question 2.
9. How does surface water through pivot irrigated acres relate to changes in the volume of the groundwater mound? Are there trends within select subareas that are different than the entire study area? Consider for Phase III evaluation.

   Applicable Data:
   - CNPPID records for pivot irrigated acres.
   - Results for the volume of the groundwater mound from Question 2.
   -
10. How does the number of registered irrigation wells relate to changes in the volume of the groundwater mound? Are there trends within select subareas that are different than the entire study area?

    Applicable Data:
    - Nebraska Department of Natural Resources (NDNR) on-line registered well database.
    - Results for the volume of the groundwater mound from Question 2.
11. How does the estimated annual volume of groundwater pumped for irrigation relate to changes in the volume of the groundwater mound?

    Applicable Data:
    - TBNRD flow meter data from 2003 to 2012.
    - CNPPID records for estimated acres served per well, estimated volume of water applied, etc.
    - NDNR registered irrigation well database.
    - Results for the volume of the groundwater mound from Question 2.

Streams and Drains

12. How does flow in streams and drains relate to changes in volume of the groundwater mound?

    Applicable Data:
    - NDNR stream flow data for Plum Creek Near Smithfield, NDNR Stream Gauge, Gosper County, ID 6767500, 1981-2004
    - Limited data from Tri-Basin NRD.
    - Results for the volume of the groundwater mound from Question 2.

Canal Lining

13. How does lining of canals/laterals relate to changes in volume of the groundwater mound? Consider for Phase III evaluation.

    Applicable Data:
    - CNPPID records for canal and lateral improvement projects.
    - Water levels from UNL CSD Nebraska Groundwater Level Reports from 1954-2011
    - Water levels from individuals wells located in close proximity to improvement projects.
    - Results for the volume of the groundwater mound from Question 2.

Farming Practices

14. How do changes in farming practices such as the acres in production for the primary crops, total crop yield, and crop yield per acre relate to changes in volume of the groundwater mound? Consider for Phase III evaluation.

    Applicable Data:
    - CNPPID records for types of crops produced.
    - Crop records from the USDA Crop Census (every 5 years)
    - Results for the volume of the groundwater mound from Question 2.

15. How do conservation practices relate to changes in volume of the groundwater mound?

    Applicable Data:
    - Crop records from the USDA Crop Census (every 5 years)
    - Results for the volume of the groundwater mound from Question 2.

Water Balance

16. How do the results from a simplified annual water balance compare to changes in volume of the groundwater mound?

    Applicable Data:
    - Results for the volume of the groundwater mound from Questions 2, 5, 7, and 11.
    - Other sources such as COHYST.

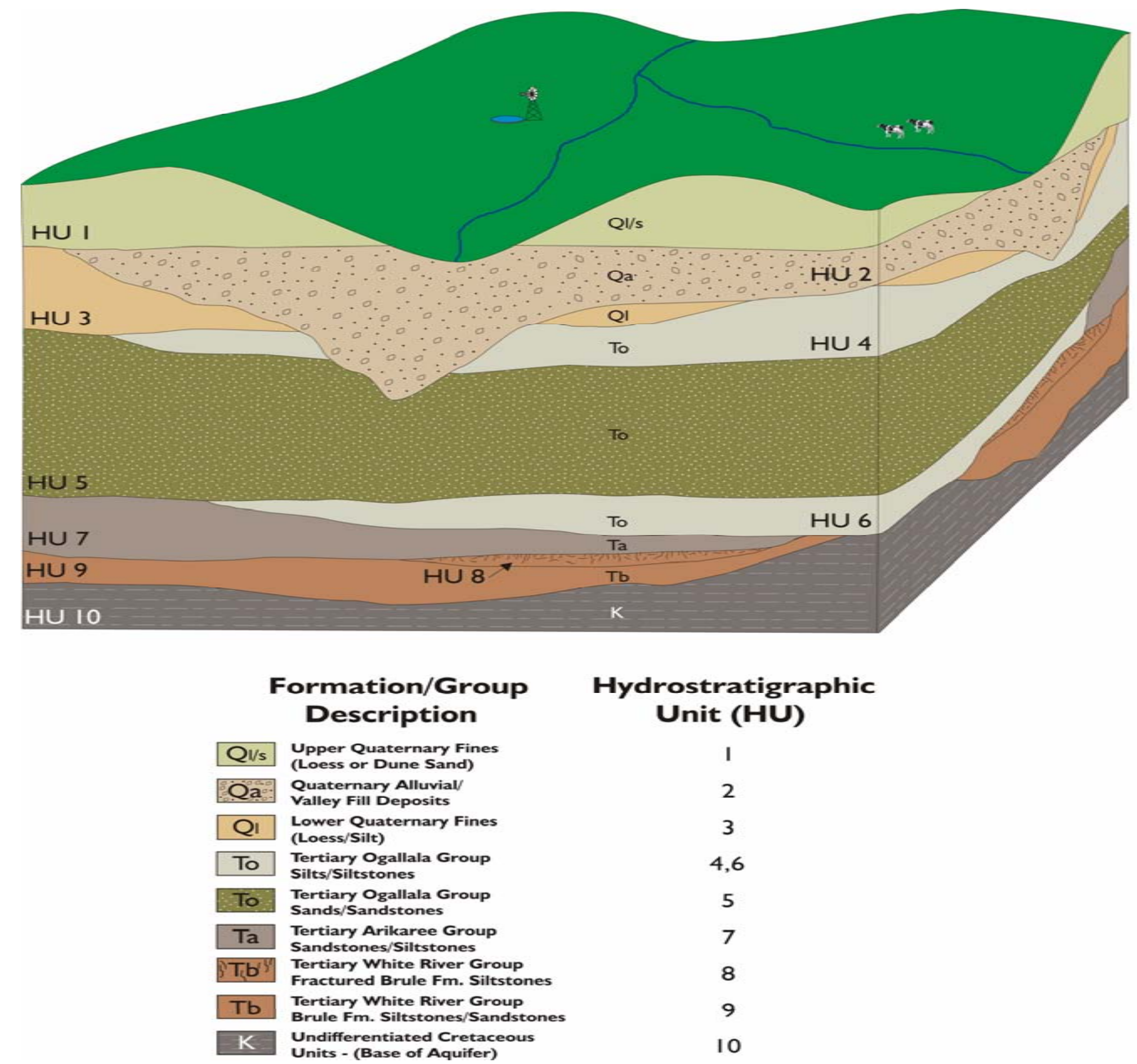
Appendix B

Hydrostratigraphic Unit Descriptions from COHYST Hydrostratigraphic Units and Aquifer Characterization Report (2006)

Table 1. Stratigraphic description of geologic and hydrostratigraphic units used in the Cooperative Hydrology Study

System	Series	Geologic Unit	Hydrostratigraphic Unit	Description	Water Supply
Quaternary	Holocene	Valley-fill deposits	Unit 2	Gravel, sand, silt, and clay with coarser materials more common. Generally stream deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 1. Lower fine material, if present, is assigned to Unit 3.	Source of major supply of water in the alluvial valleys. Usually in direct communication with active streams.
	Pleistocene and Holocene	Dune sand	Unit 1	Generally fine sand but may contain some medium and even coarse sand. May also contain some finer material. Wind blown deposits.	Source of water to livestock and domestic wells. Usually shallow water table related to evapotranspiration areas in the models. Often in communication with shallow lakes within the sand hills.
		Loess deposits	Unit 1 when above Unit 2, otherwise Unit 3	Generally silt, but may contain some very fine sand and clay. Deposited as wind blown dust.	Unit generally low transmissivity with occasional fractures. Rarely used as water source for low yielding wells.
	Pleistocene	Alluvial deposits	Unit 2	Gravel, sand, silt, and clay with coarser materials more common. Generally stream deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 1. Lower fine material, if present, is assigned to Unit 3.	Major source of water for all uses throughout cohyst area. Limited to alluvial valleys and channel deposits in the west and extensive deposits in the east. Often in hydrologic connection with active streams. Generally of good quality for all uses.
Tertiary	Pliocene	Broadwater Formation	Unit 2	Coarse fluvial gravel and sand dominate with some silt and clay. Assigned to Hydrostratigraphic Unit 2. Generally found in channel deposits north of the North Platte and Platte River.	Major source of water where saturated thickness is sufficient for large capacity wells. Occasionally in communication with Pleistocene sediments.
	Upper and middle Miocene	Ogallala Group	Units 4-6	Heterogeneous mixture of gravel, sand, silt, and clay. Generally stream deposits but also contains wind blown deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 4. Center coarse material, if present, is assigned to Unit 5. Lower fine material, if present, is assigned to Unit 6. Often sandstone and conglomerate layers exist through our area.	Major source of water throughout much of the study area. Does not exist in eastern part of eastern model area or the northwest corner of the western model area. Generally yields sufficient water for all uses. Occasionally in communication with Pliocene and Pleistocene sediments.
	Lower Miocene and upper Oligocene	Arikaree Group	Unit 7	Predominately very fine to fine-grained sandstone but may also contain siltstone. Locally, may contain conglomerate, gravel, and sand.	Major source of water in the northwestern part of the western model unit where sufficient saturated thickness exists to supply large capacity wells. Used for livestock and domestic wells. Generally in communication with upper and middle Miocene sediments
	Lower Oligocene	Brule Formation of White River Group	Unit 8 of High Plains aquifer or Unit 9 below High Plains aquifer	Predominately siltstone, but may contain sandstone and channel deposits. Sometimes highly fractured with areas of fracturing difficult to predict. Upper part of Brule Formation is included in High Plains aquifer and Hydrostratigraphic Unit 8 only if fractured or contains sandstone or channel deposits, otherwise it is Unit 9 and is excluded from the High Plains aquifer. Wind-blown volcanic deposits with some fluvial deposits.	Generally an aquiclude except where fractured or alluvial channel deposits exist. Fractures and channel deposits generally are only identified in the western model unit along drainage basins. High capacity wells are common where these conditions exist and where they are in communication with overlying saturated sediments that have sufficient transmissivity to supply water at the rate of withdrawal. Often used as stock and domestic wells.
	Upper Eocene	Chadron Formation of White River Group	Unit 9; below the High Plains aquifer	Silt, siltstone, clay, and claystone. Generally forms impermeable base of High Plains aquifer. Fluvial deposits and wind-blown volcanic deposits.	Generally an aquiclude except for basal fluvial sediments. These sediments exist as channel deposits in the western and central model areas. They are generally deep and used for domestic or livestock where no other supply exists. Rare high capacity wells exist in the western model unit.
Cretaceous	Undifferentiated	Undifferentiated	Unit 10; below the High Plains aquifer	Shale, chalks, limestone, siltstone, and sandstone. Except for a few minor areas of Fox Hills Sandstone in the extreme western part of the COHYST area and the Dakota Group in the extreme eastern part of the area, generally forms an impermeable base of High Plains aquifer. Deep marine deposits to beach deposits.	Generally an aquiclude except for sand deposits. Often used as domestic or livestock wells where no other supply exists.

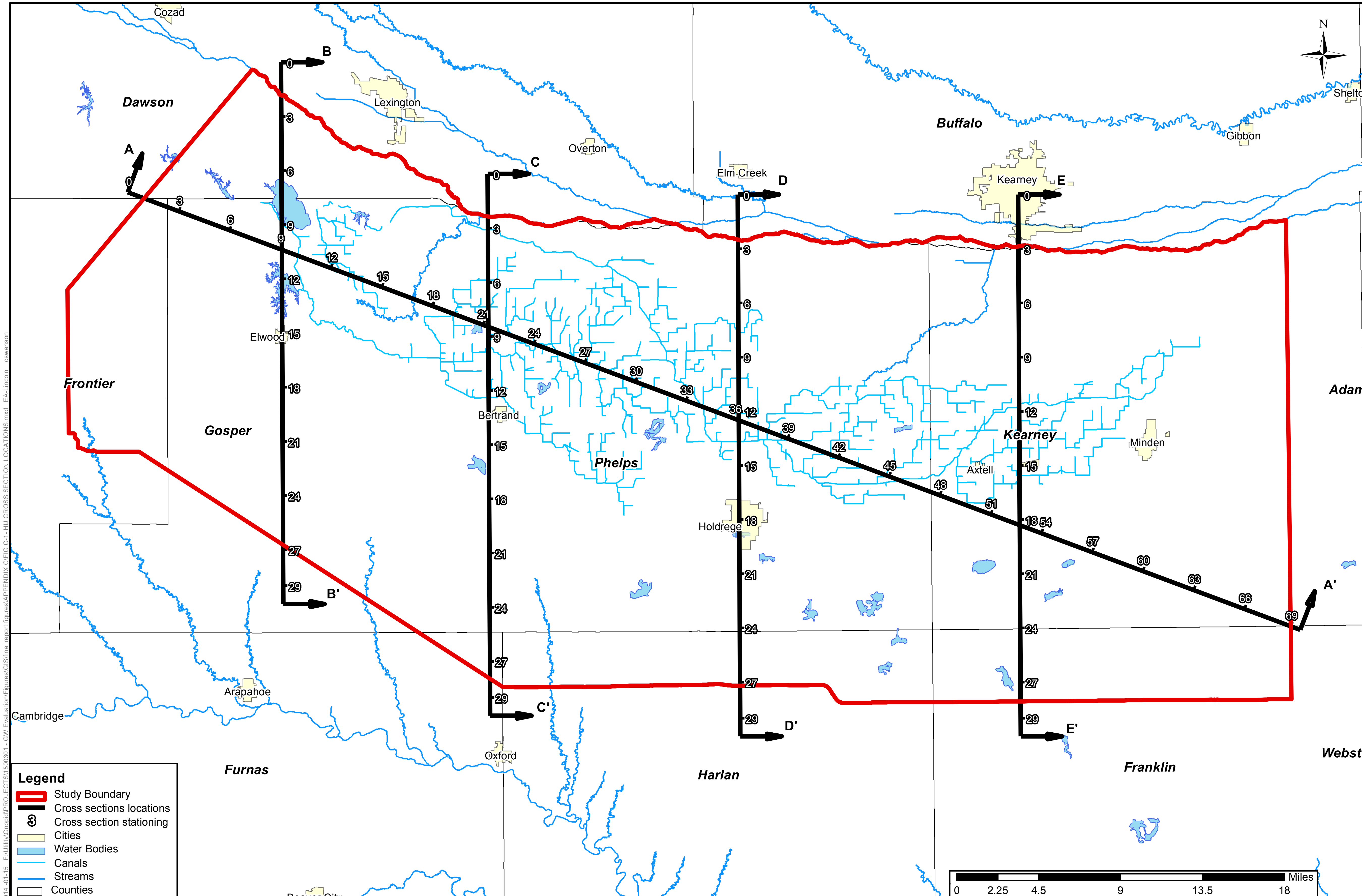
Figure 12. Stratigraphic display of geologic and hydrostratigraphic units used in the Cooperative Hydrology Study



Note: Table 1 was adapted from Gutentag and others, 1984
The word communication as used in table 1 means a direct connection to an adjacent HU and or stream

Appendix C

Hydrostratigraphic Cross Section



CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

HYDROSTRATIGRAPHIC CROSS SECTION LOCATIONS

EA Engineering, Science, and Technology, Inc.®

FIGURE	C-1
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FILE NAME	-
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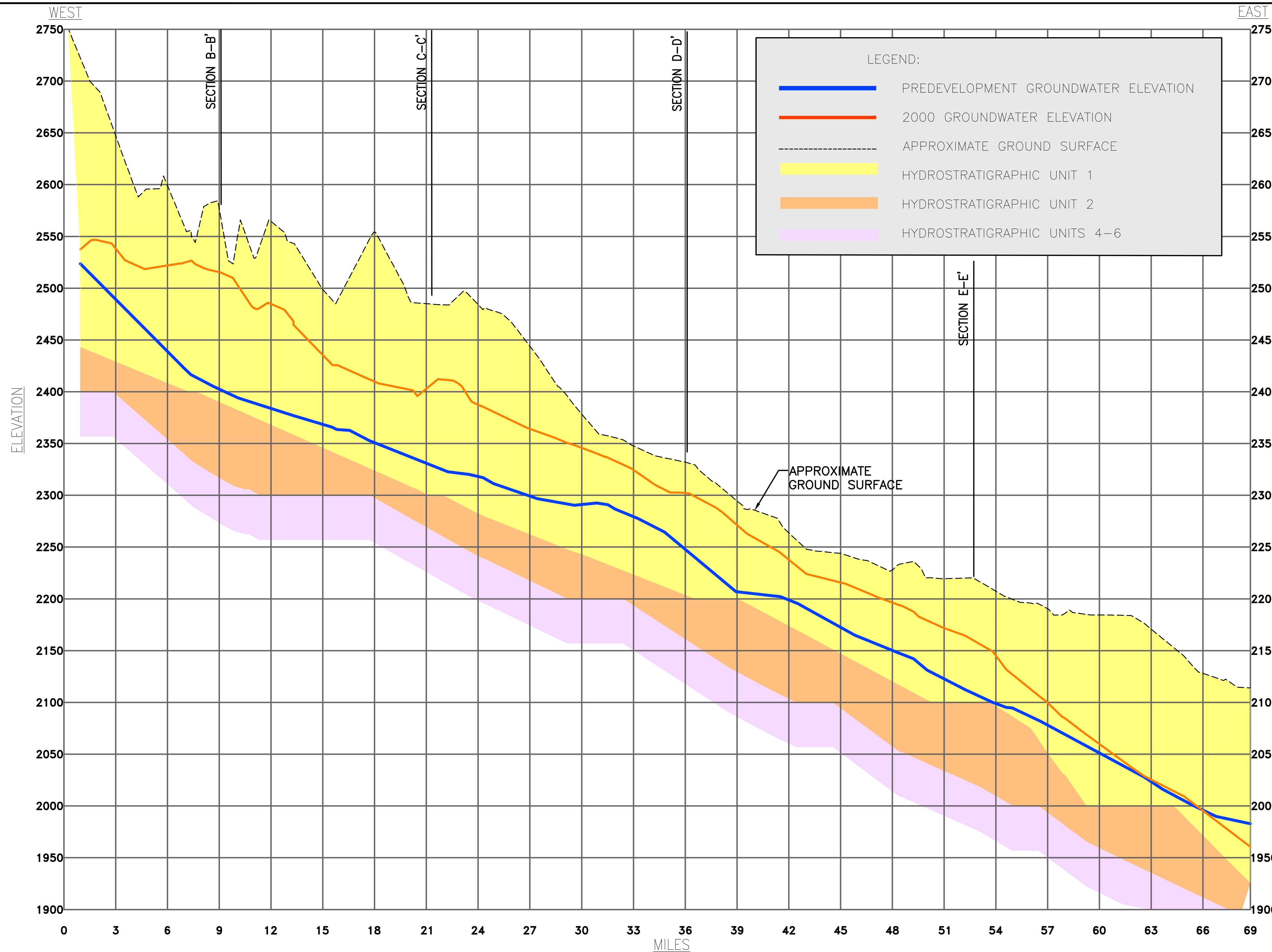
DRAWN BY	CNS
DESIGNED BY	CNS
PROJECT MGR.	DJS



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VERTICAL SCALE: 1"=100'

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DATE:11/21/2013 TIME:14:28 DRAWN BY:cswanson

EA Engineering, Science, and Technology, Inc.

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

HYDROSTRATAGRAPHIC UNITS COMPARED TO GROUNDWATER LEVELS
SECTION A-A'

FIGURE	C-2
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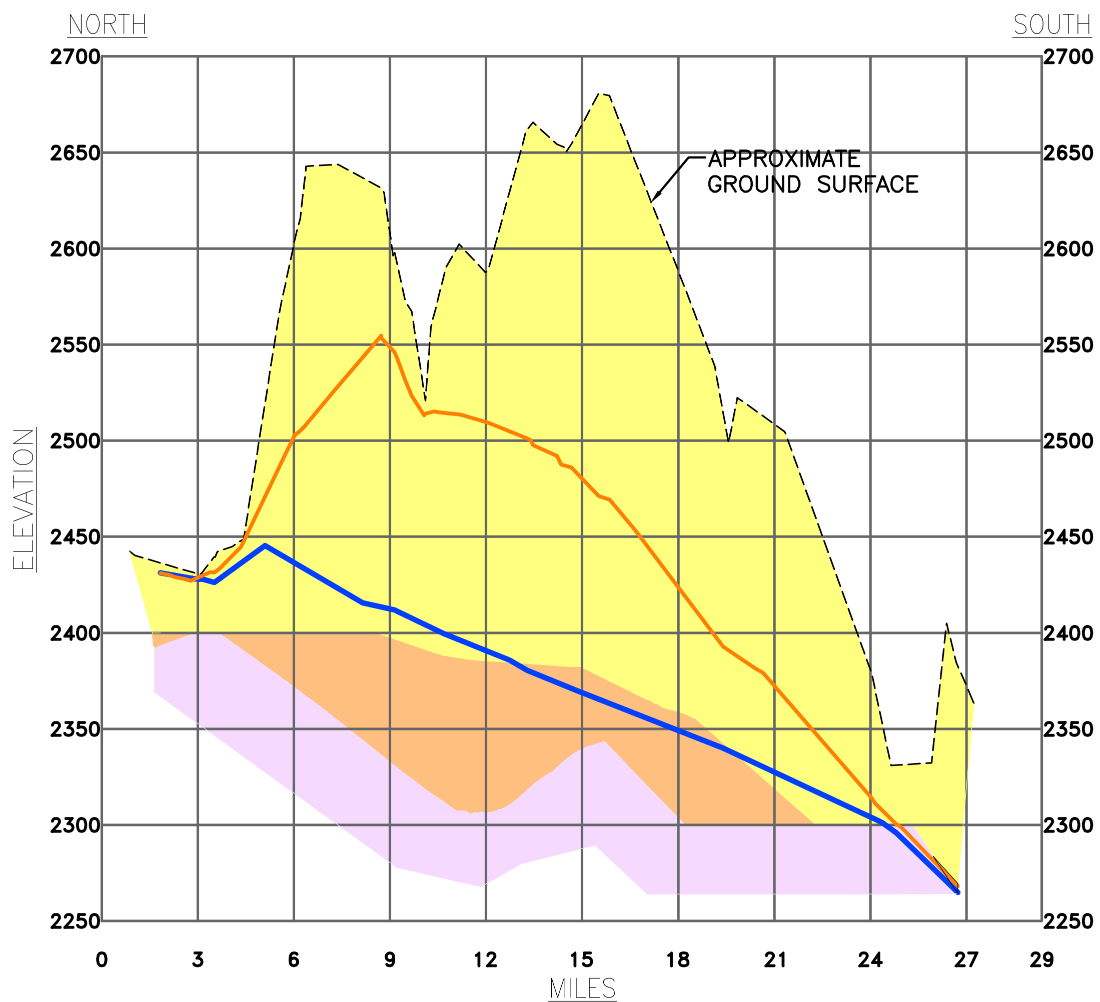

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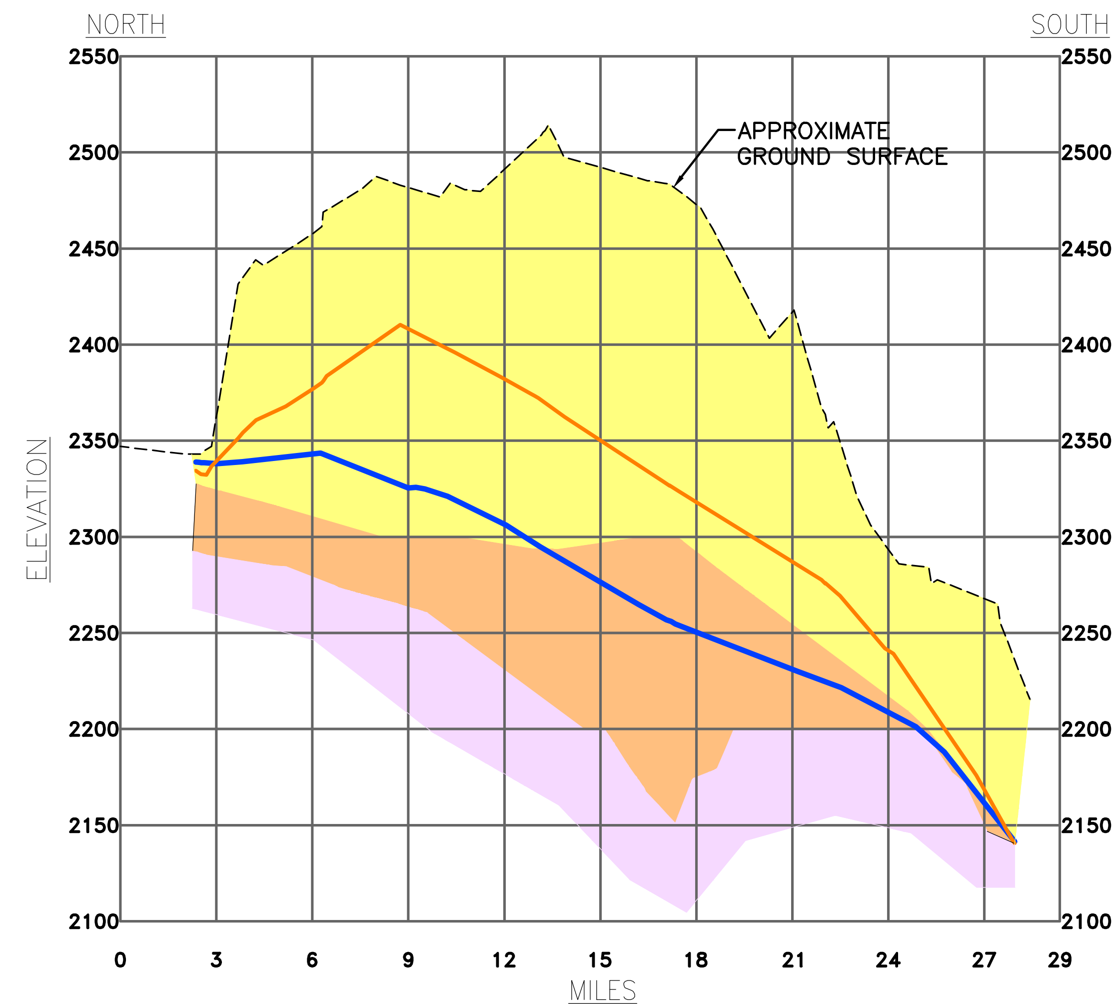
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER ELEVATION
- 2000 GROUNDWATER ELEVATION
- APPROXIMATE GROUND SURFACE
- HYDROSTRATIGRAPHIC UNIT 1
- HYDROSTRATIGRAPHIC UNIT 2
- HYDROSTRATIGRAPHIC UNITS 4–6

HYDROSTRATAGRAPHIC UNITS COMPARED TO GROUNDWATER LEVELS SECTION B-B' AND C-C'

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

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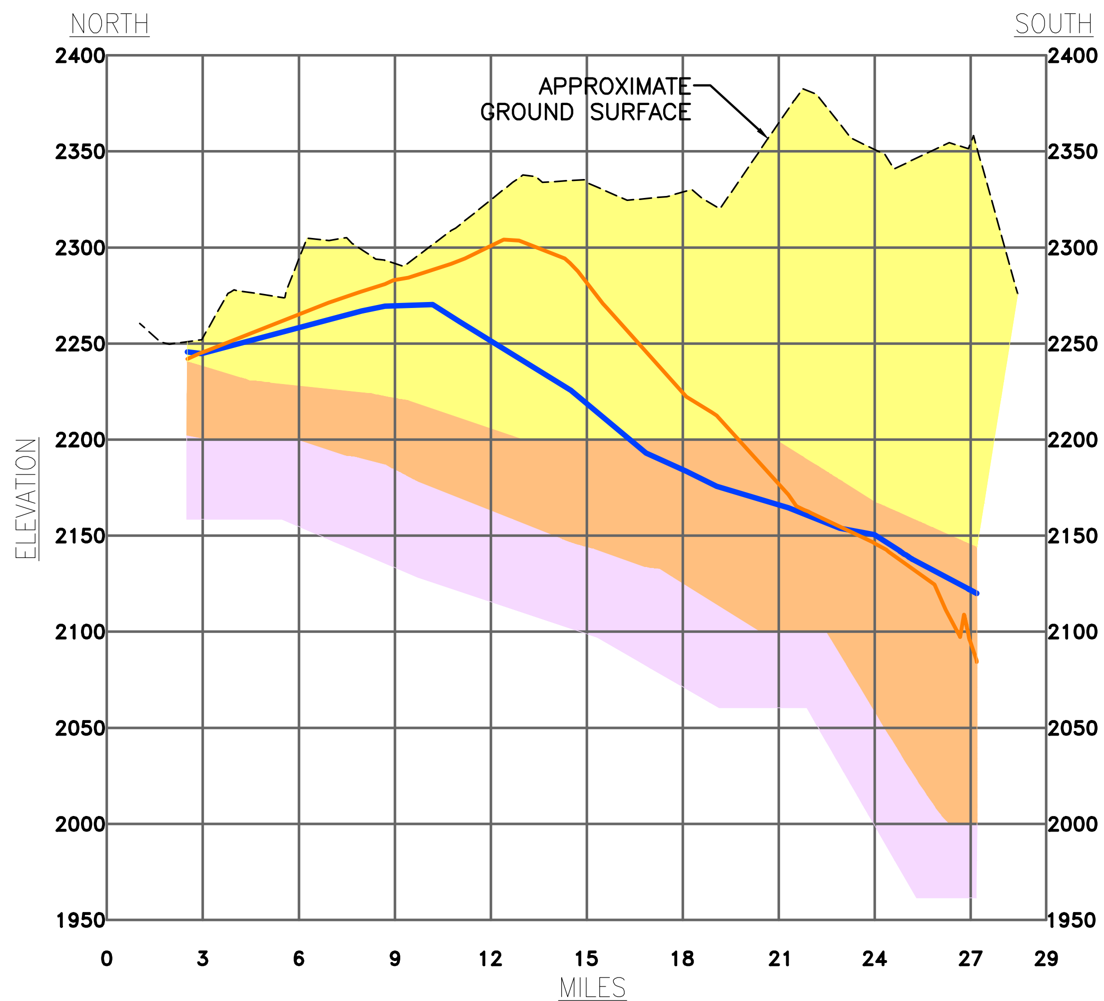

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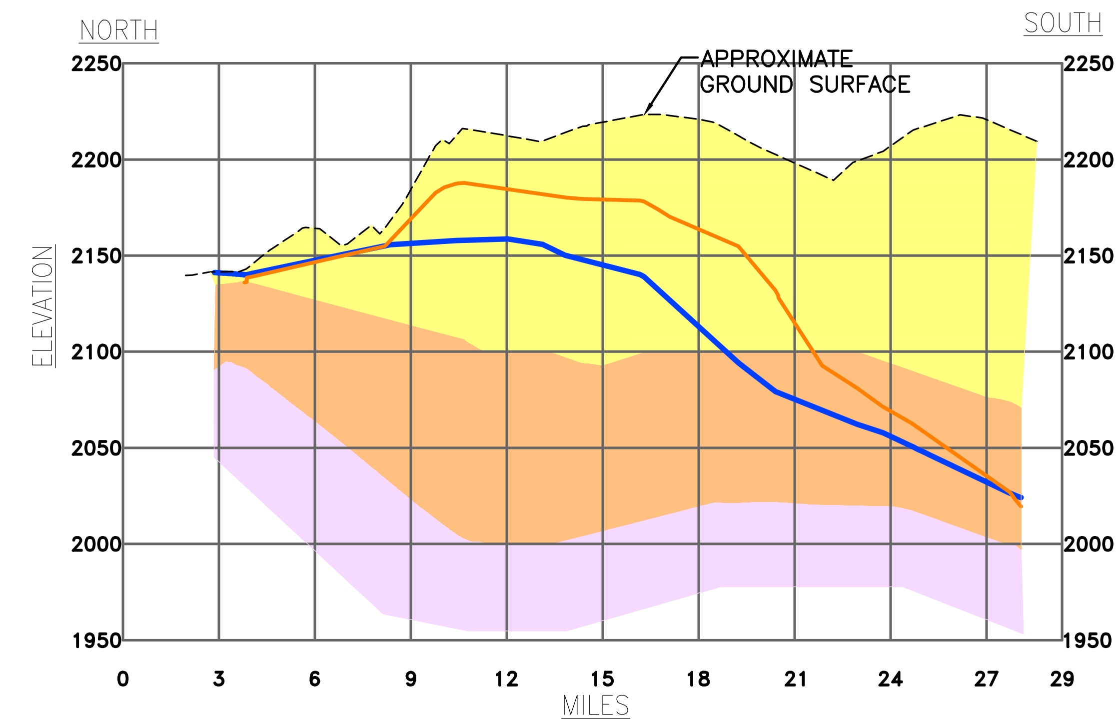

SECTION E–E'
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VERTICAL SCALE: 1"=100'

LEGEND:

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- 2000 GROUNDWATER ELEVATION
- APPROXIMATE GROUND SURFACE
- HYDROSTRATIGRAPHIC UNIT 1
- HYDROSTRATIGRAPHIC UNIT 2
- HYDROSTRATIGRAPHIC UNITS 4–6

HYDROSTRATAGRAPHIC UNITS COMPARED TO GROUNDWATER LEVELS SECTION D-D" AND E-E'

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	C-4
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DESIGNED BY	CNS
PROJECT MGR.	DJS

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Appendix D

Comparison of Groundwater Mound Volume Results

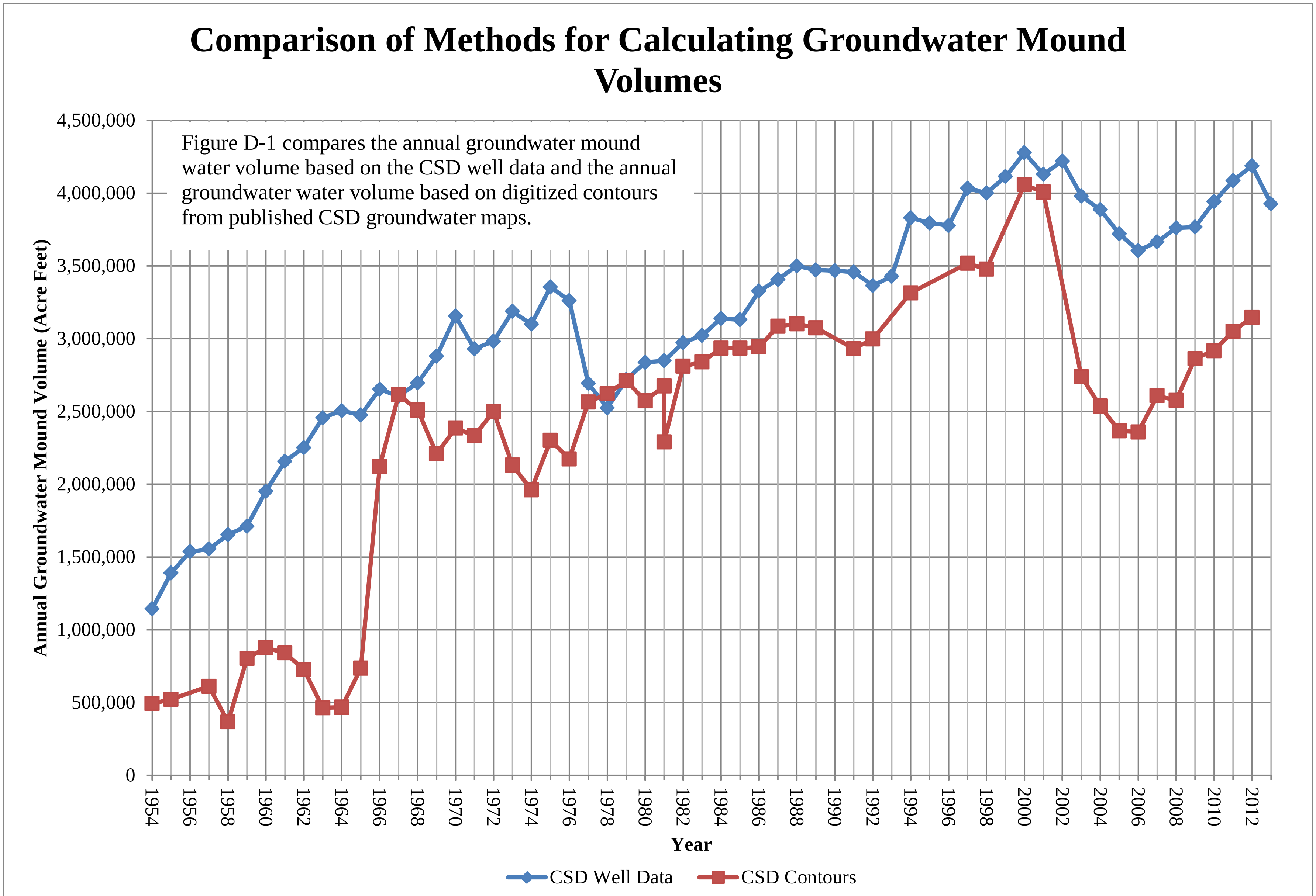
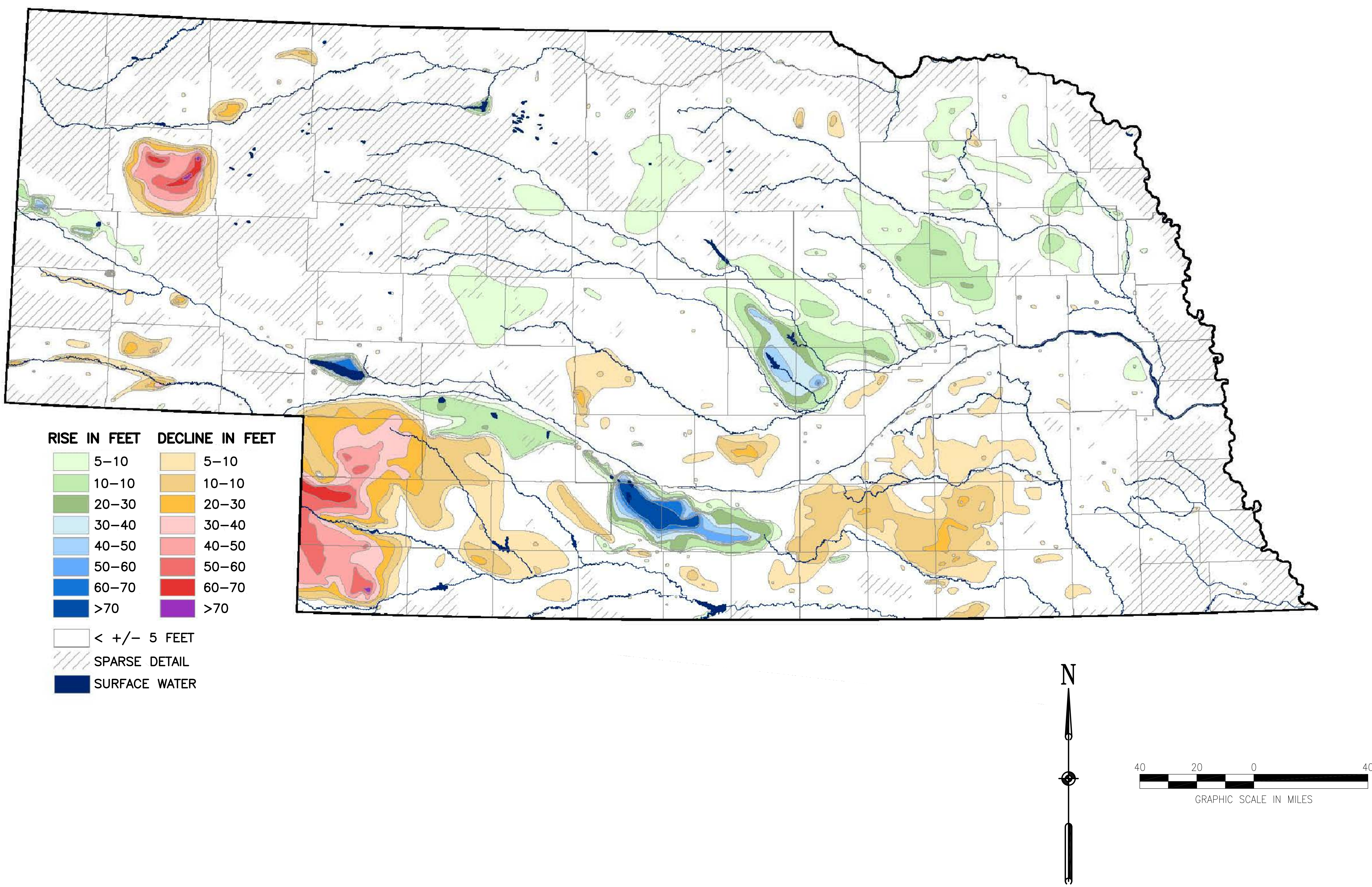


Figure D-1. Comparison of groundwater mound volumes from a DTM created based CSD well data and a DTM created based on digitized contours from published CSD groundwater maps.

GROUNDWATER-LEVEL CHANGES IN NEBRASKA
PREDEVELOPMENT TO SPRING 2011



GROUNDWATER-LEVEL CHANGES IN NEBRASKA PREDEVELOPMENT TO SPRING 2011

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	D-2
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Table D1. Wells Removed

Point ID	CSD ID	Northing	Easting	Problem	Years Removed	Info
1	402841099553601	226791.1	1677172.4	~150-200 feet lower than surrounding points	1977-1992	Problem is with the DTW measurement, not surface elevation
2	402614099495601	220029.1	1687001.7	~200 feet lower than surrounding points	1972, 1981	Problem seems to be surface elevation
3	403202099075201	256409.4	1881786.6	70-90 feet lower than surrounding points	1966, 1981-1982	Problem seems to be surface elevation
4	403558099371801	279303.0	1745348.0	30-80 feet higher than surrounding points in most years	1960-1962, 1981-1998, 2010-2012	Surface Elevation is ~20-30 feet higher than surrounding points, DTW is ~20-30 feet less than surrounding points in most years.
5	403710099495102	285502.4	1686055.2	80-100 feet higher than surrounding points	2000, 2002-2004, 2007-2009, 2012, 2013	There is another point with the same Lat/Long. Elevation difference between the 2 points is 50 feet
6	403558099522501	279162.0	1674335.7	80-100 feet lower than surrounding points	2000, 2002-2011	Surface Elevation is 50-80 feet lower than surrounding points
7	403703099503601	285500.1	1684823.7	40-60 feet lower than surrounding points	2000, 2002-2004, 2006-2013	Surface Elevation is 70-80 feet lower than 2 nearby points. Has the same elevation as another nearby point, but DTW is greater
8	402537099082901	218359.1	1880110.8	150-200 feet higher	2001	DTW measurement for 2001 is a bad data point
9	403322099254101	263854.7	1799204.0	~100 feet higher	2001	DTW measurement for 2001 is a bad data point

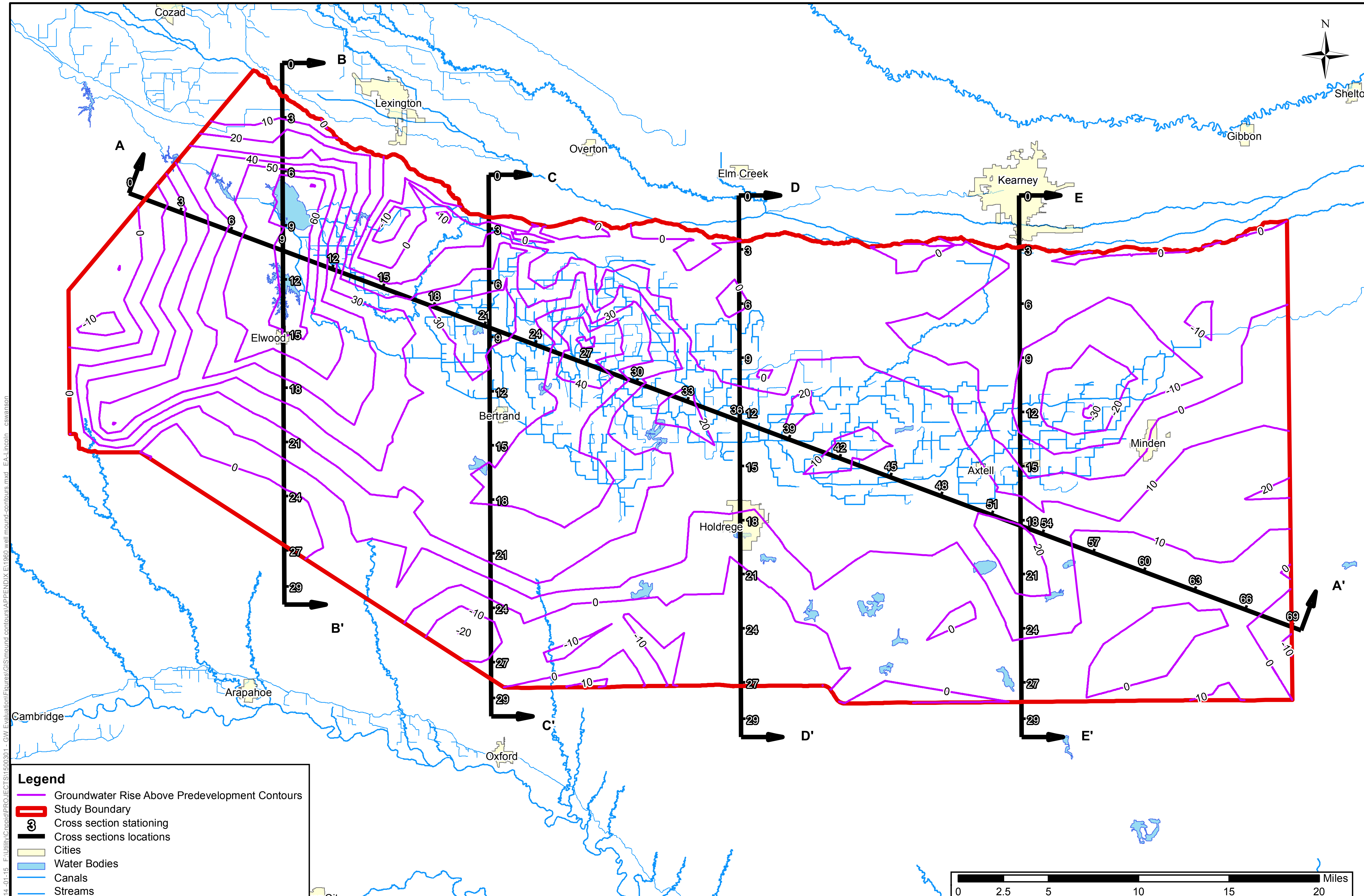
Table D2. Number of Wells per Year for Groundwater Mound Volume Calculations

Year	Wells
1954	93
1955	82
1956	78
1957	107
1958	104
1959	106
1960	127
1961	179
1962	174
1963	168
1964	173
1965	169
1966	184
1967	183
1968	185
1969	182
1970	174
1971	169
1972	160
1973	171
1974	156
1975	157
1976	160
1977	219
1978	220
1979	219
1980	216
1981	337
1982	241
1983	208

Year	Wells
1984	209
1985	209
1986	216
1987	213
1988	209
1989	217
1990	222
1991	215
1992	230
1993	221
1994	231
1995	233
1996	230
1997	218
1998	236
1999	219
2000	279
2001	208
2002	272
2003	277
2004	270
2005	291
2006	277
2007	303
2008	305
2009	293
2010	281
2011	283
2012	282
2013	268

Appendix E

Groundwater Cross Sections – Decades

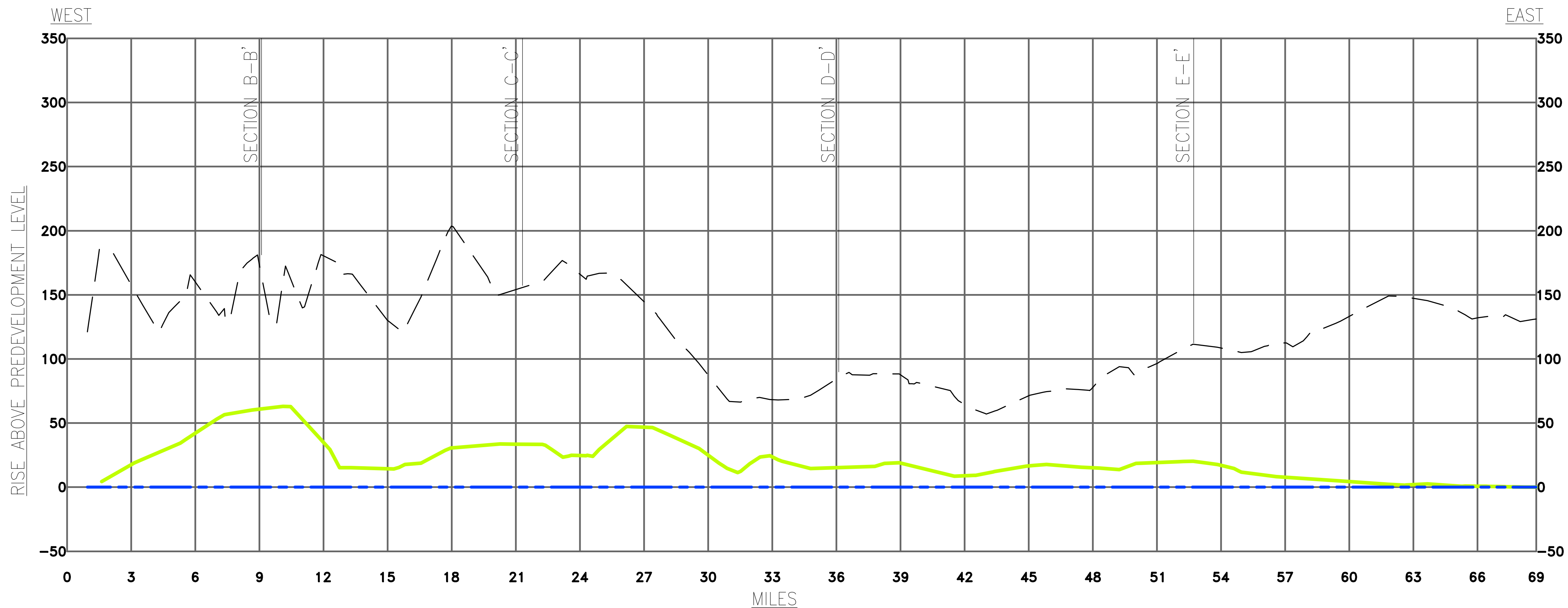


GROUNDWATER MOUND CONTOURS
1960

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E1960-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1960 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1960 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
Science, and
Technology, Inc.

FIGURE	E1960-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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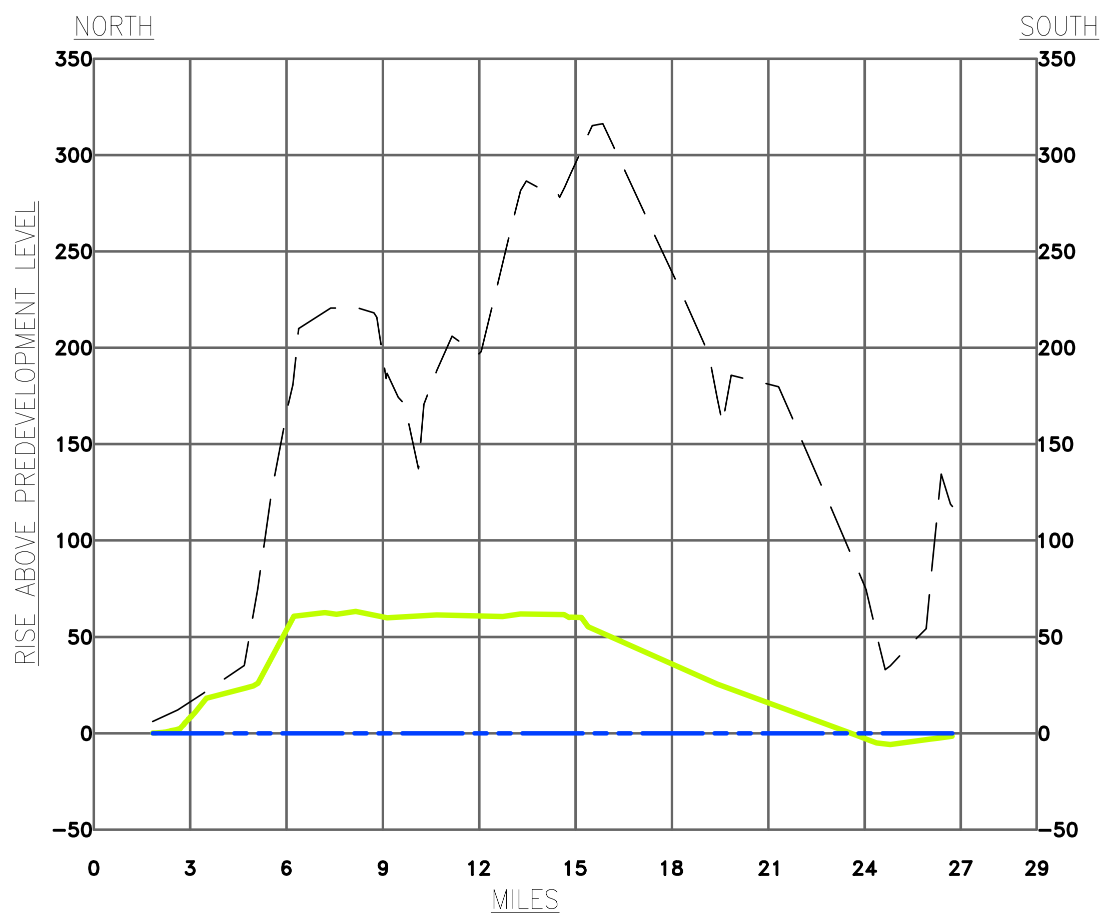
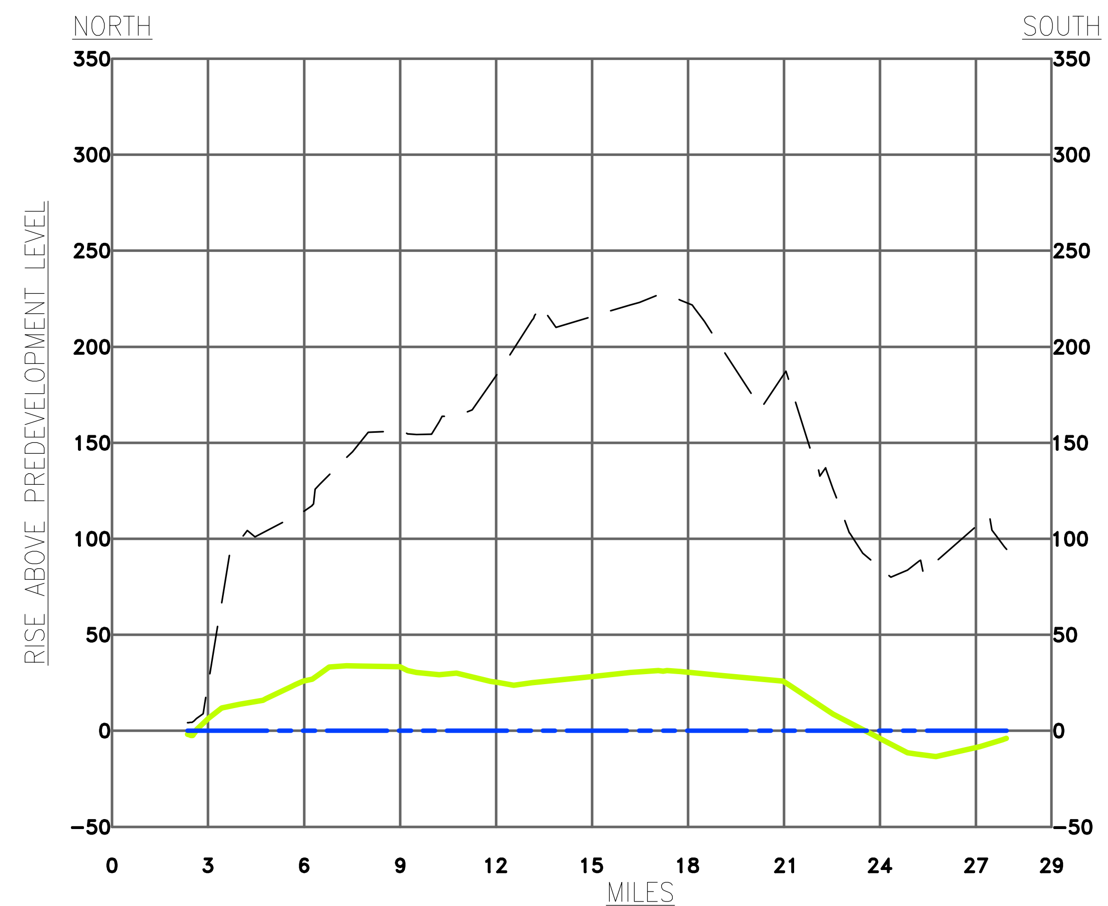
DATE:11/21/2013 TIME:15:00 DRAWN BY: cswanson



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1960 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1960 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E1960-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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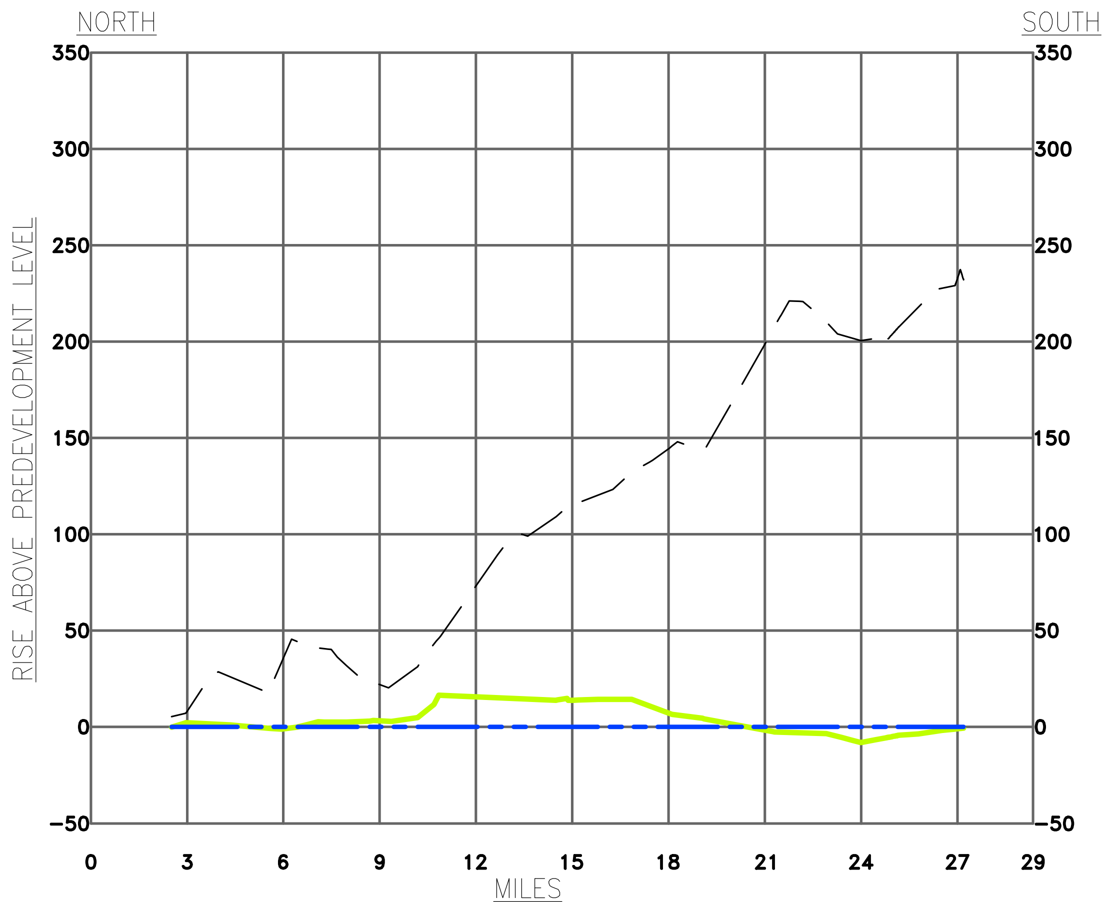
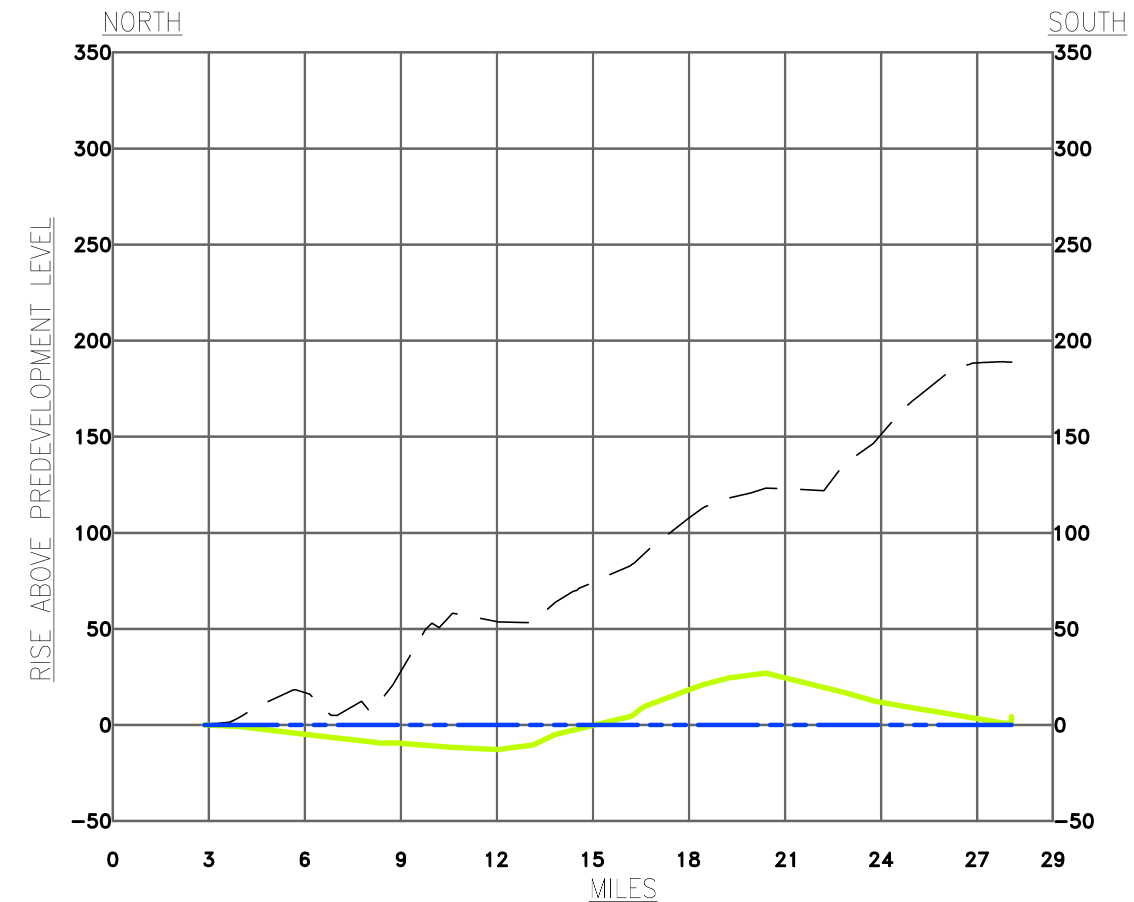
DATE:11/21/2013 TIME:15:00 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1960 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1960 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E1960-4
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FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\1960 Sections.dwg
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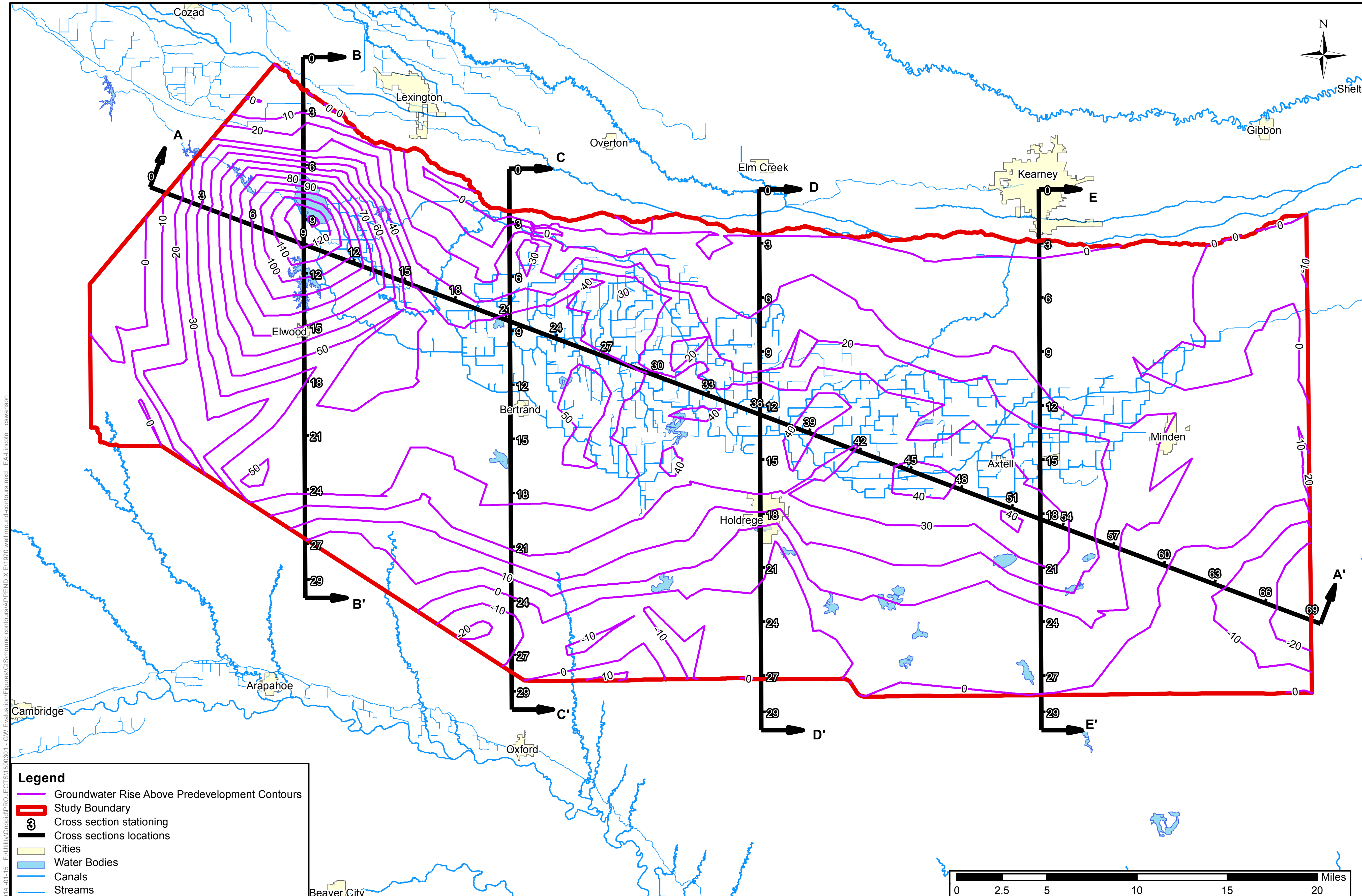
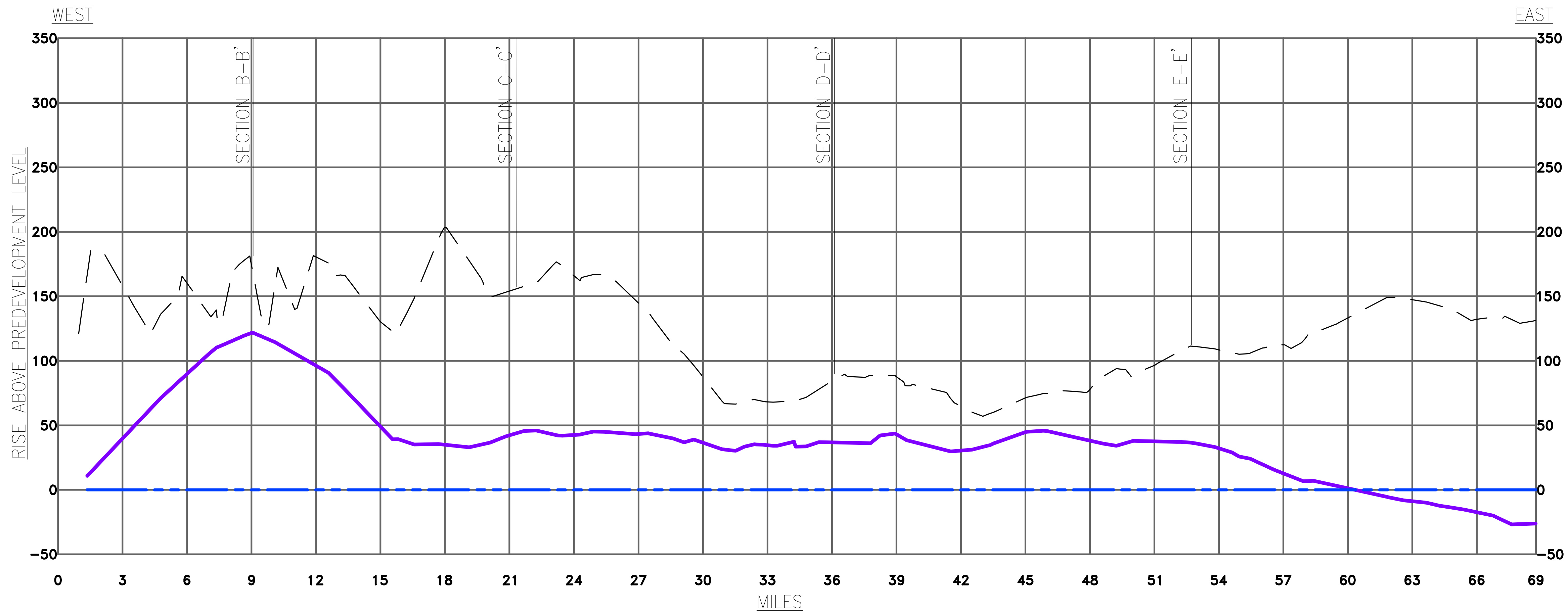


GROUNDWATER MOUND CONTOURS
1970

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E1970-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1970 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1970 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E1970-2
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FILE NAME	-
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SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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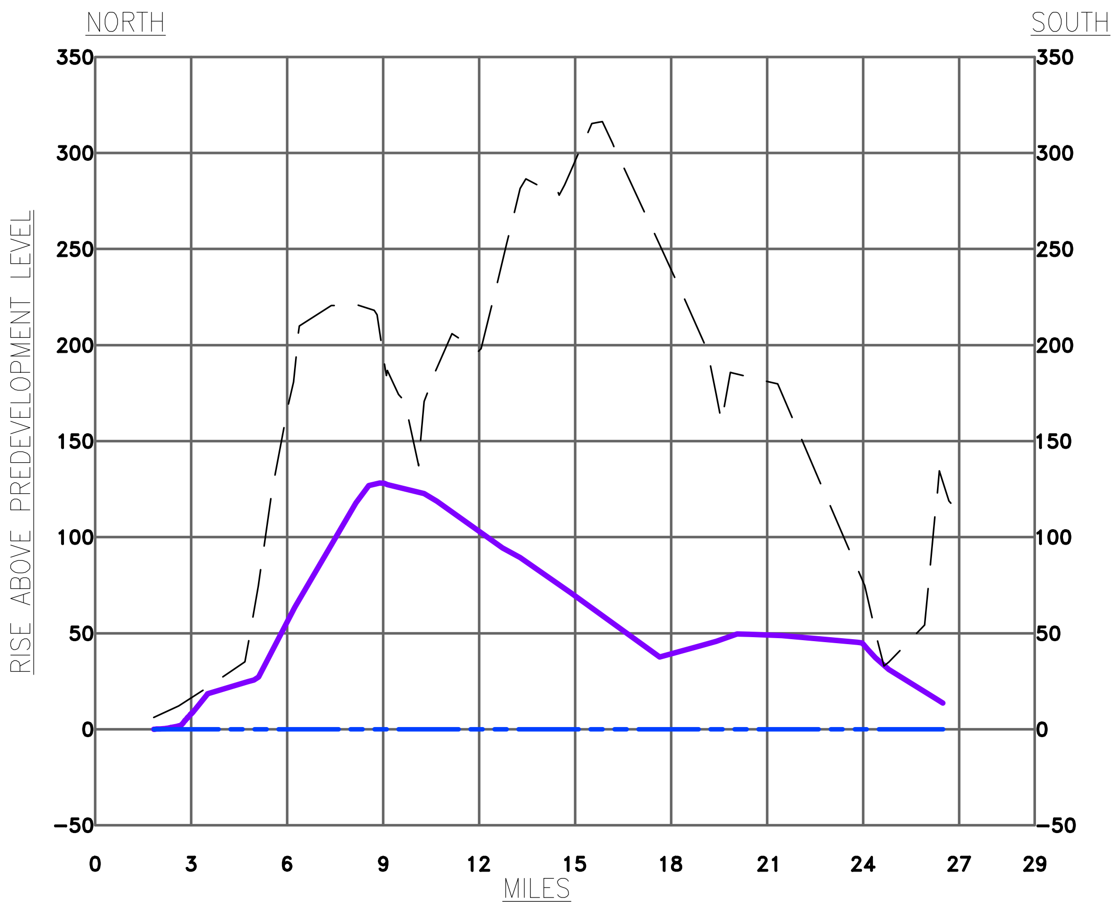
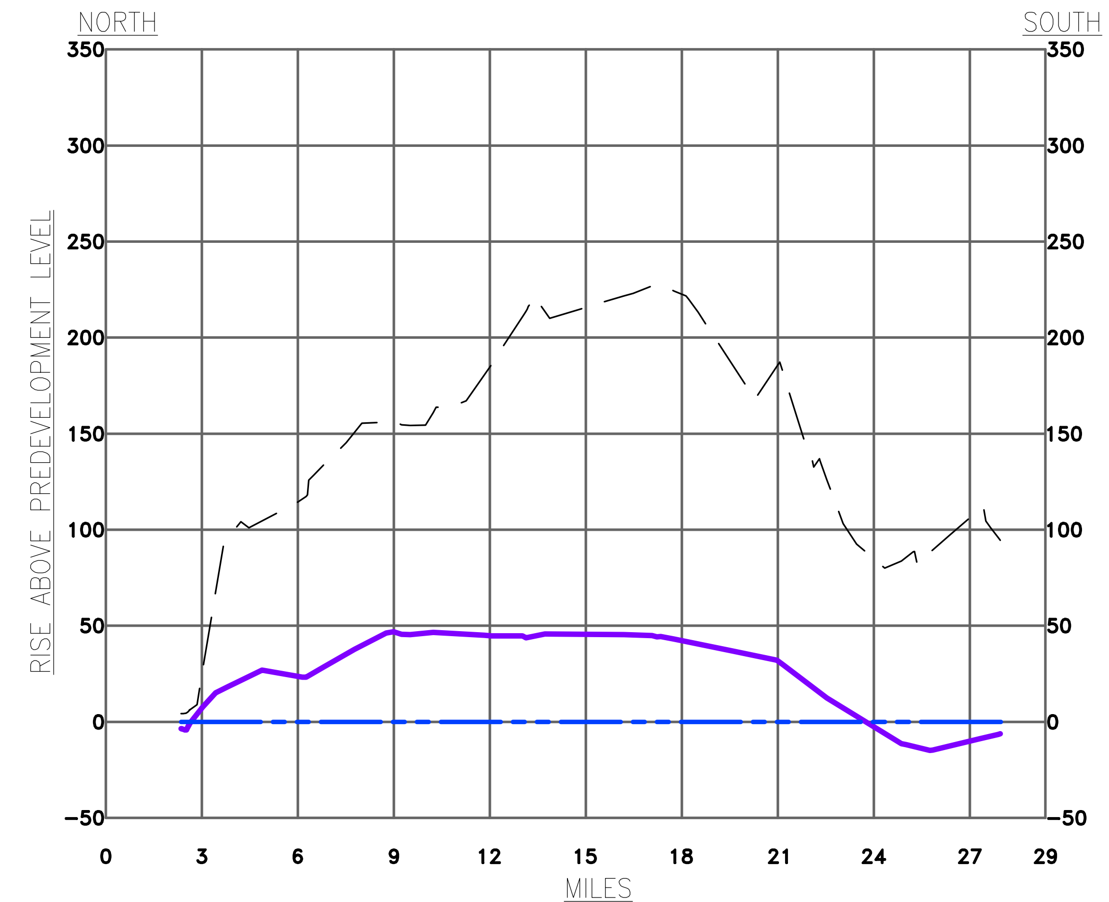


SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1970 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

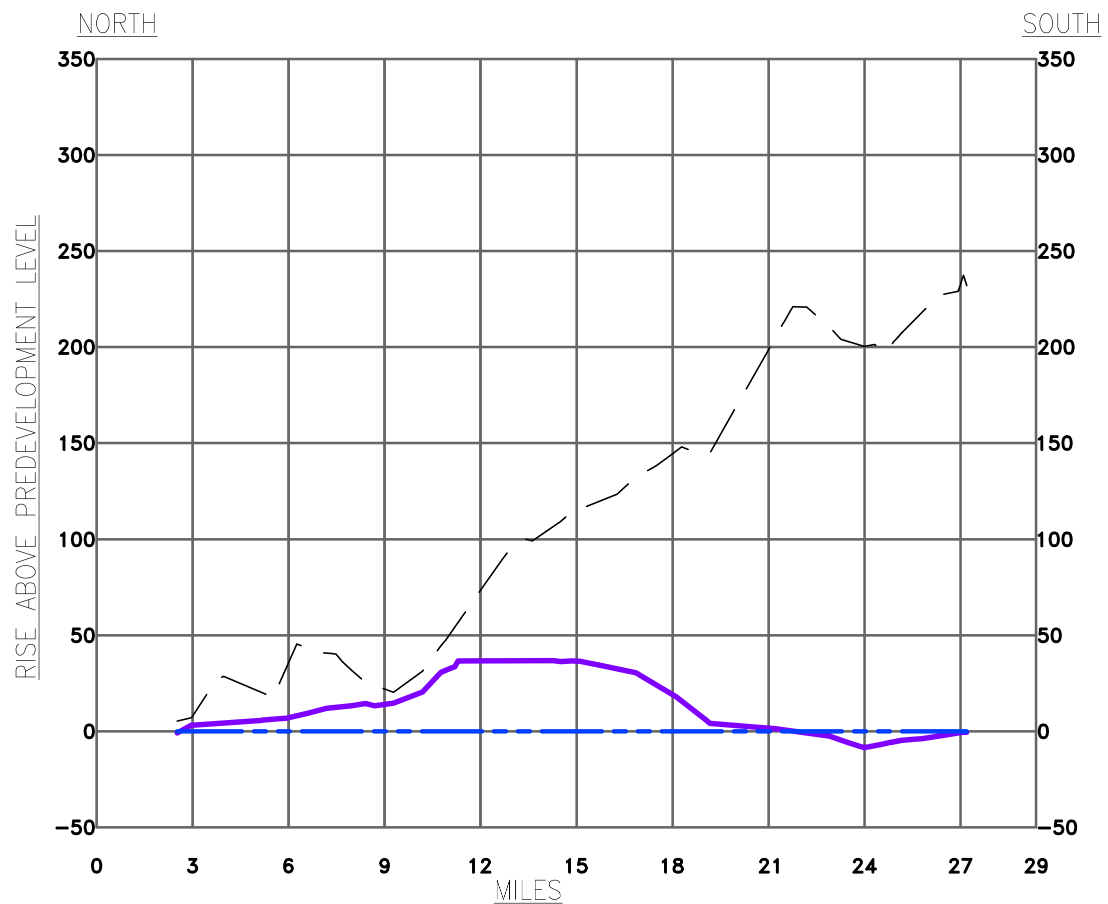
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\1970 Sections.dwg
DATE:11/21/2013 TIME:15:43 DRAWN BY: cswanson

GROUNDWATER LEVELS 1970 CROSS SECTIONS

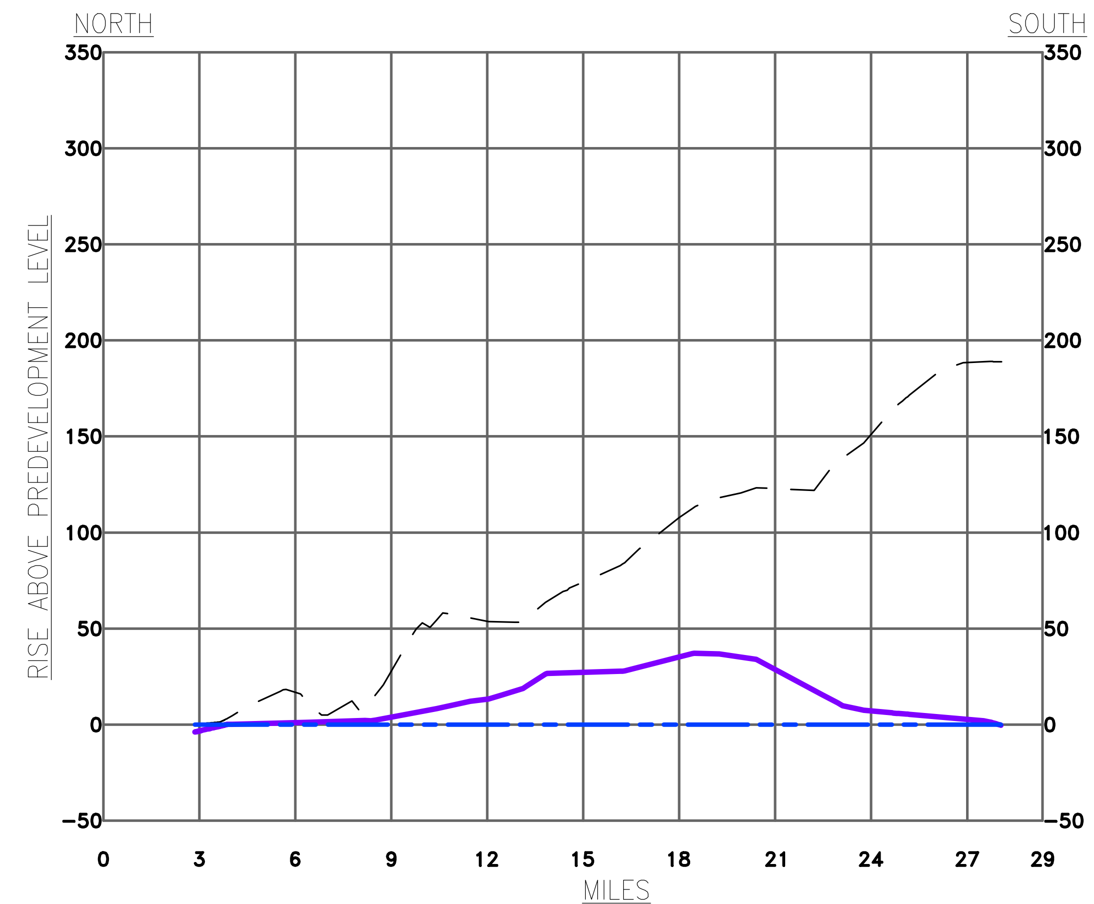
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E1970-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1970 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1970 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E1970-4
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FILE NAME	-
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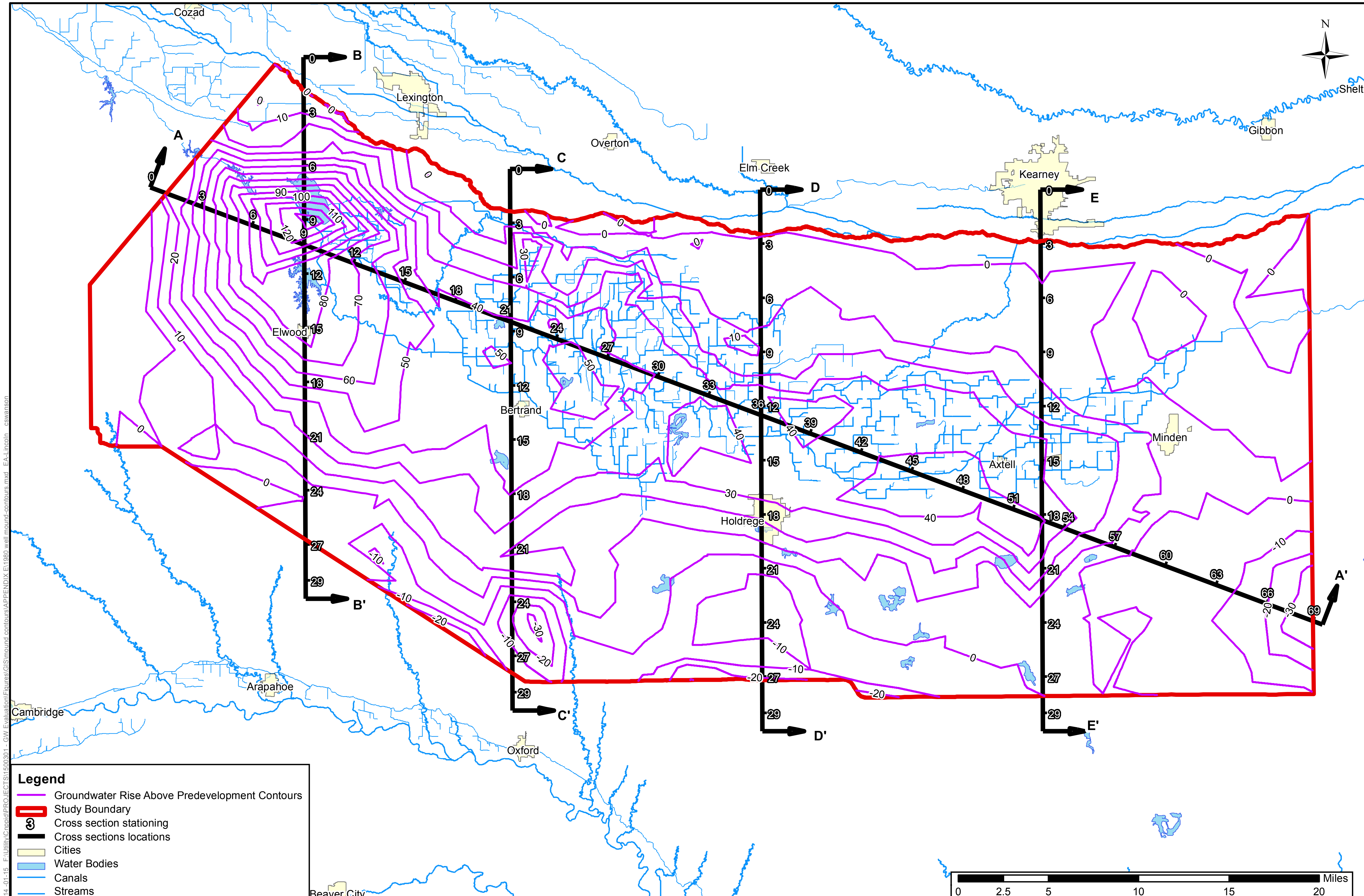
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\1970 Sections.dwg
DATE:11/21/2013 TIME:15:43 DRAWN BY: cswanson



GROUNDWATER MOUND CONTOURS
1980

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E1980-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
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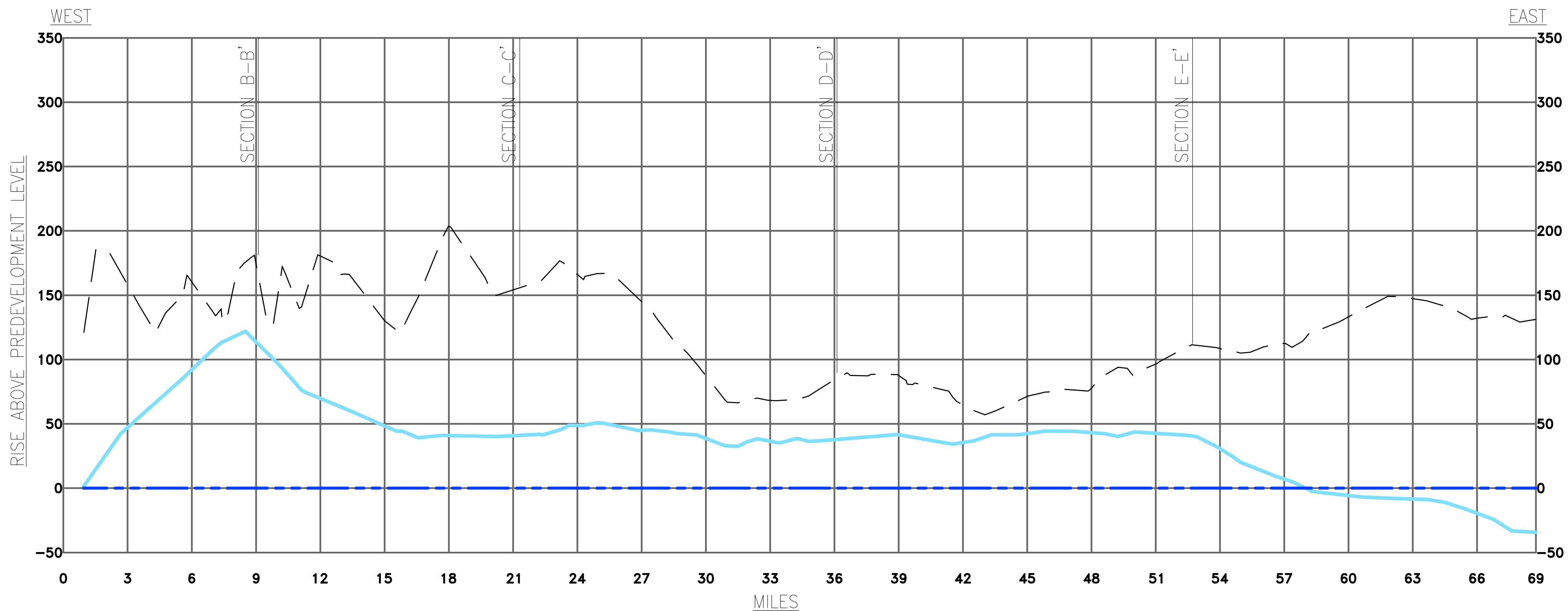
PROJECT MGR.	DJS



SECTION A-A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1980 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1980 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E1980-2
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FILE NAME	-
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DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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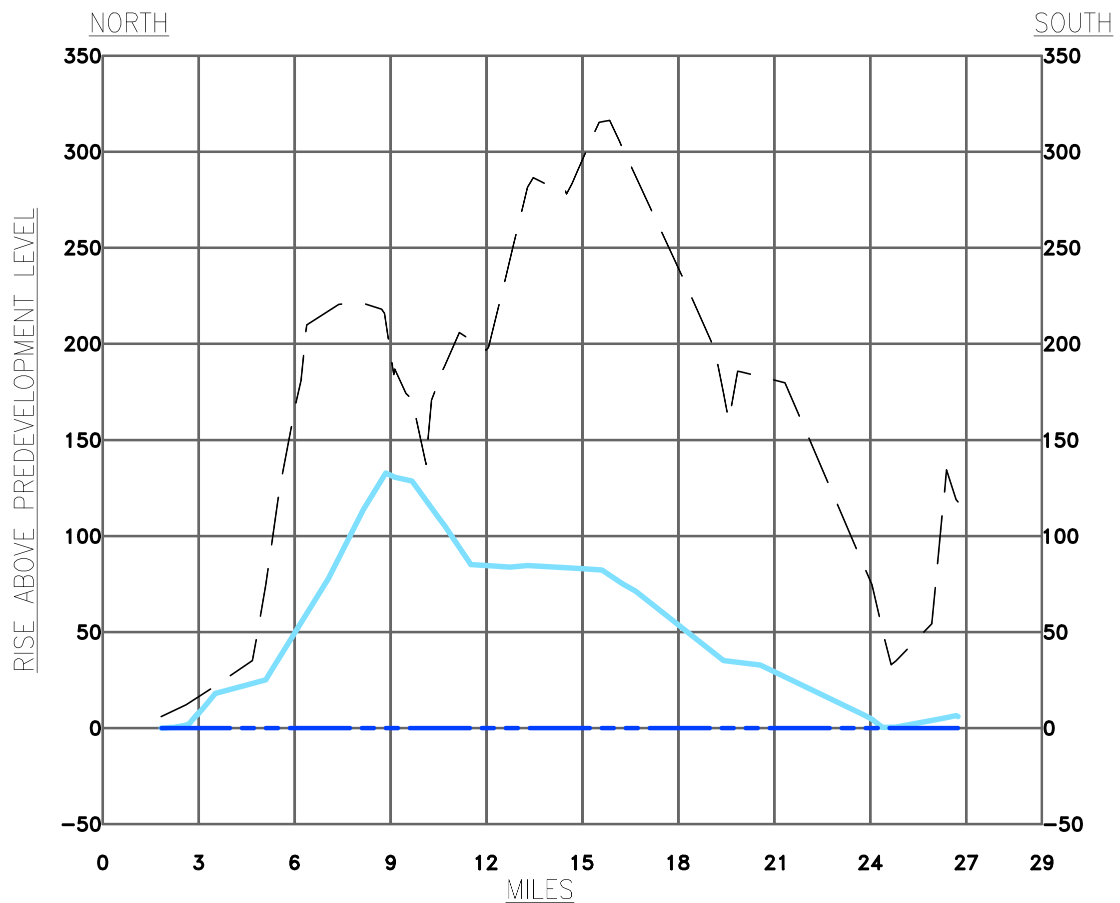
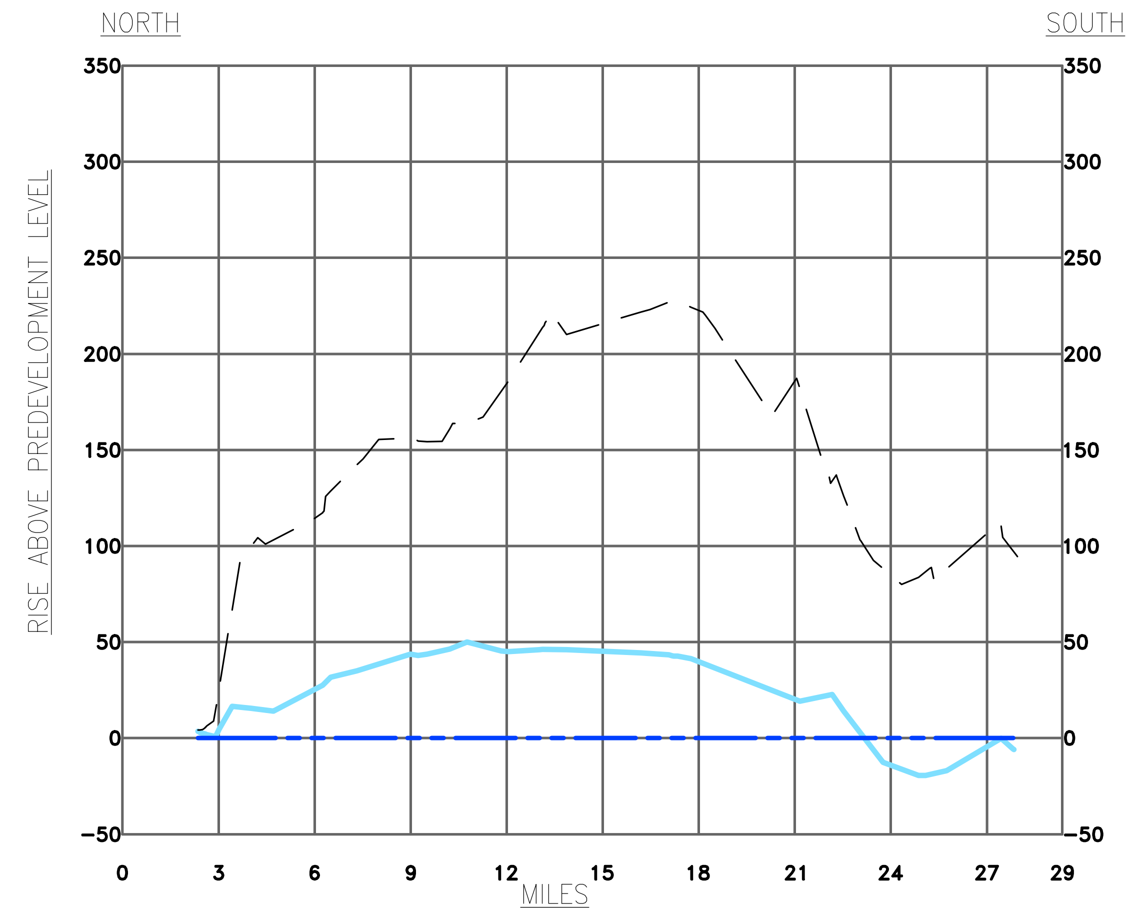


SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1980 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1980 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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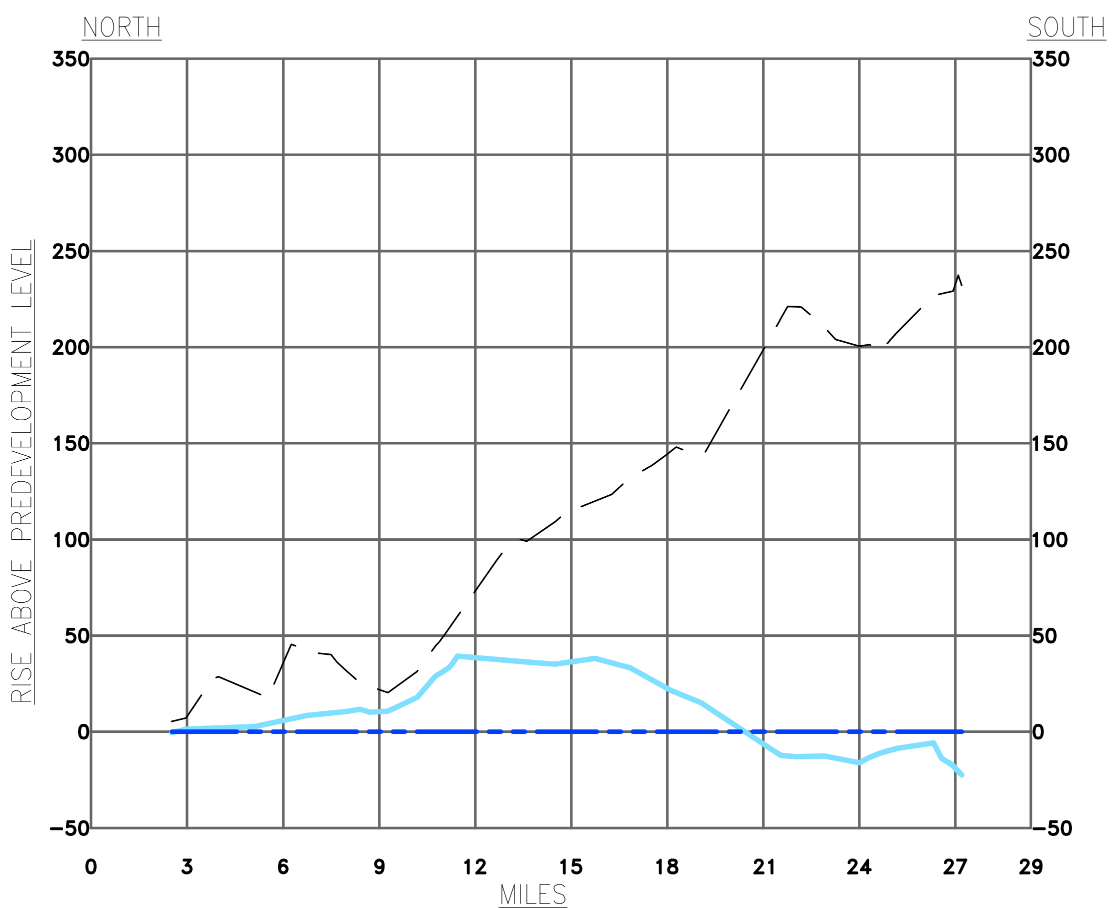
DATE:11/21/2013 TIME:16:07 DRAWN BY: cswanson



SECTION D–D'
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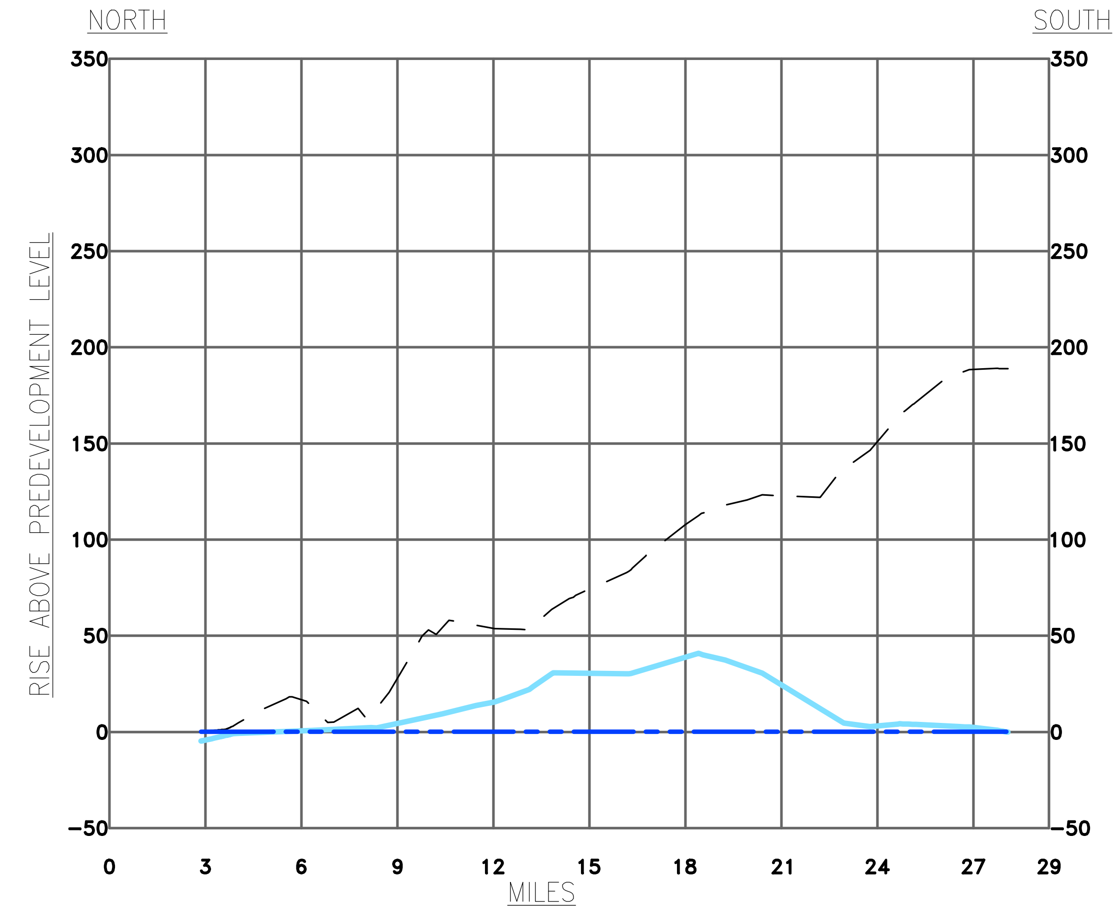
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1980 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1980 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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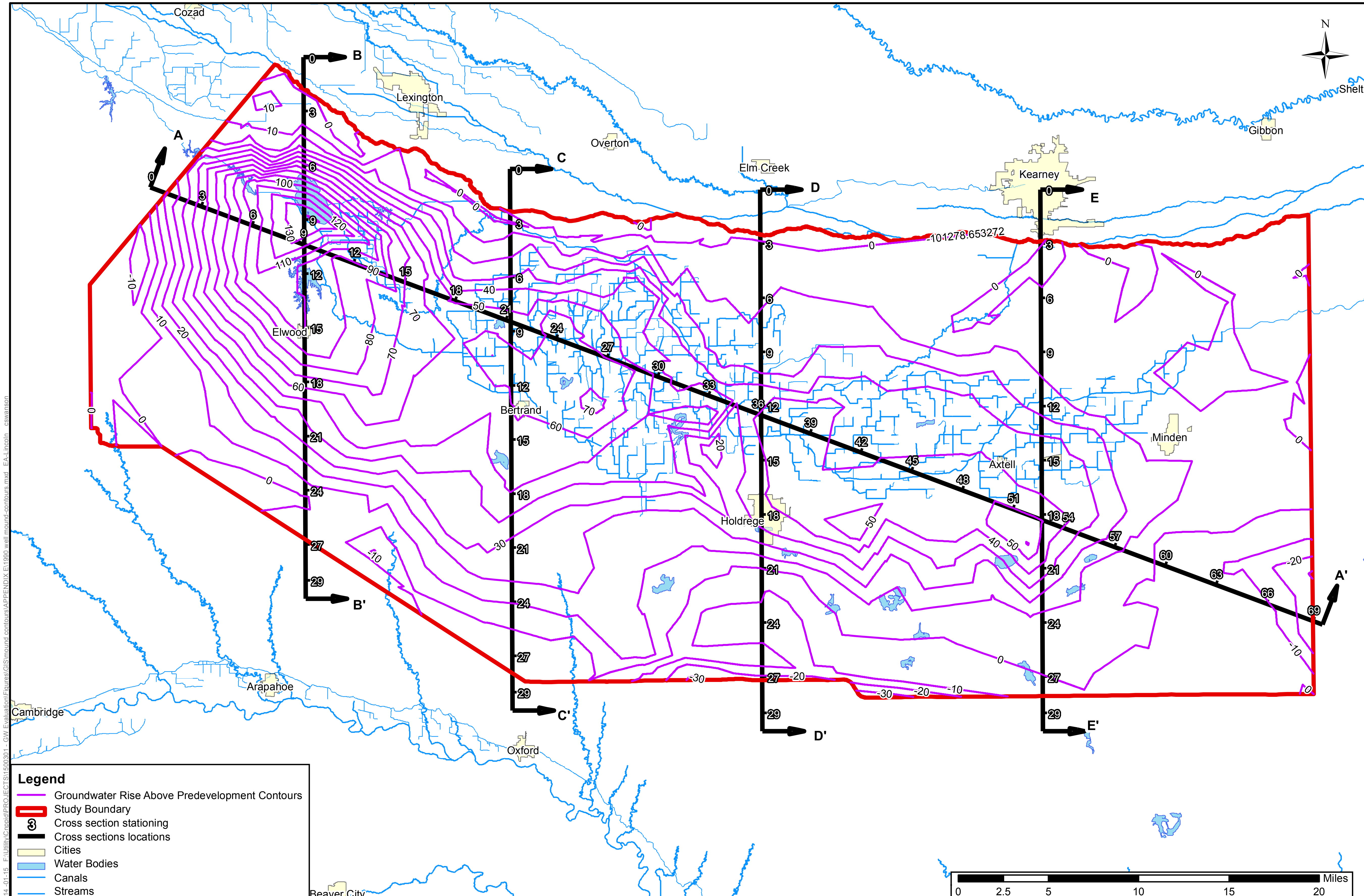
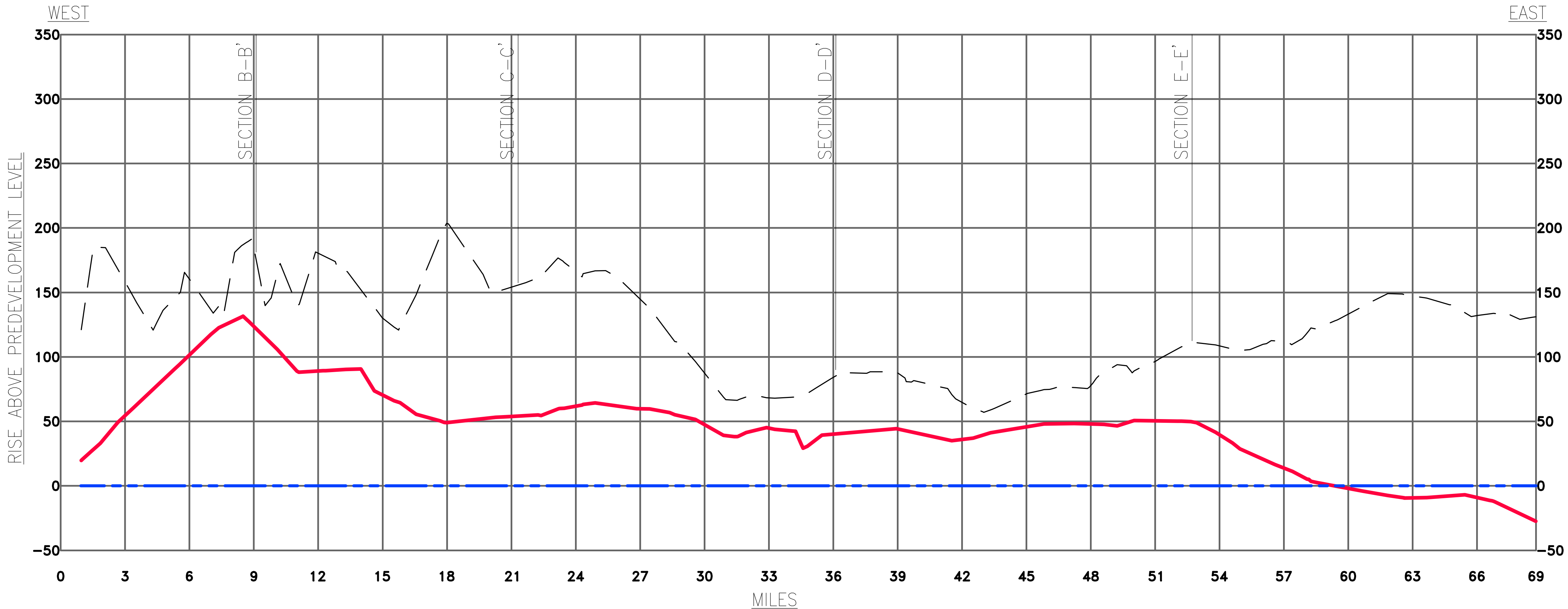


GROUNDWATER MOUND CONTOURS
1990

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E1990-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A-A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1990 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

GROUNDWATER LEVELS 1990 CROSS SECTIONS

EA Engineering, Science, and Technology, Inc.®

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
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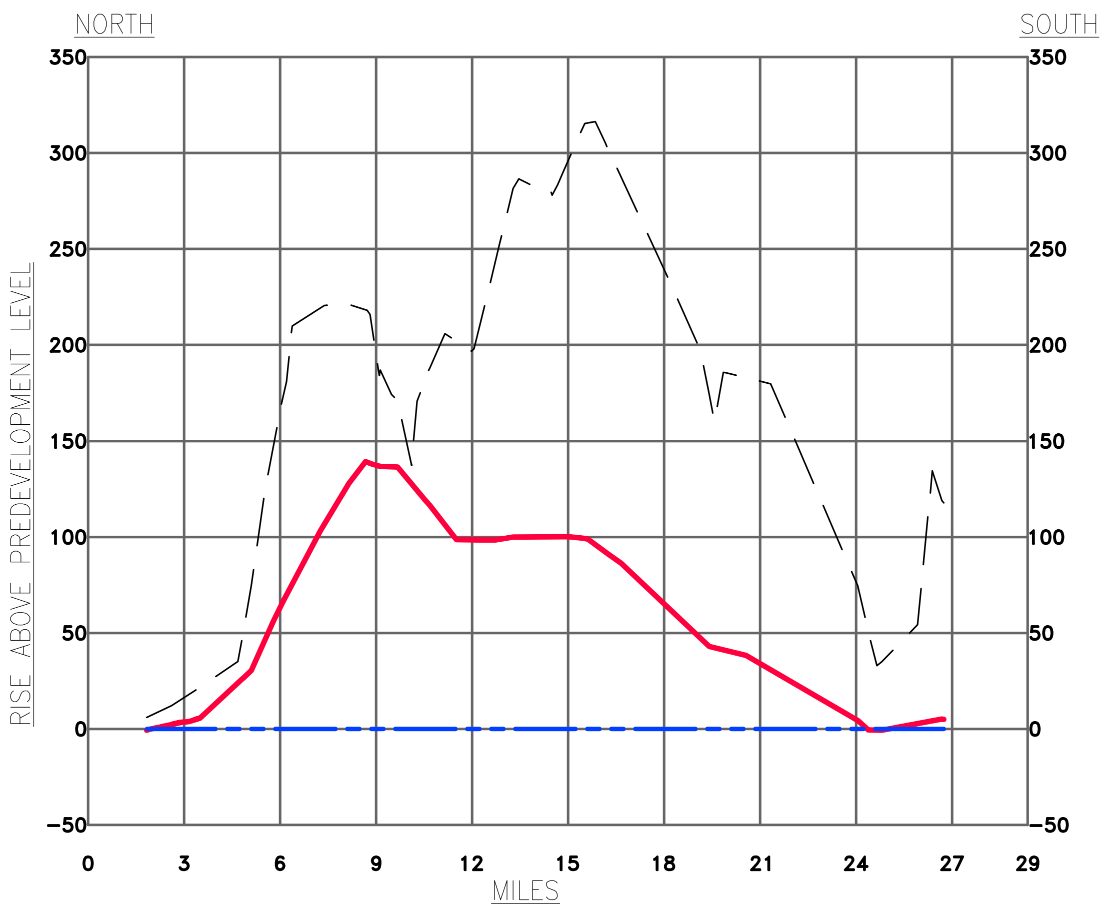
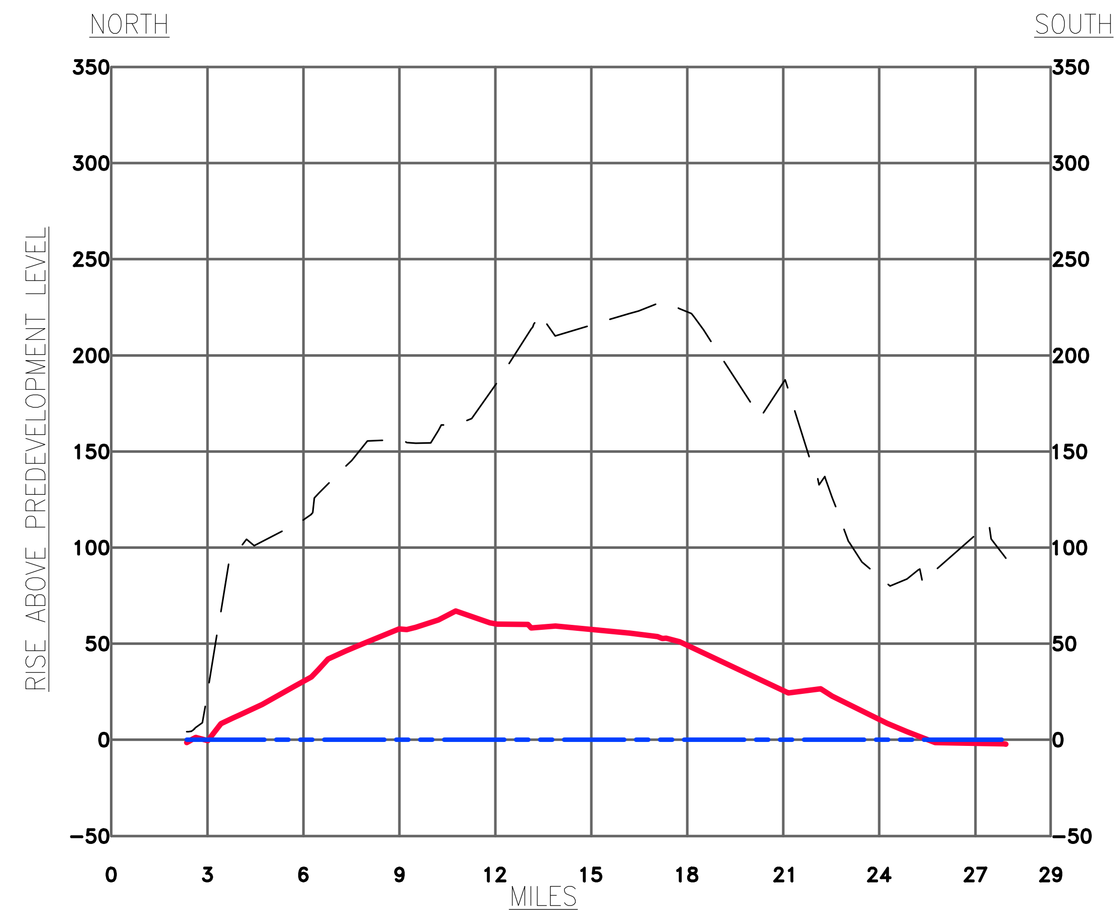


SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

1990 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
1990 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E1990-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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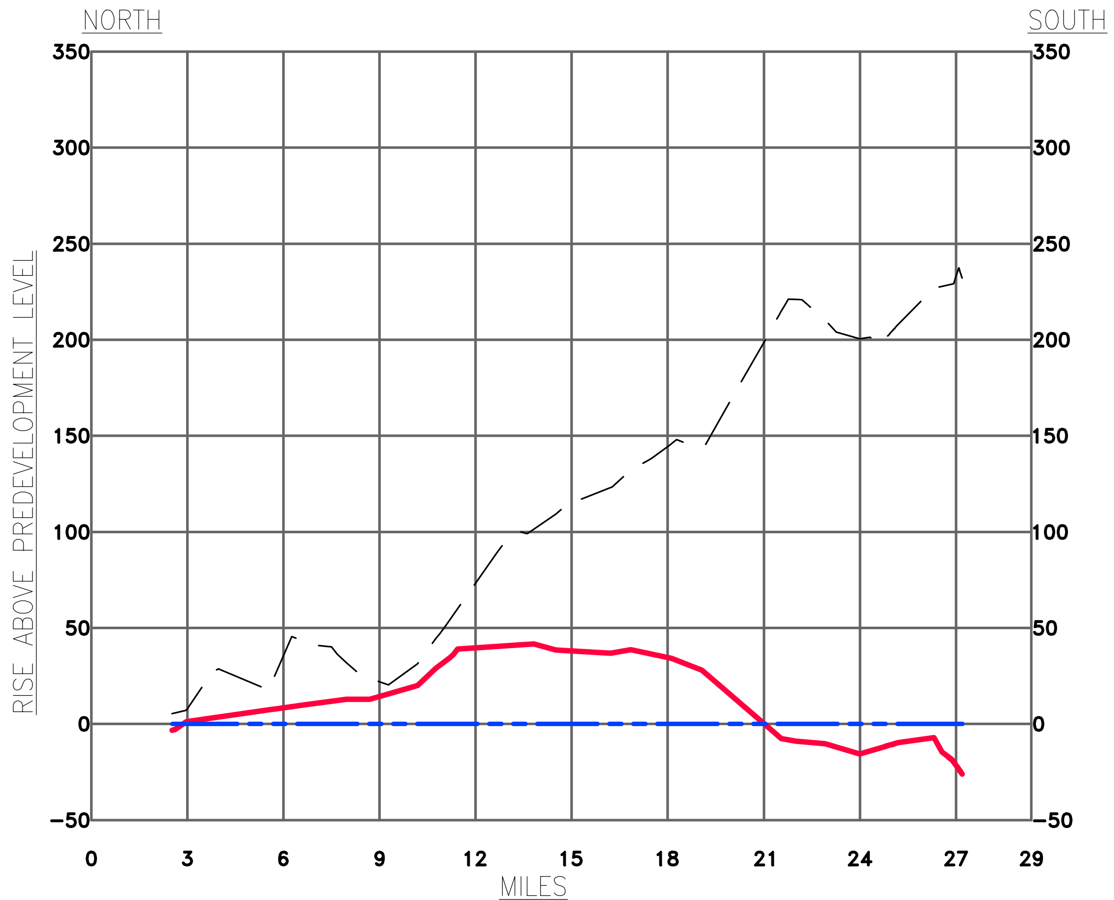
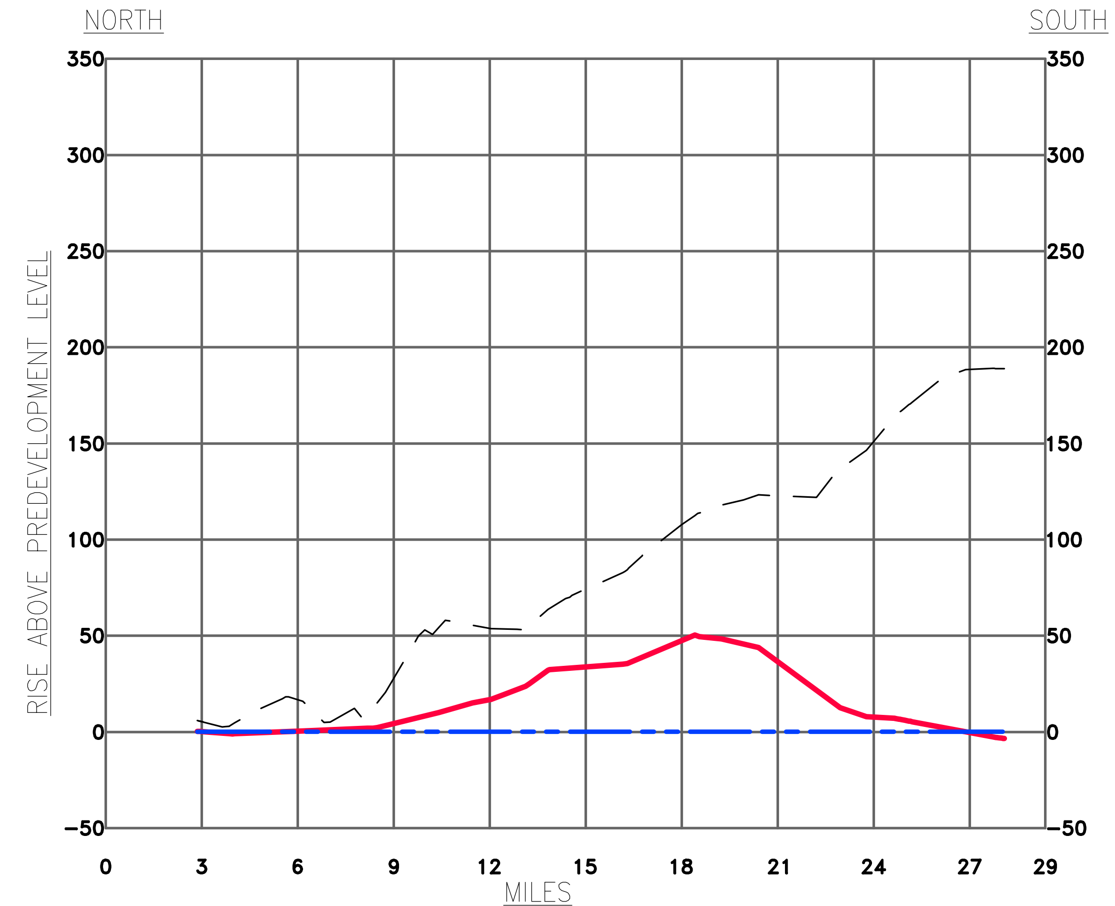
DATE:11/21/2013 TIME:16:17 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 1990 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

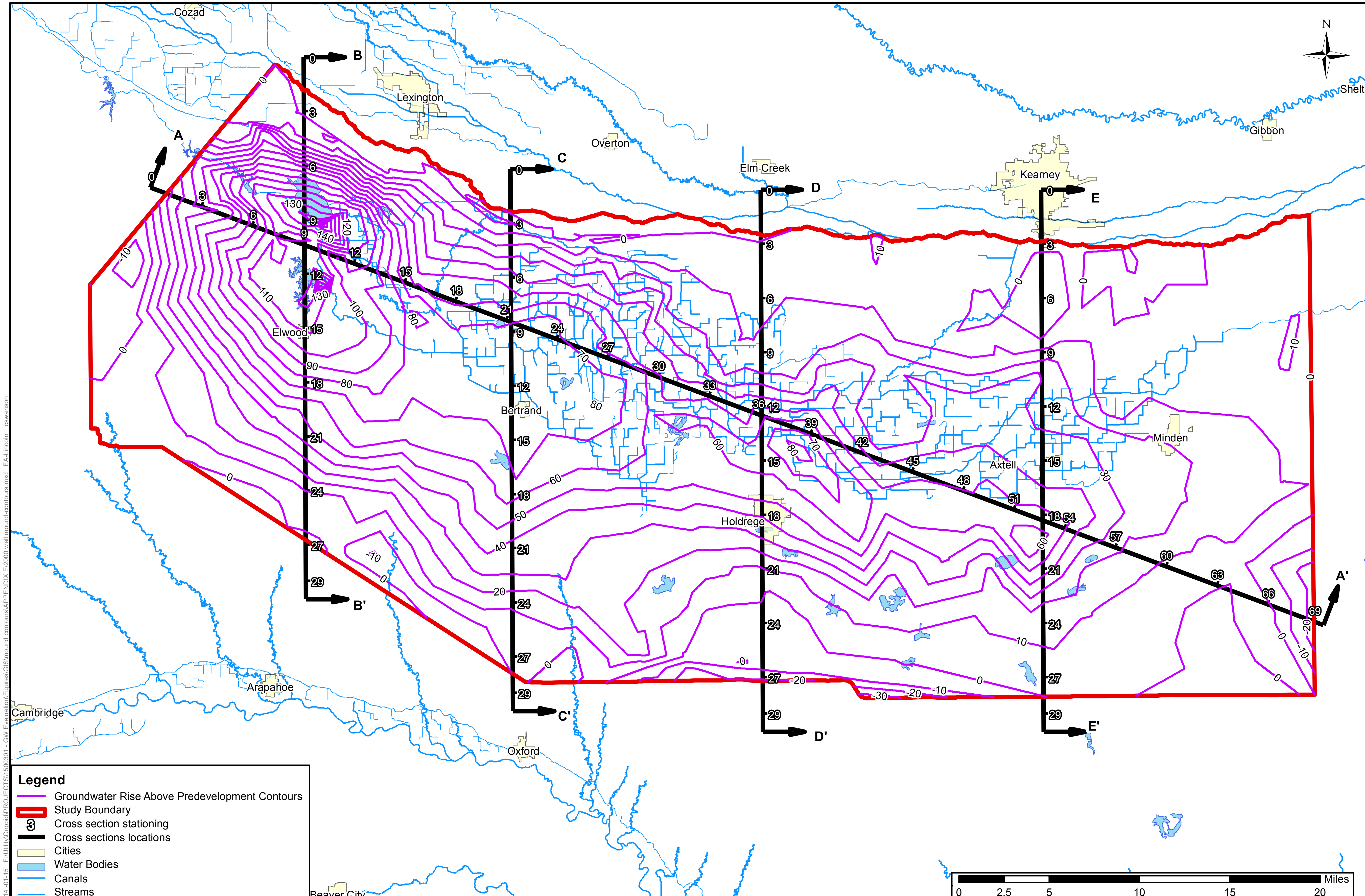
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\1990 Sections.dwg
DATE:11/21/2013 TIME:16:17 DRAWN BY:cswanson

GROUNDWATER LEVELS
1990 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	PLS	DJS	DEC 2013	AS SHOWN	1500301	-	-	E1990-4

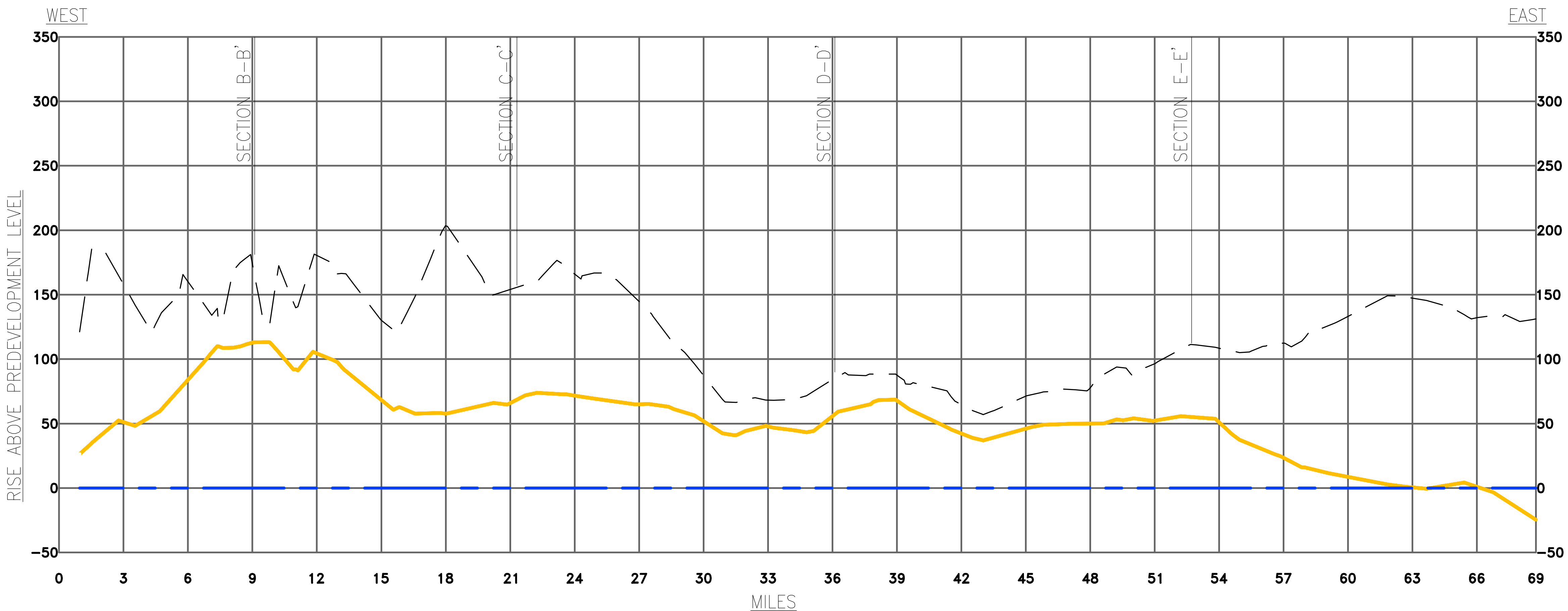


GROUNDWATER MOUND CONTOURS
2000

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E2000-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL
2000 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2000 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E2000-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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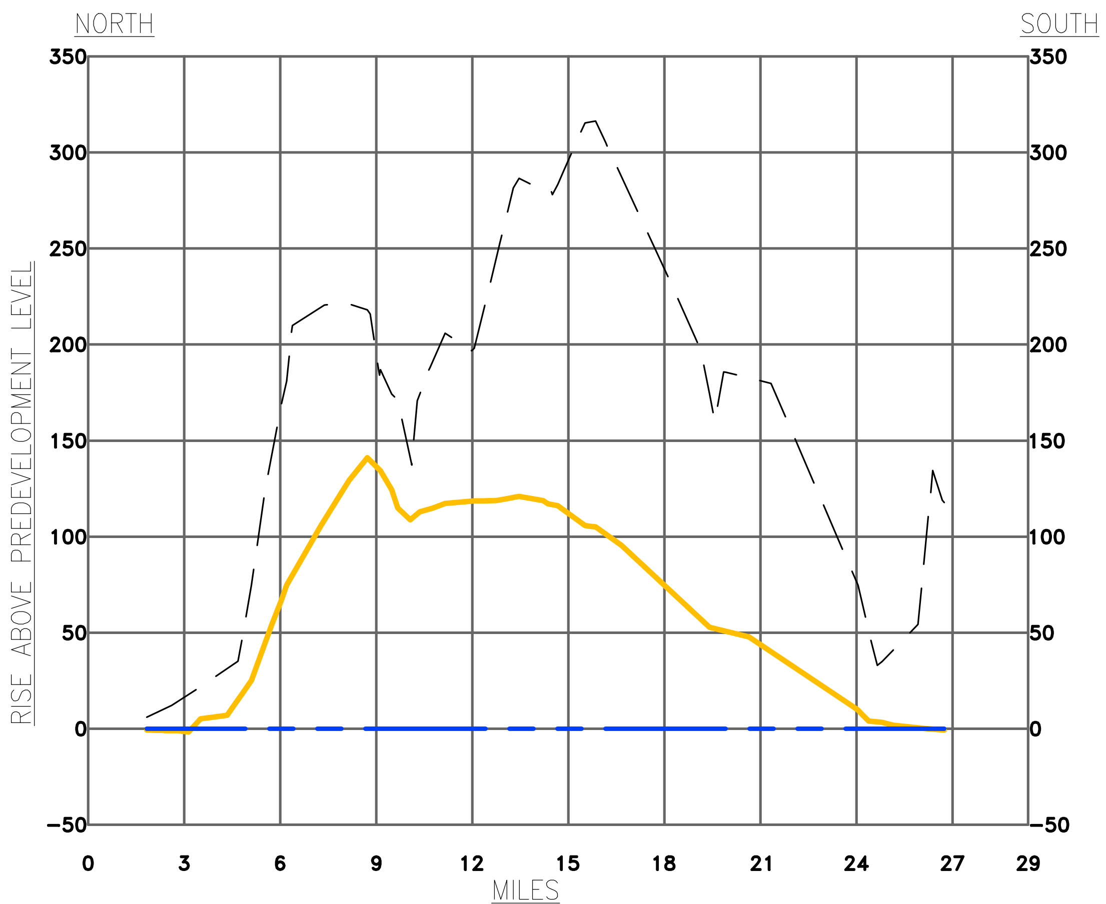
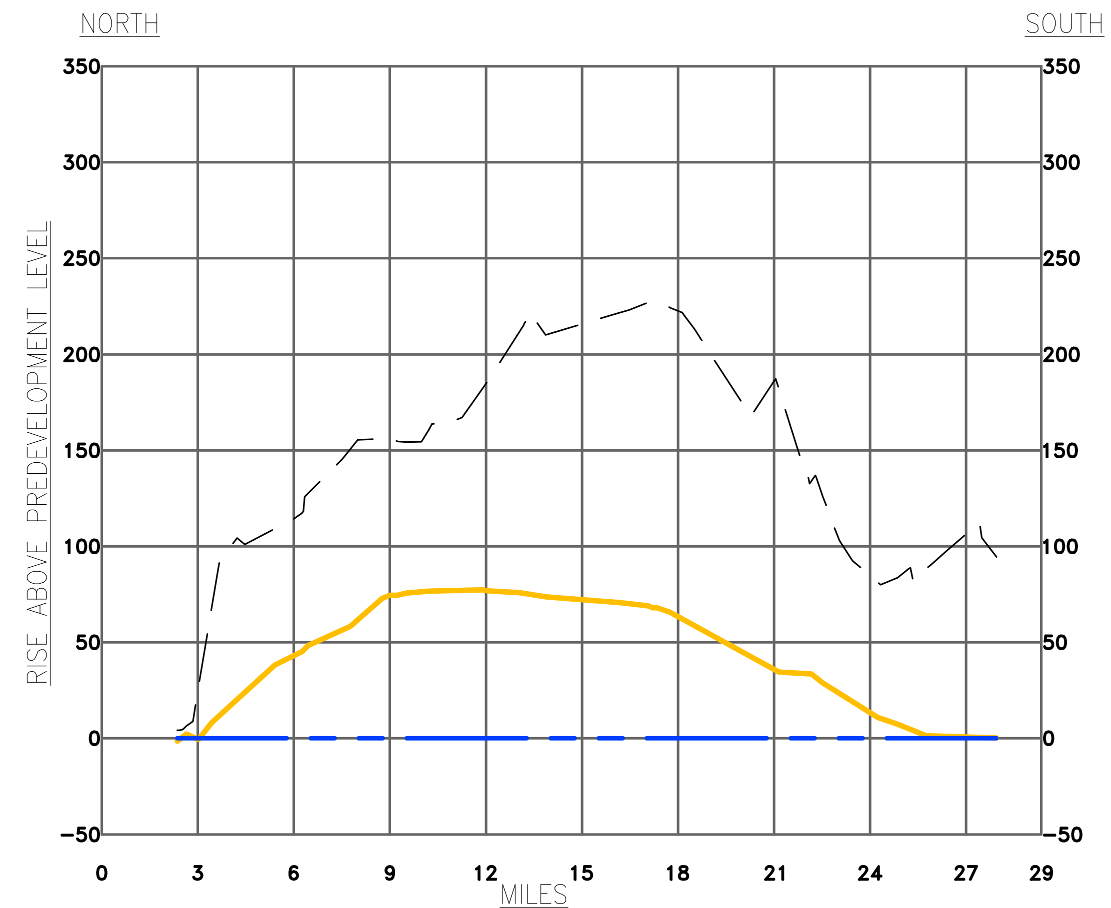


SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2000 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS 2000 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	E2000-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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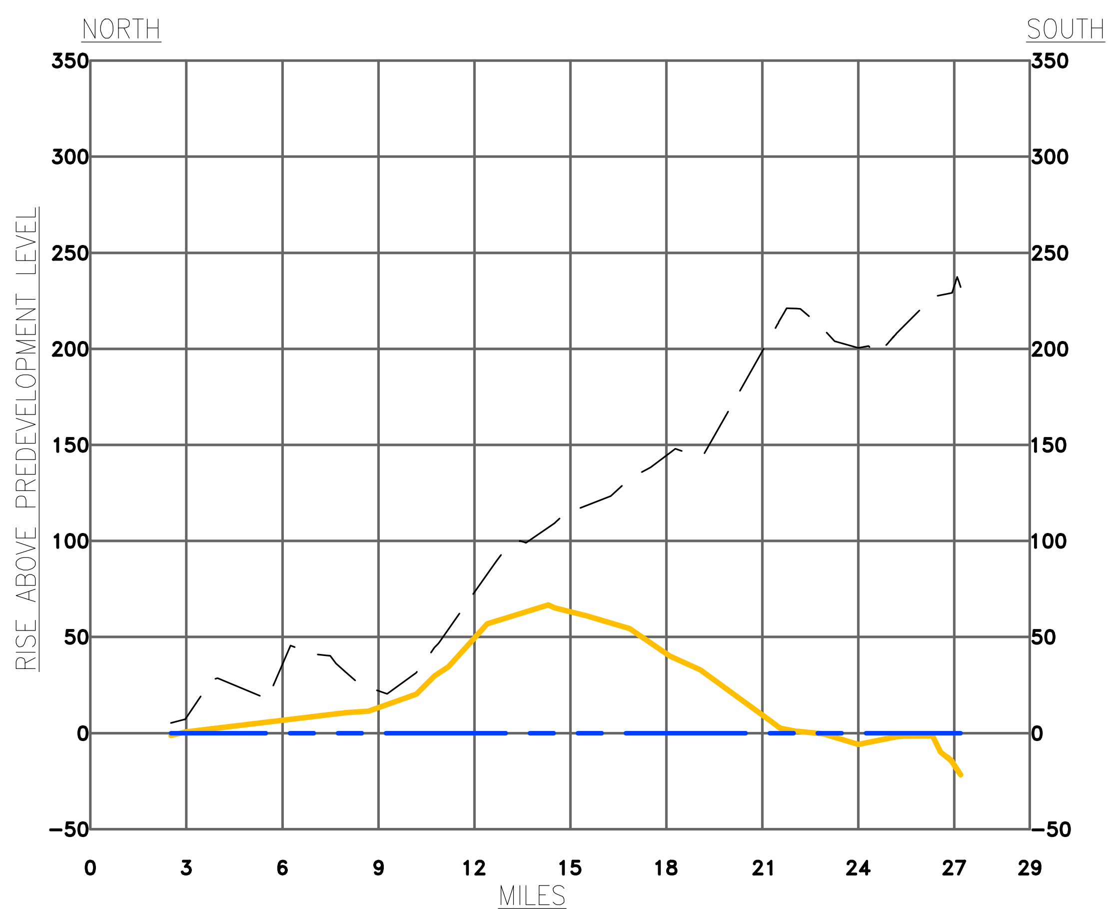
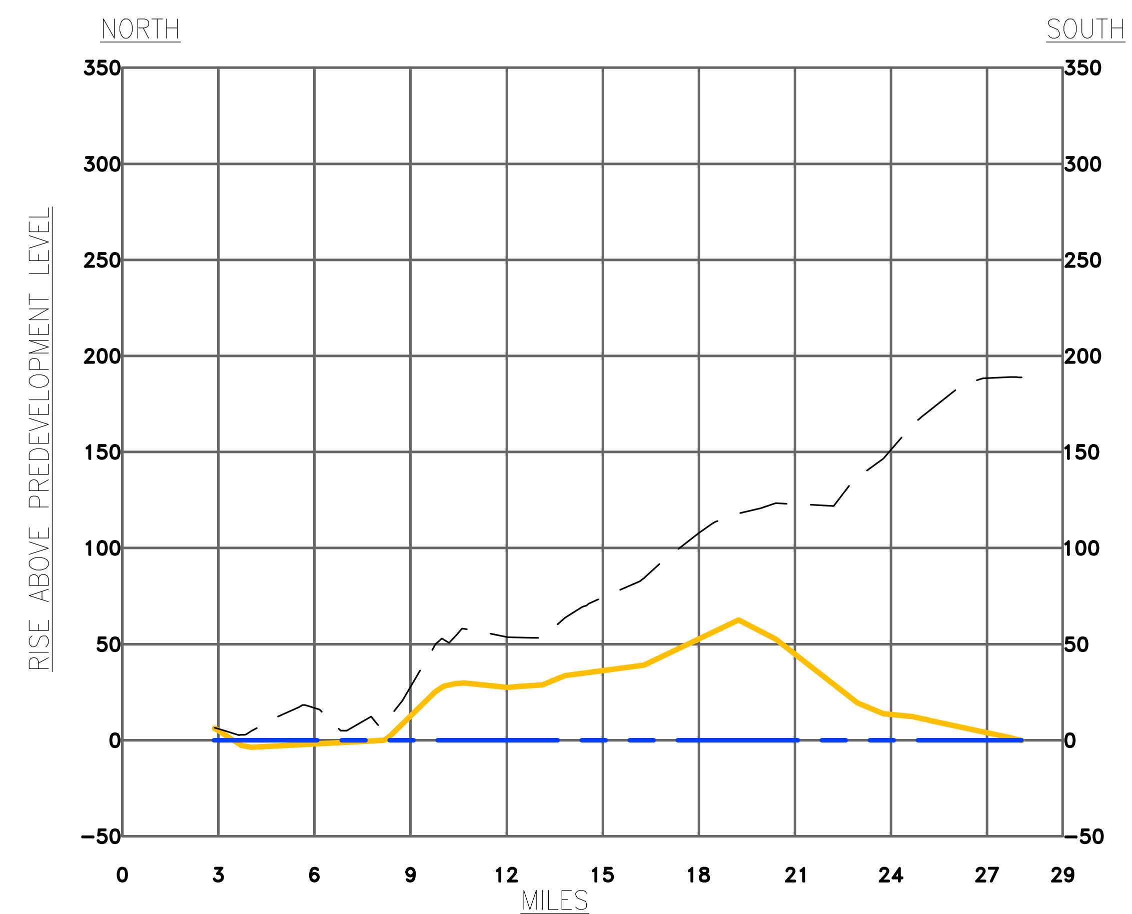


SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL
2000 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

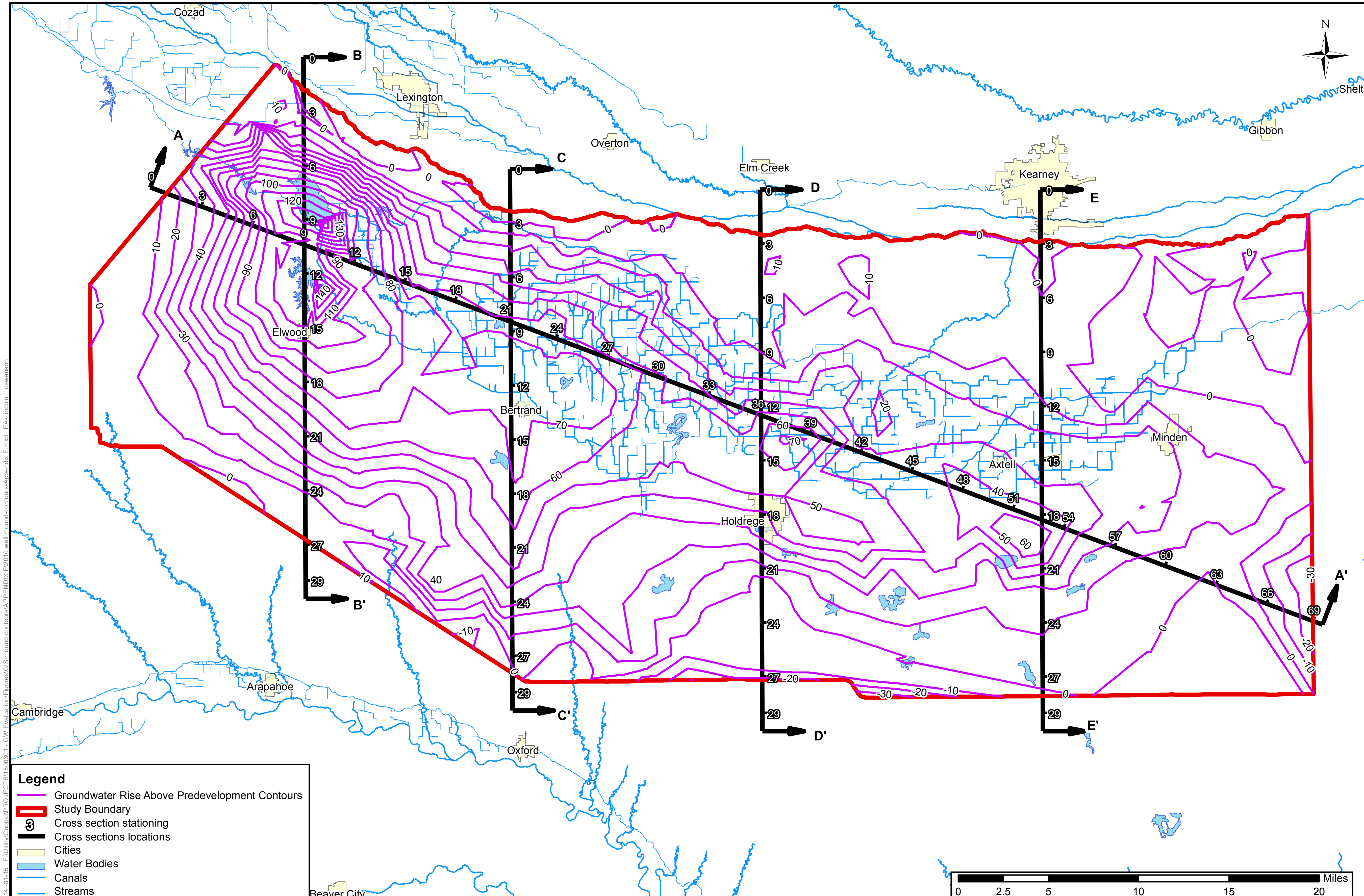
GROUNDWATER LEVELS
2000 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
Science, and
Technology, Inc.

FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
E2000-4	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2000 Sections.dwg
DATE:11/21/2013 TIME:16:28 DRAWN BY:cswanson

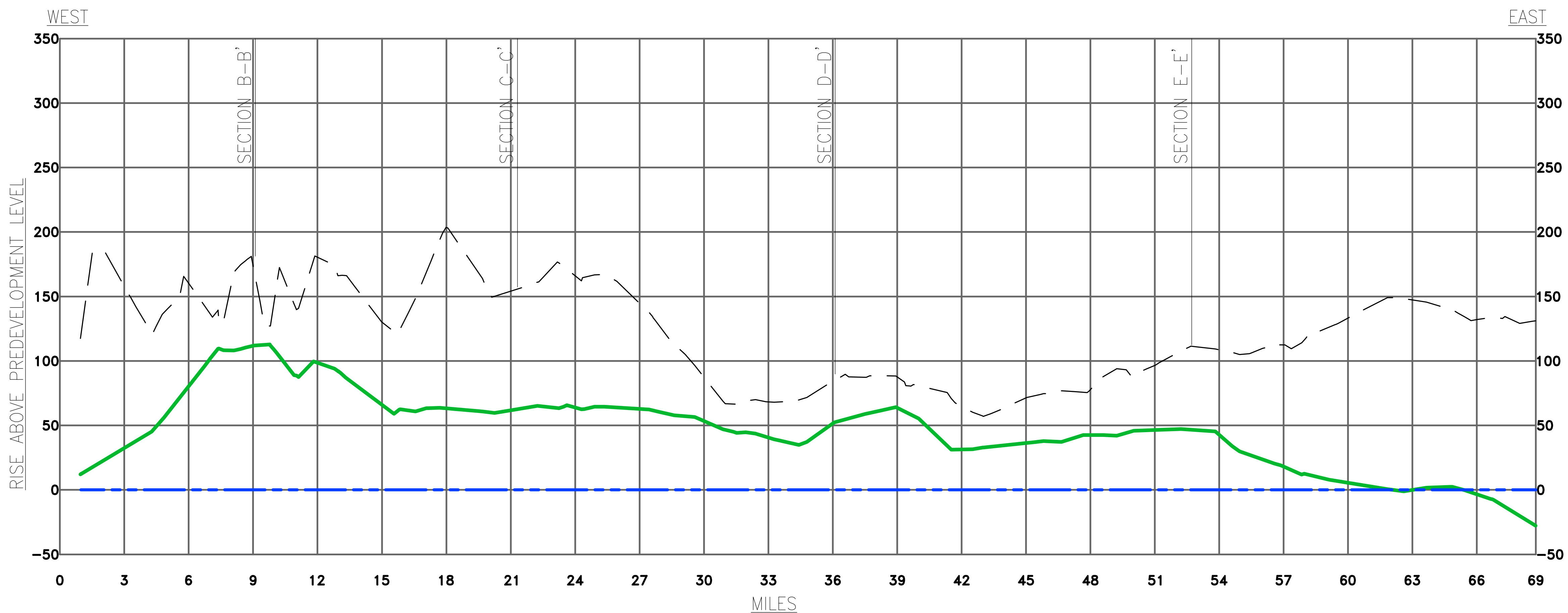


GROUNDWATER MOUND CONTOURS 2010

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	E2010-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A-A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2010 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2010 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
E2010-2	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS

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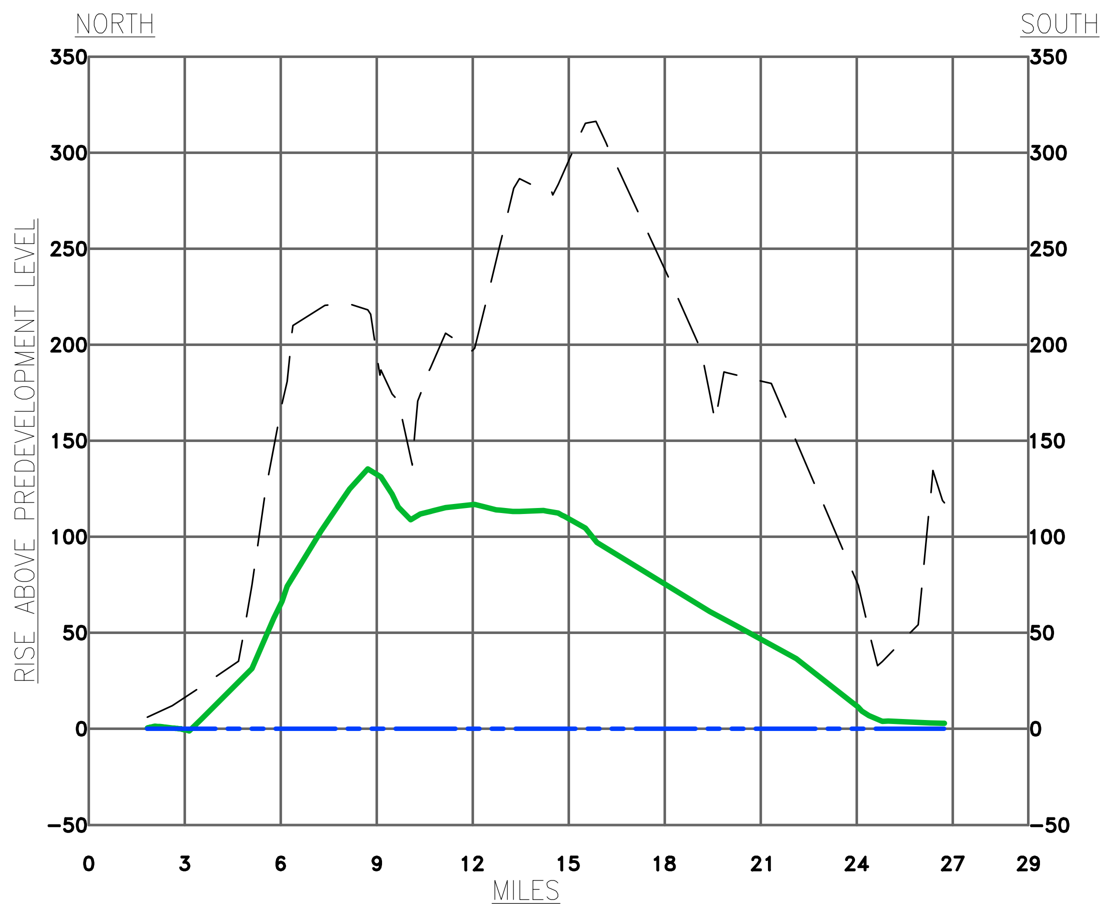
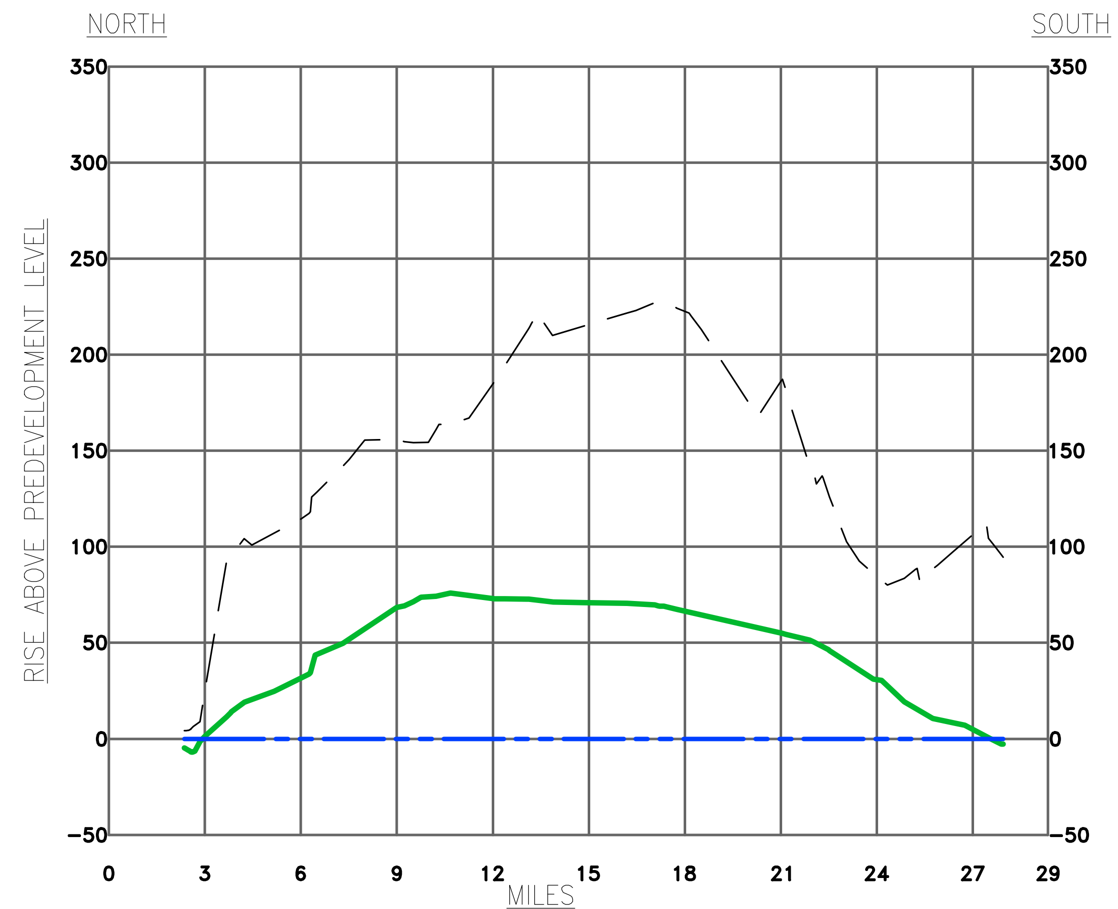
DATE:11/21/2013 TIME:16:32 DRAWN BY: cswanson



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2010 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2010 CROSS SECTIONS

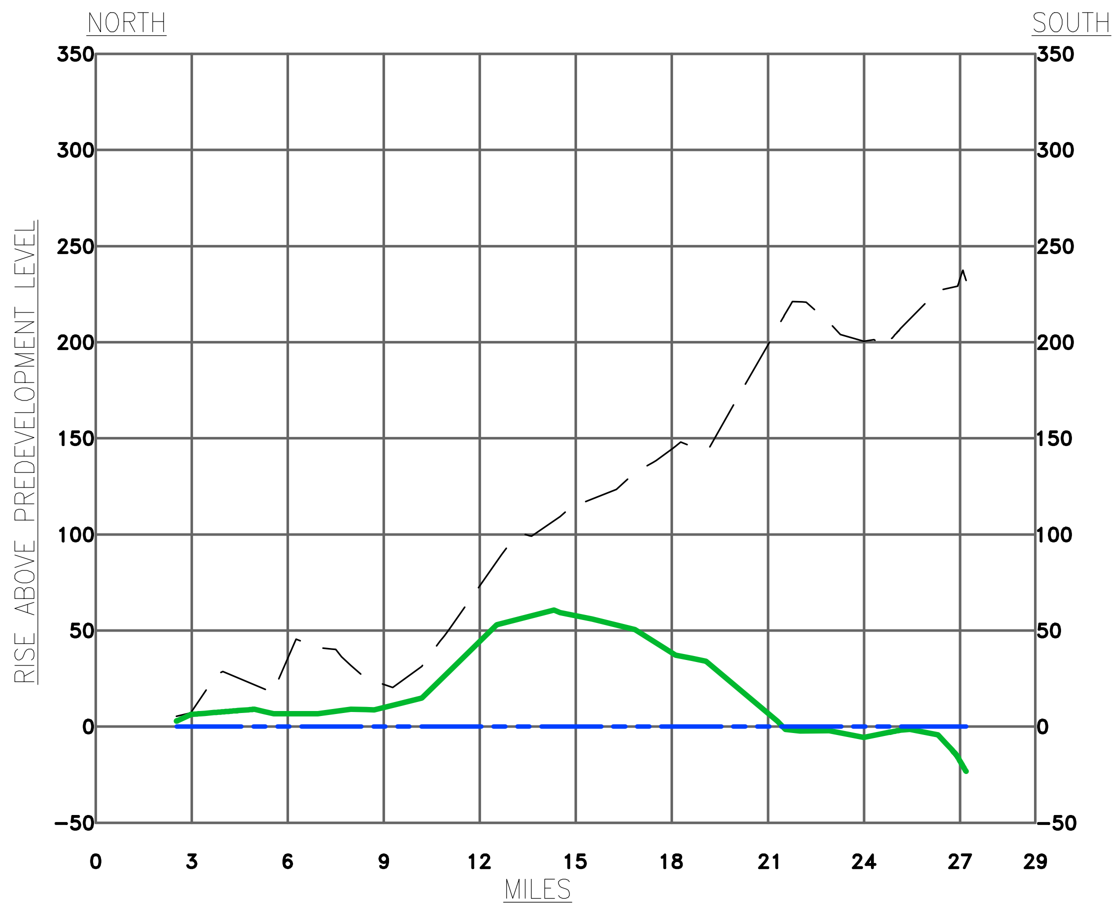
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

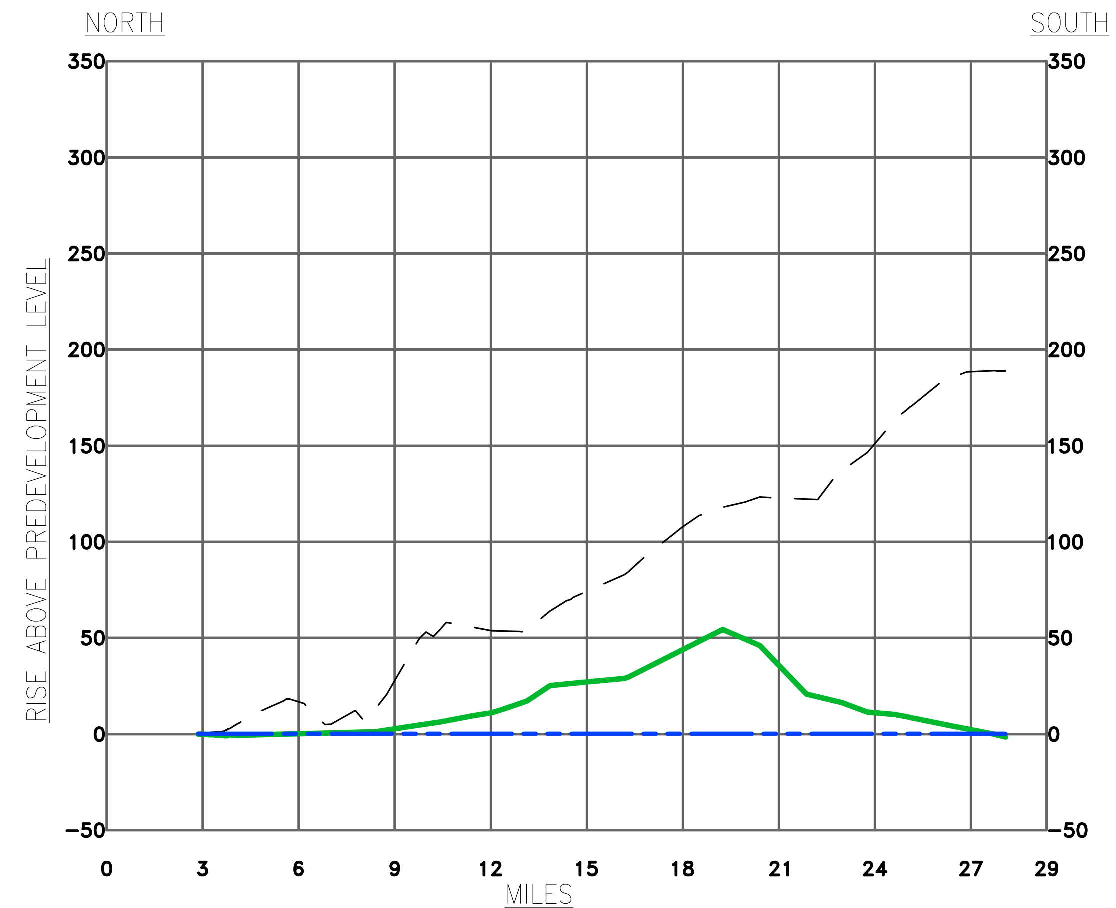
FIGURE	E2010-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2010 Sections-E-16-E18.dwg
DATE:11/21/2013 TIME:16:32 DRAWN BY: cswanson

GROUNDWATER LEVELS 2010 CROSS SECTIONS



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2010 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

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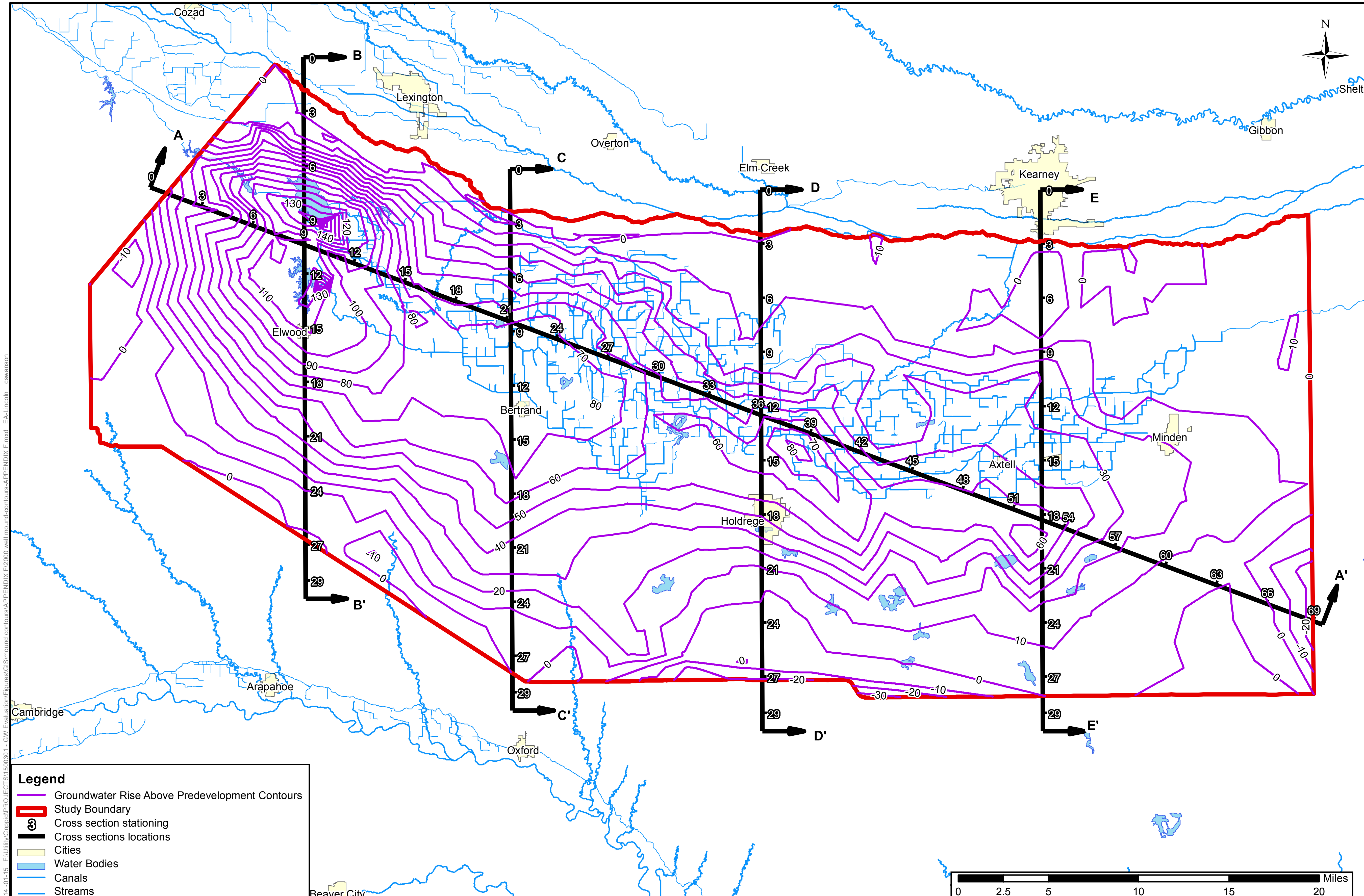
FIGURE	E2010-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2010 Sections-E-16-E18.dwg
DATE:11/21/2013 TIME:16:32 DRAWN BY: cswanson

Appendix F

Groundwater Cross Sections – 2000-2013



GROUNDWATER MOUND CONTOURS
2000

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2000-1
DRAWING NO.	–
FILE NAME	–
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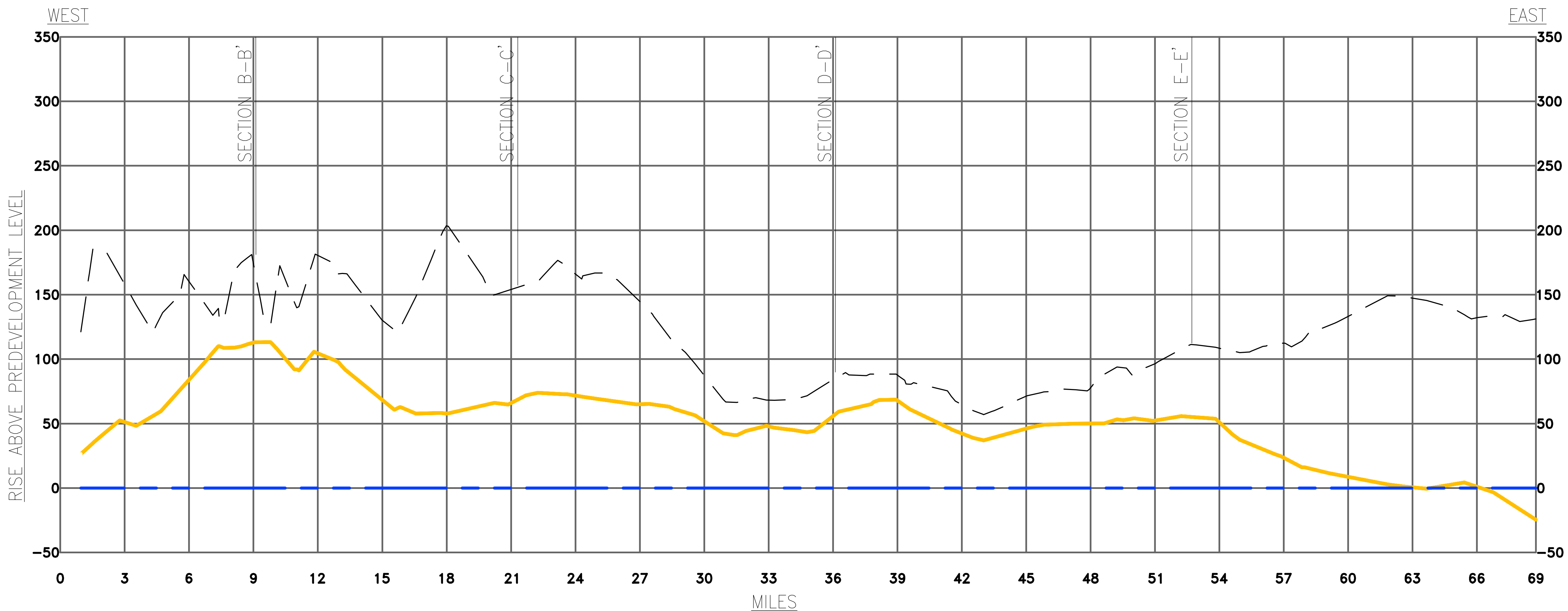
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2000 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2000 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2000 Sections.dwg
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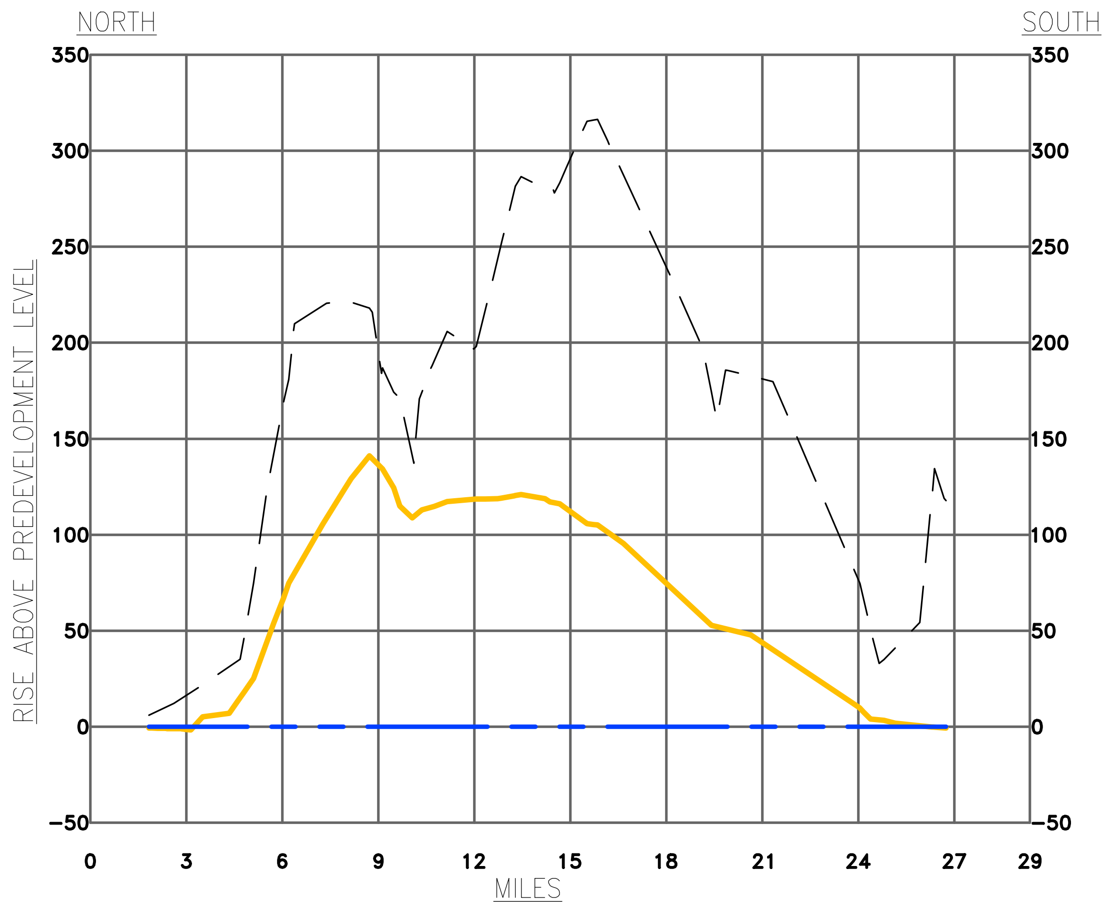
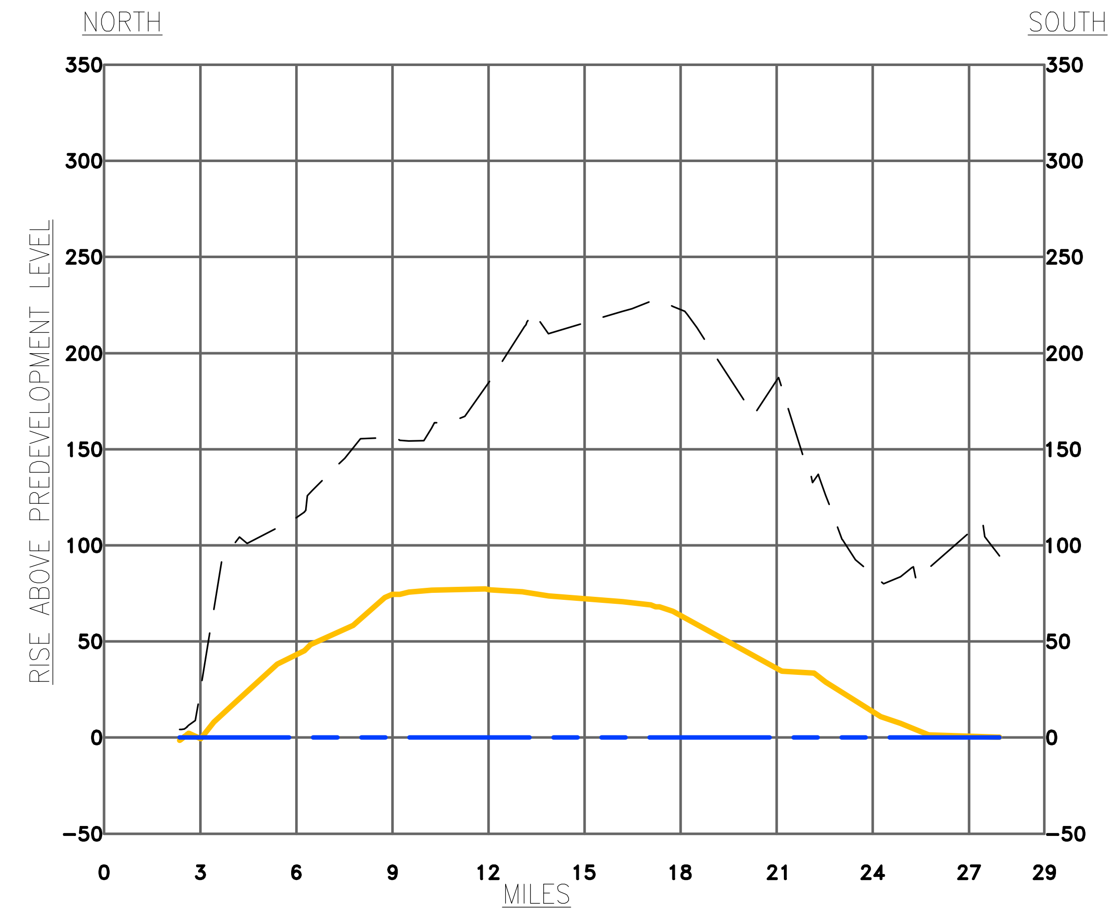


SECTION B-B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2000 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

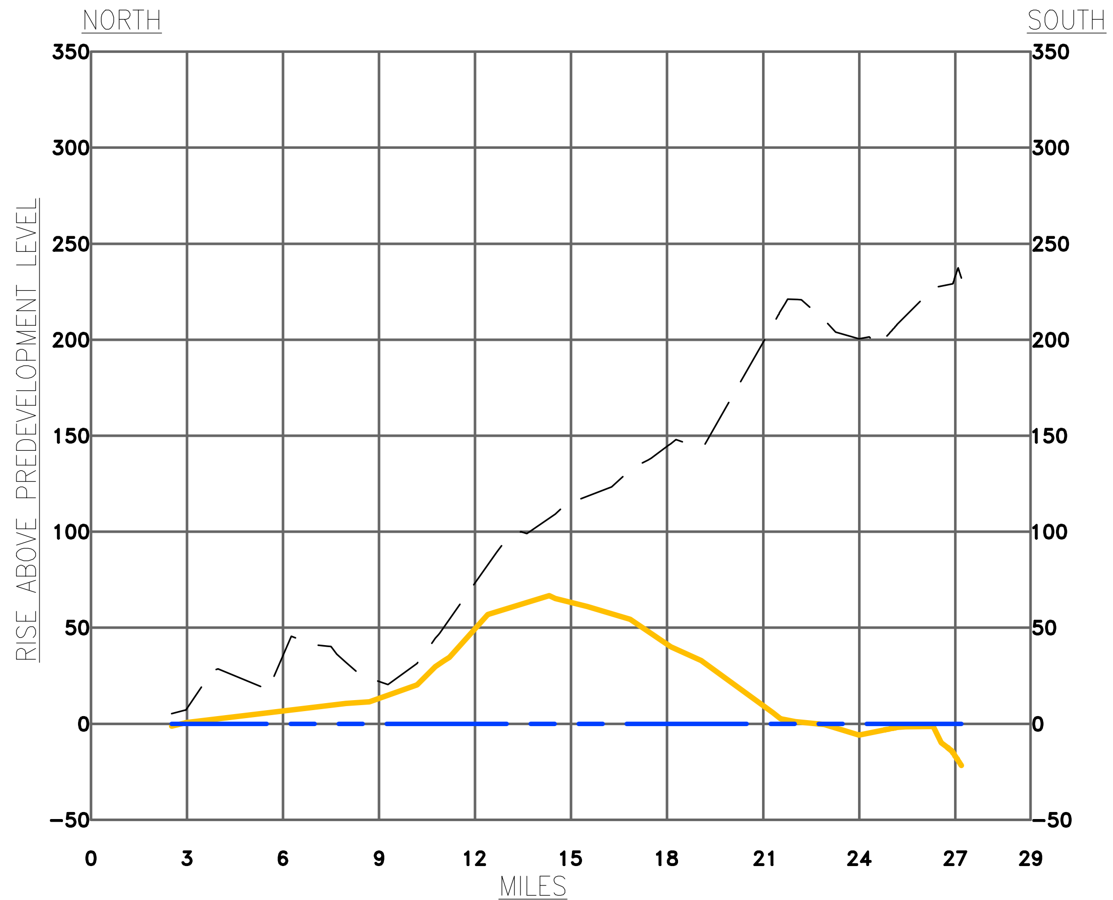
GROUNDWATER LEVELS
2000 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

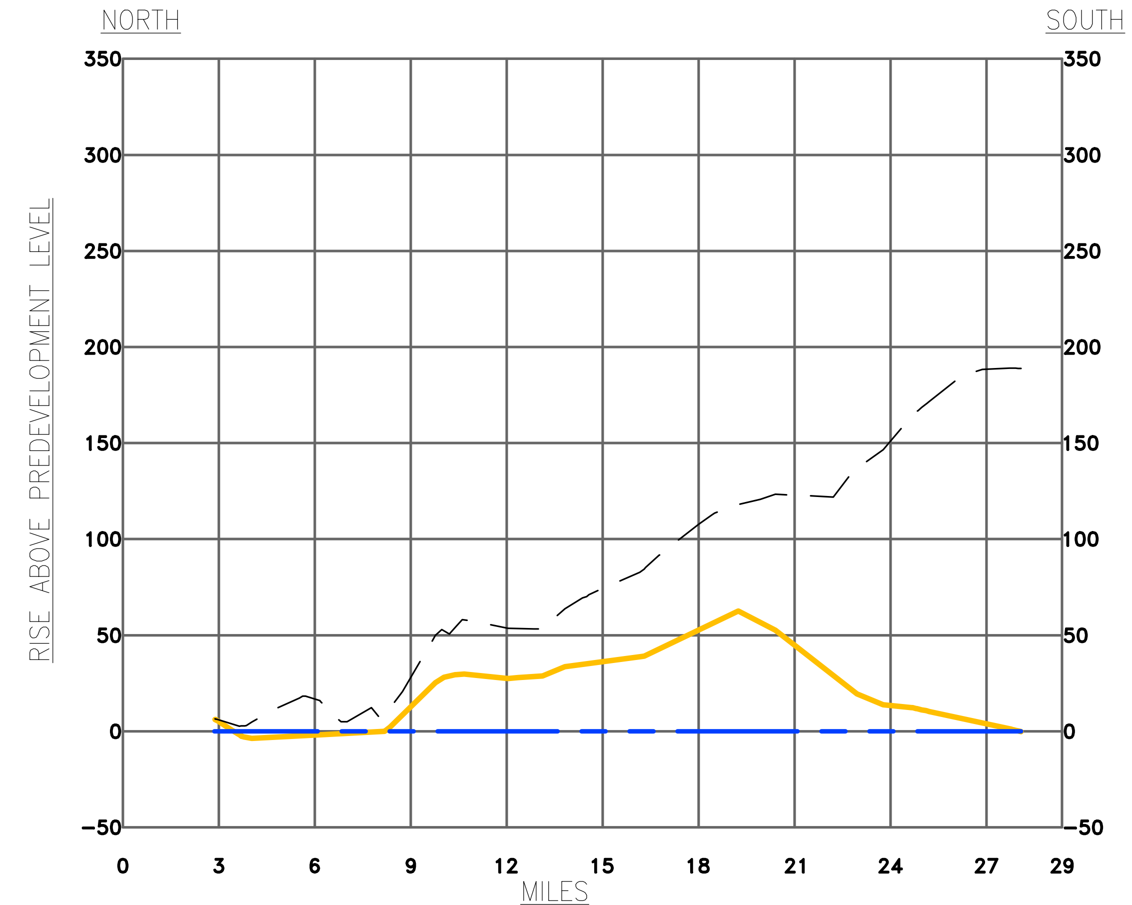
EA Engineering, Science, and Technology, Inc.

FIGURE	F2000-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2000 Sections.dwg
DATE:11/21/2013 TIME:16:28 DRAWN BY: cswanson



SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2000 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2000 Sections.dwg
DATE:11/21/2013 TIME:16:28 DRAWN BY:cswanson

GROUNDWATER LEVELS
2000 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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Technology, Inc.

FIGURE	F2000-4
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FILE NAME	-
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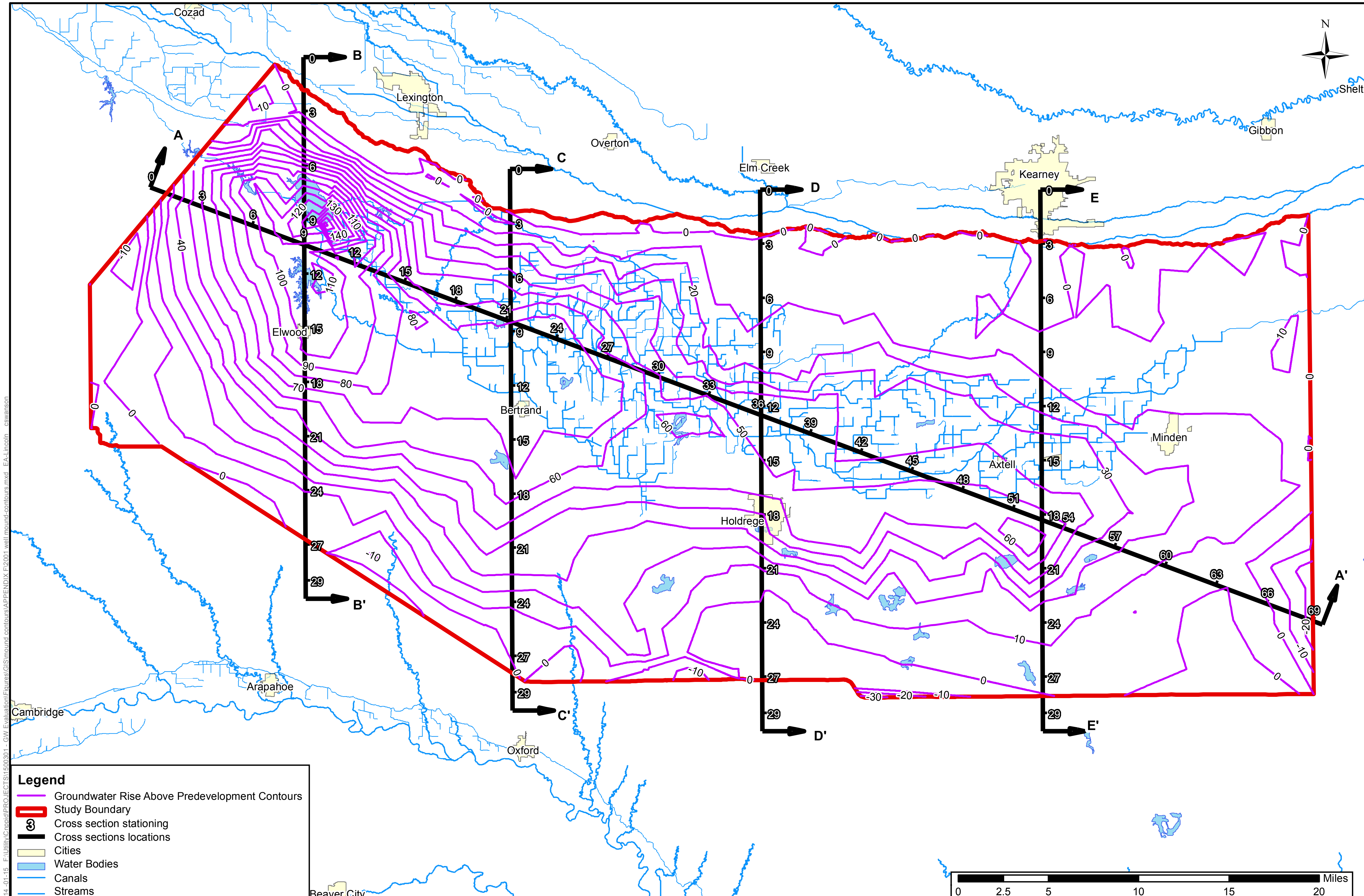
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

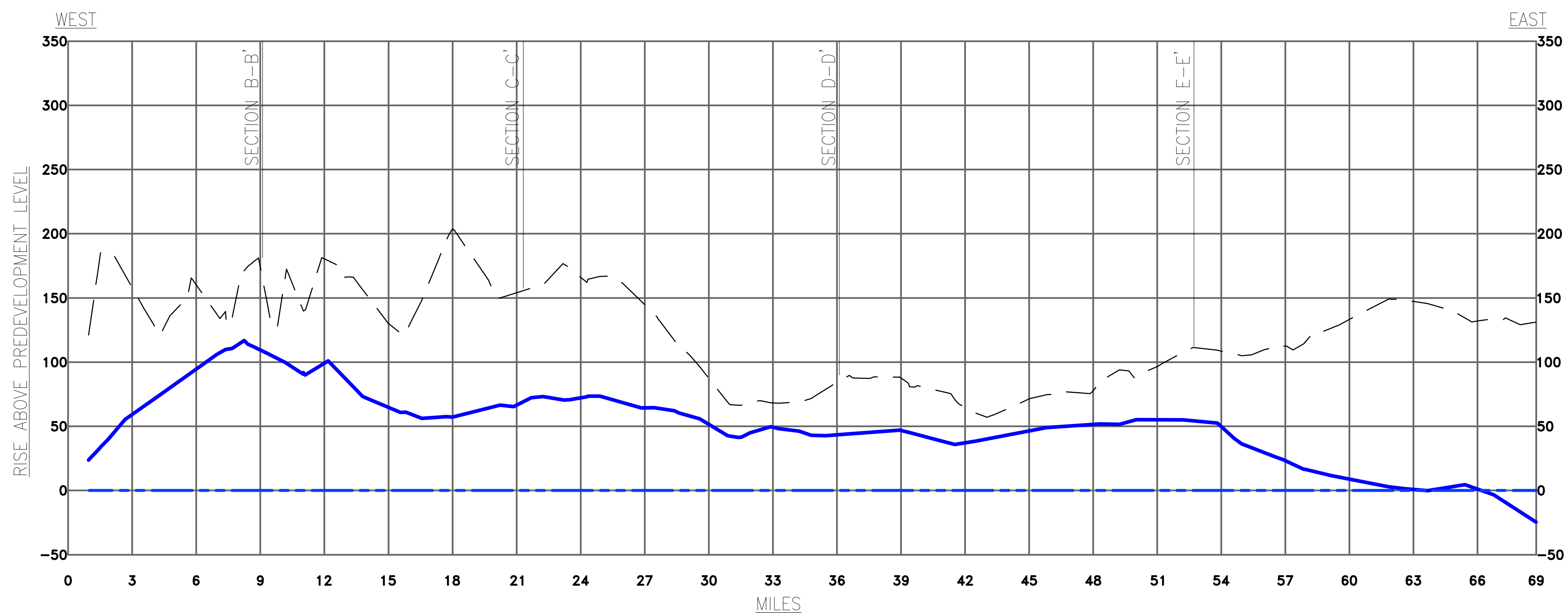


GROUNDWATER MOUND CONTOURS 2001

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2001-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2001 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

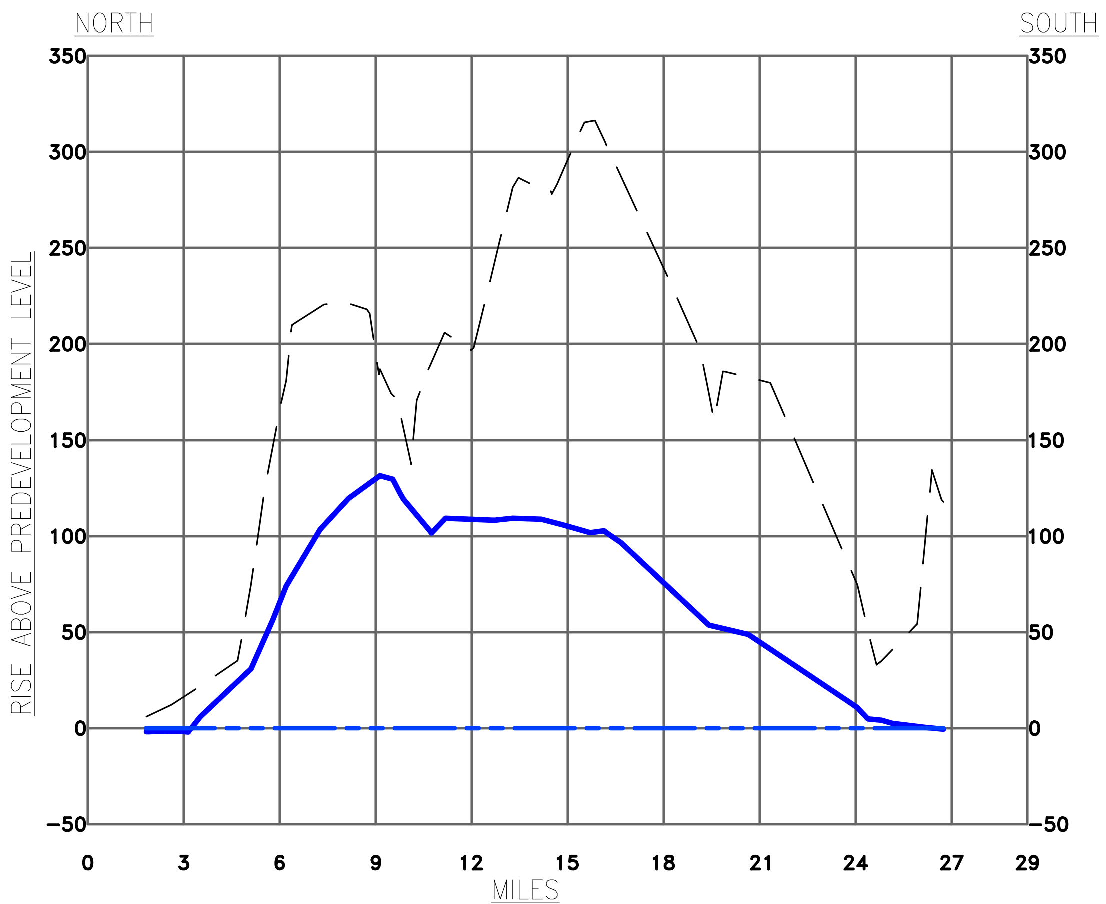
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2001 Sections.dwg
DATE:11/21/2013 TIME:16:51 DRAWN BY: cswanson

EA Engineering, Science, and Technology, Inc.

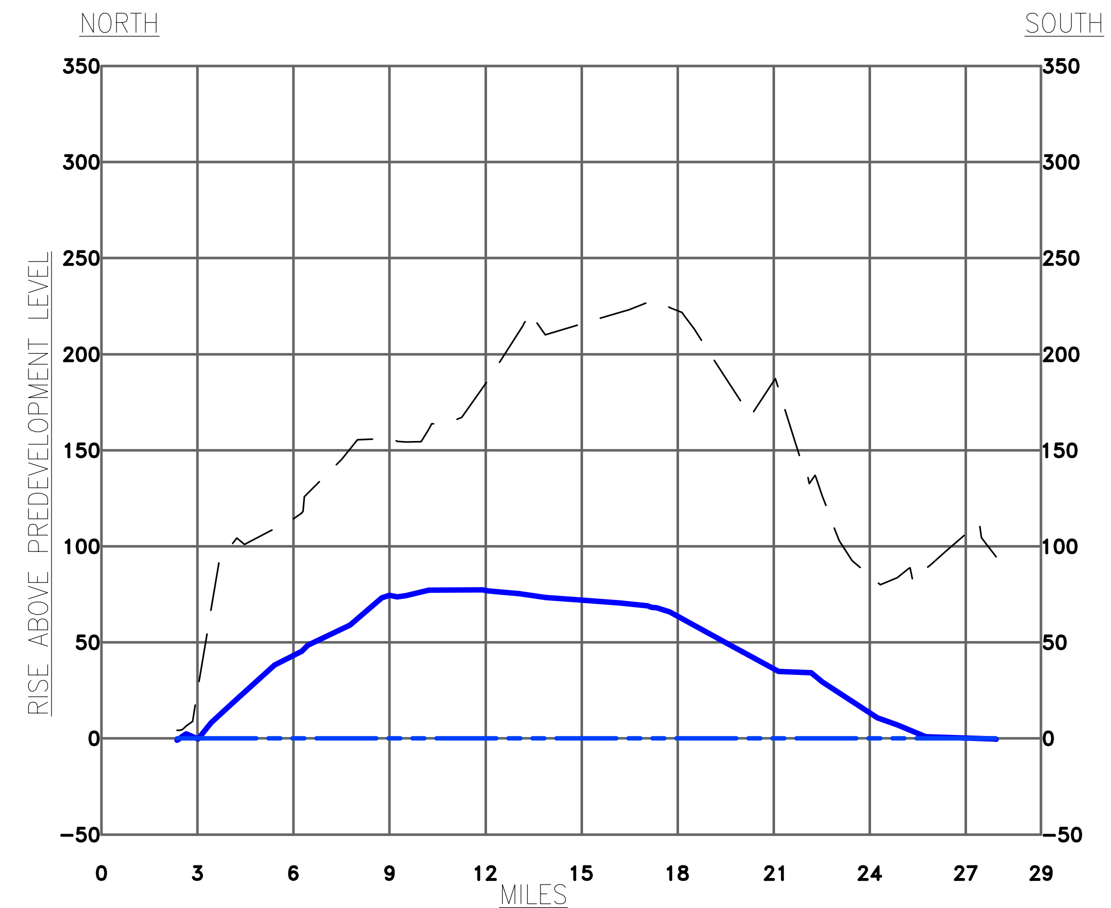
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

GROUNDWATER LEVELS
2001 CROSS SECTIONS

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	PLS	DJS	DEC 2013	AS SHOWN	1500301	-	-	F2001-2



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2001 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

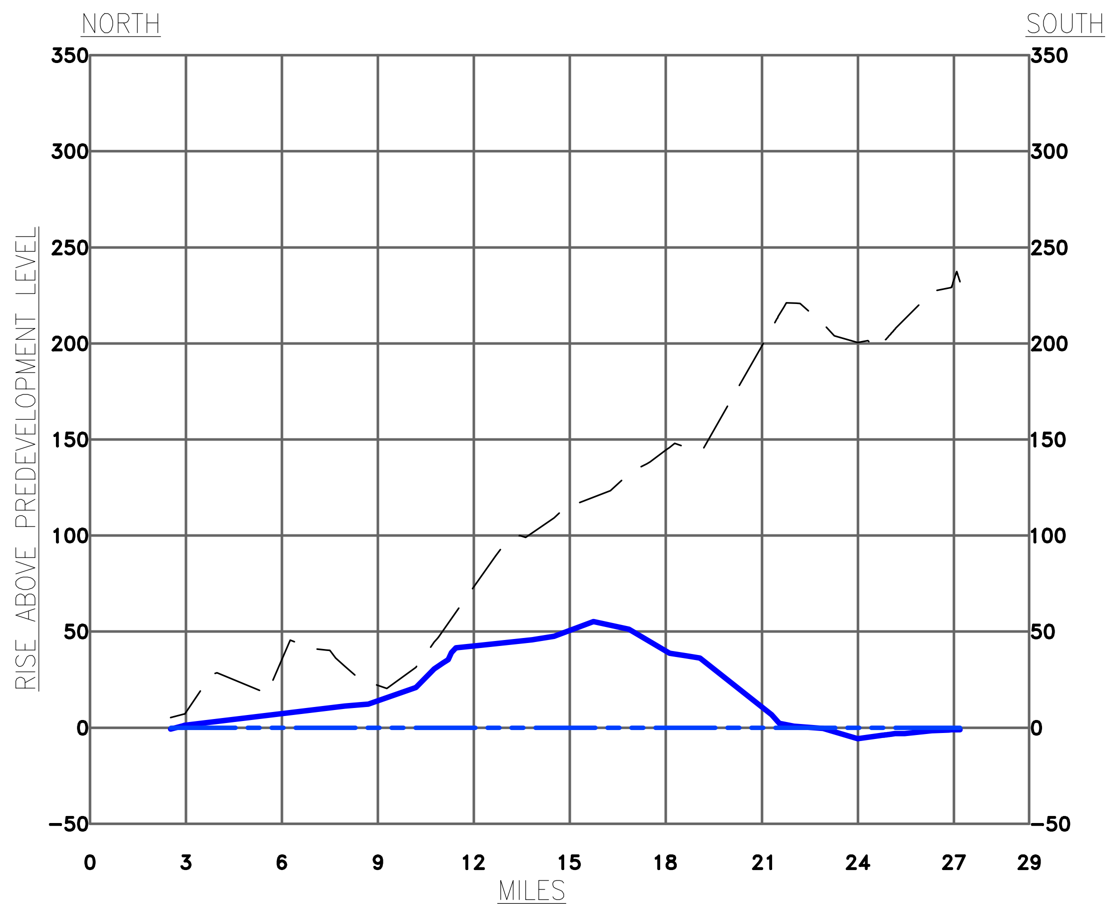
GROUNDWATER LEVELS
2001 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

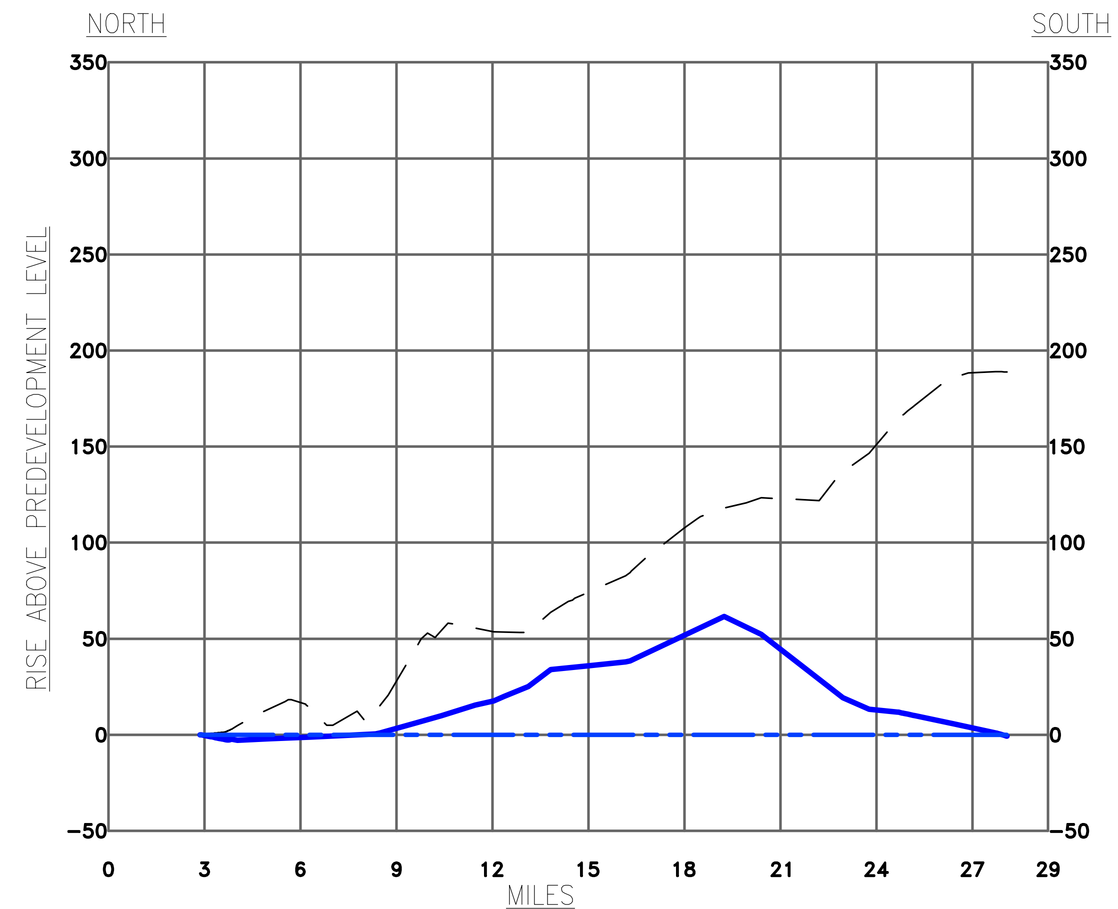
EA Engineering, Science, and Technology, Inc.®

FIGURE	F2001-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2001 Sections.dwg
DATE:11/21/2013 TIME:16:51 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2001 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

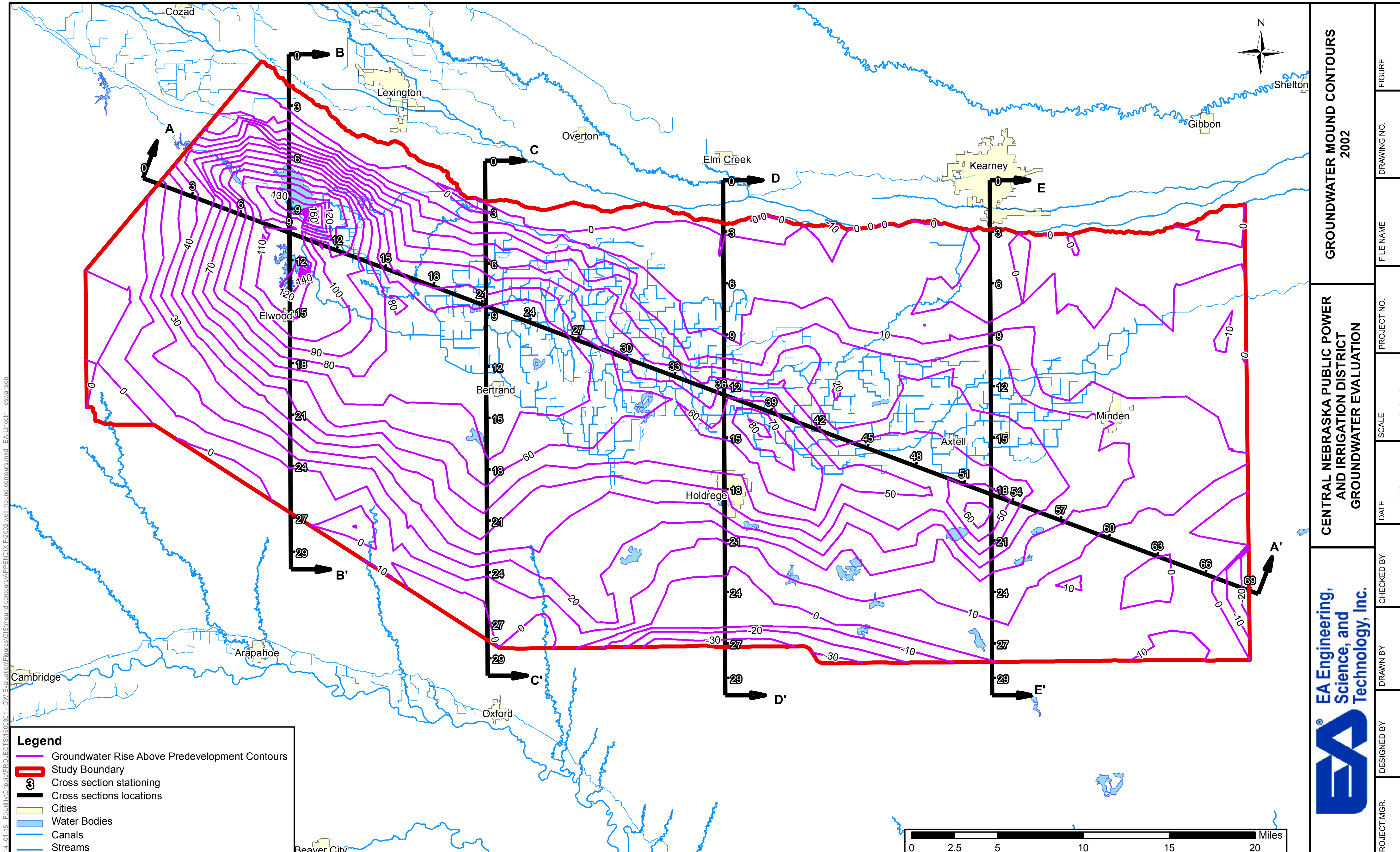
GROUNDWATER LEVELS
2001 CROSS SECTIONS

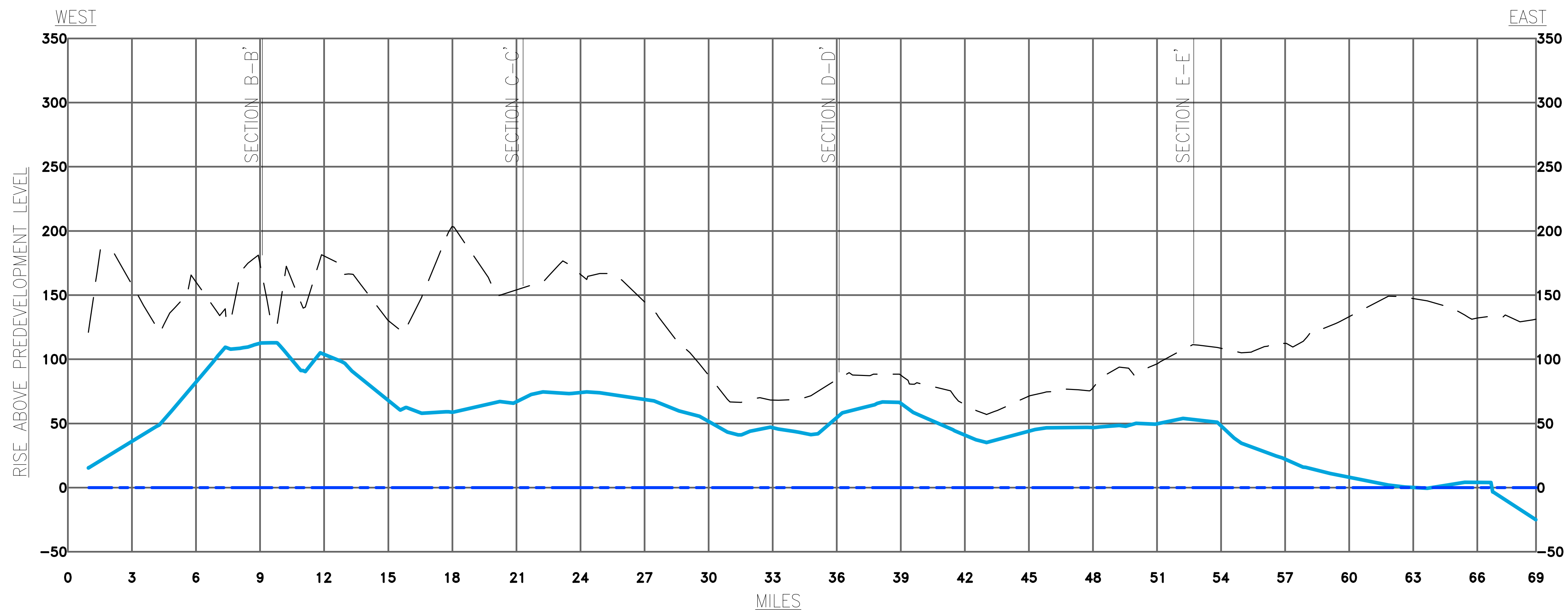
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
Science, and
Technology, Inc.

FIGURE	F2001-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2001 Sections.dwg
DATE:11/21/2013 TIME:16:51 DRAWN BY:cswanson


GROUNDWATER MOUND CONTOURS 2002
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION
EA Engineering, Science, and Technology, Inc.
FIGURE F2002-1
DRAWING NO. –
FILE NAME –
PROJECT NO. 1500301
SCALE AS SHOWN
DATE DEC 2013
CHECKED BY DJS
DRAWN BY DMM
DESIGNED BY DJS
PROJECT MGR. DJS
Legend
Groundwater Rise Above Predevelopment Contours
Study Boundary
Cross section stationing
Cross sections locations
Cities
Water Bodies
Canals
Streams
Miles
0
2.5
5
10
15
20
N
Cozad
Lexington
Overton
Elm Creek
Kearney
Gibbon
Shelton
Elwood
Bertrand
Holdrege
Axtell
Minden
Arapahoe
Cambridge
Oxford
Beaver City
A
A'
B
B'
C
C'
D
D'
E
E'



SECTION A-A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2002 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

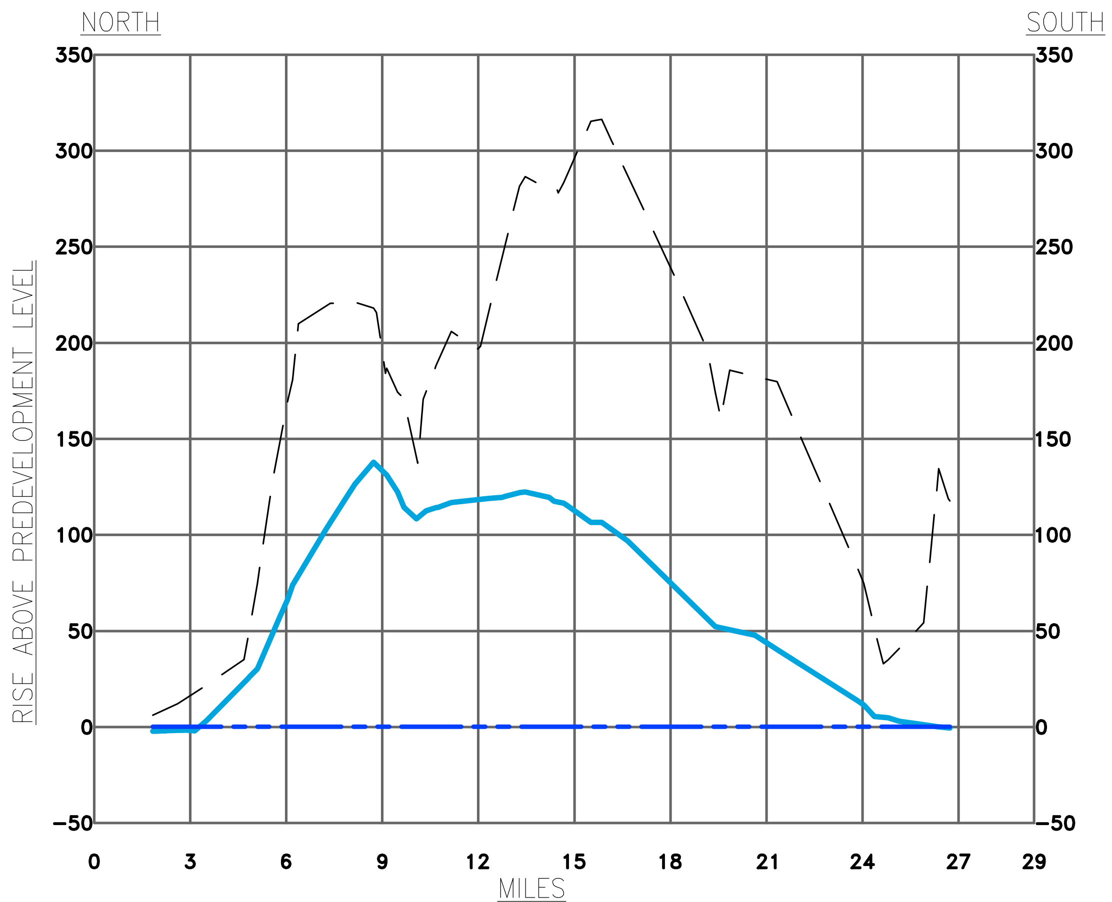
GROUNDWATER LEVELS
2002 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

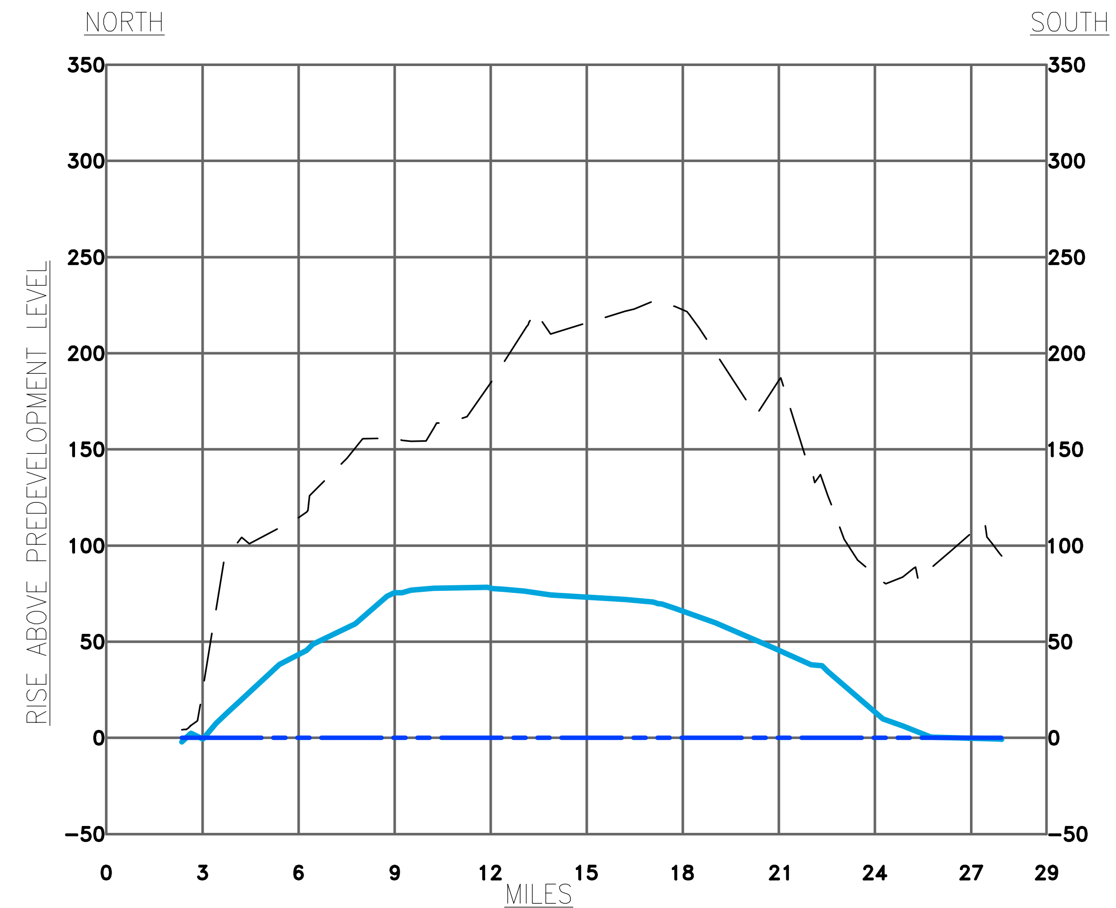
EA Engineering, Science, and Technology, Inc.®

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	PLS	DJS	DEC 2013	AS SHOWN	1500301	-	-	F2002-2

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2002 Sections.dwg
DATE:11/21/2013 TIME:17:05 DRAWN BY: cswanson



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2002 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

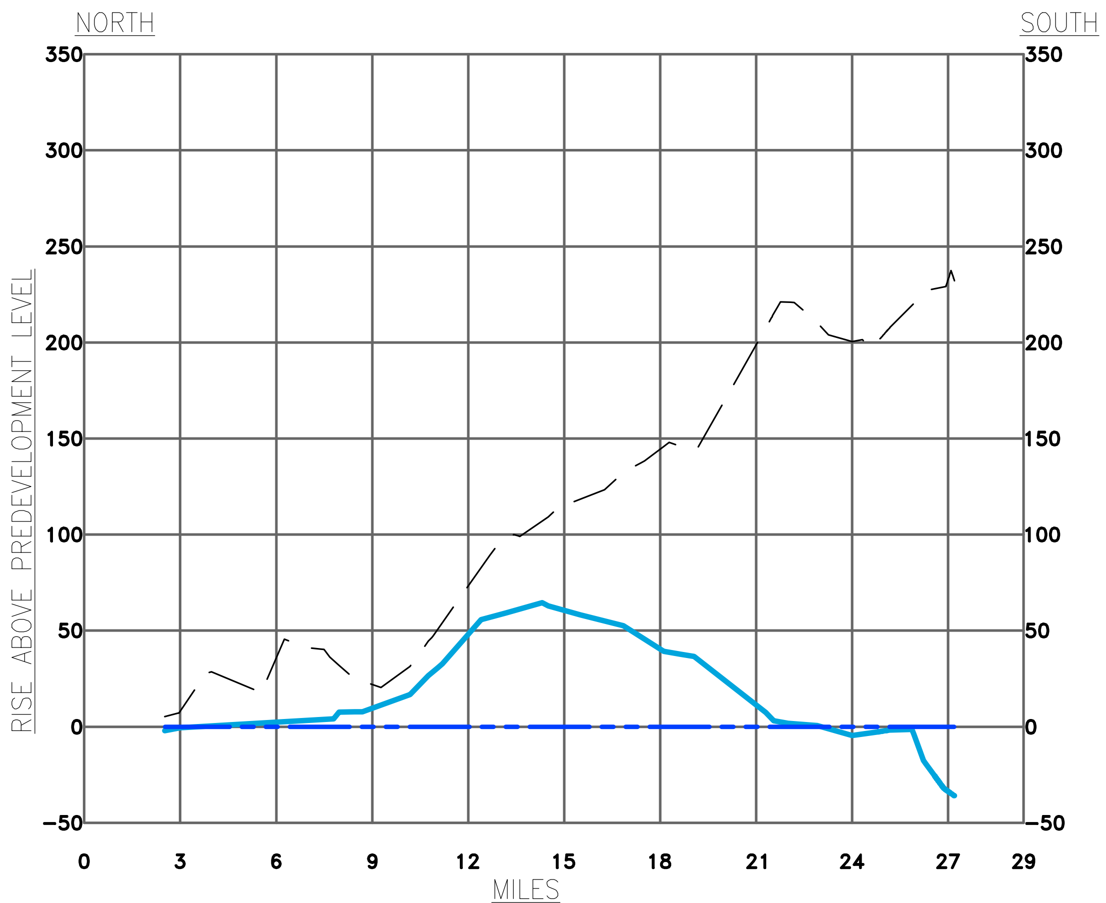
GROUNDWATER LEVELS
2002 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

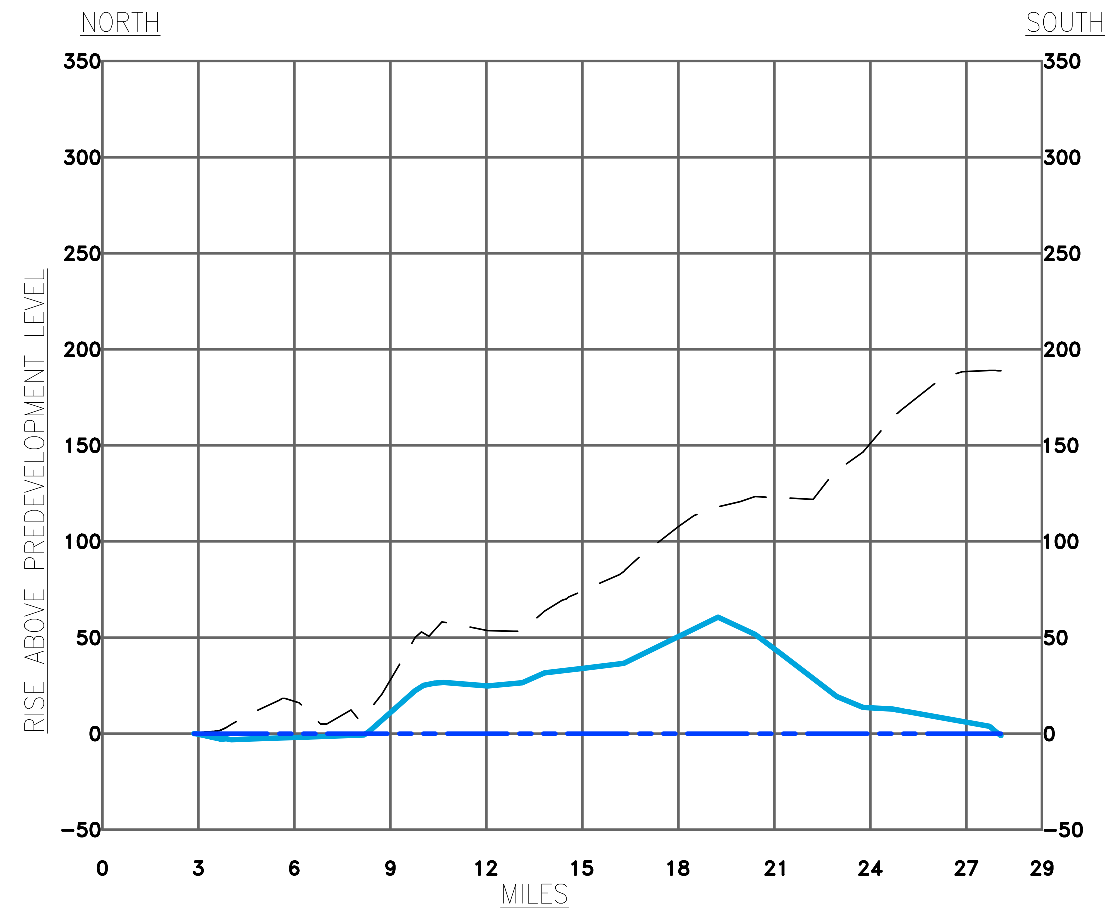
EA Engineering, Science, and Technology, Inc.

FIGURE	F2002-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2002 Sections.dwg
DATE:11/21/2013 TIME:17:05 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2002 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2002 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
F2002-4	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS

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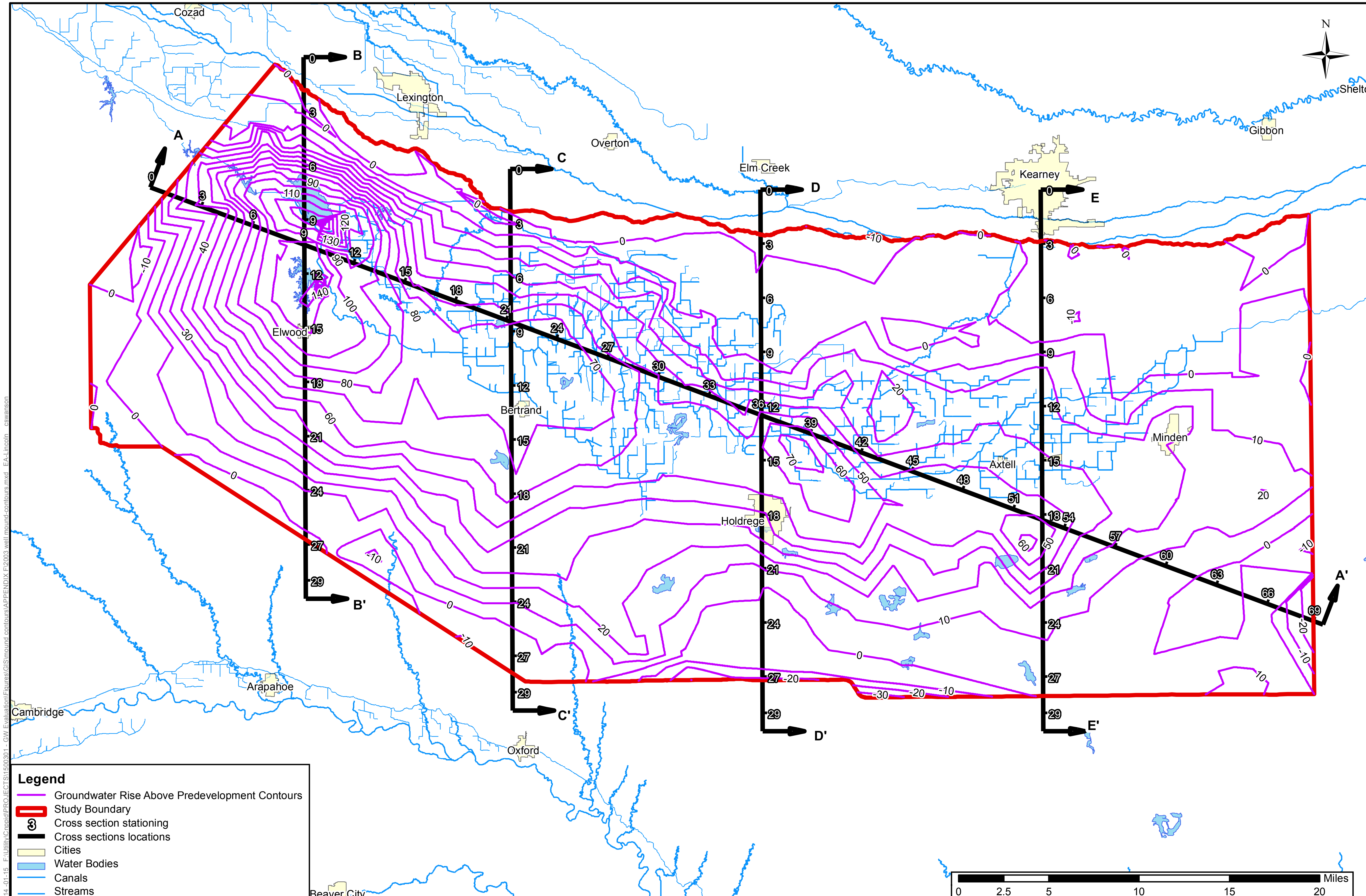
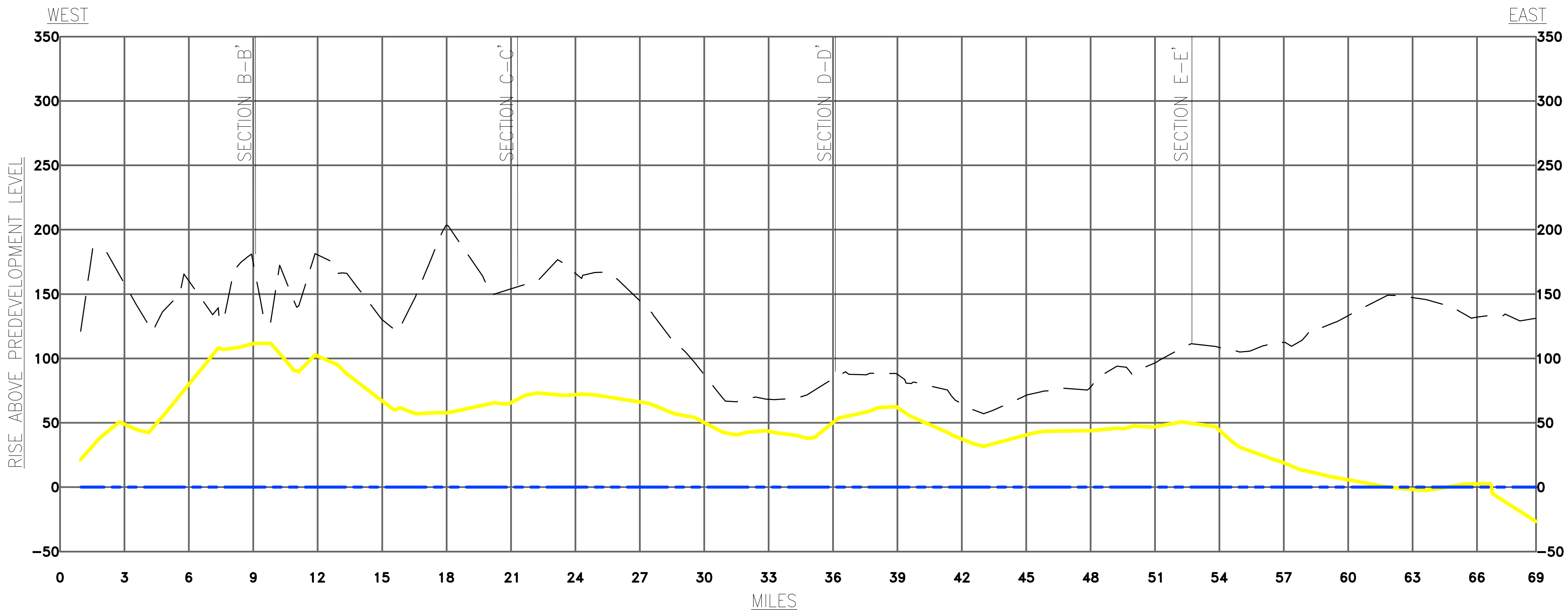


GROUNDWATER MOUND CONTOURS
2003

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2003-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2003 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2003 Sections.dwg
DATE:11/21/2013 TIME:17:14 DRAWN BY: cswanson

GROUNDWATER LEVELS
2003 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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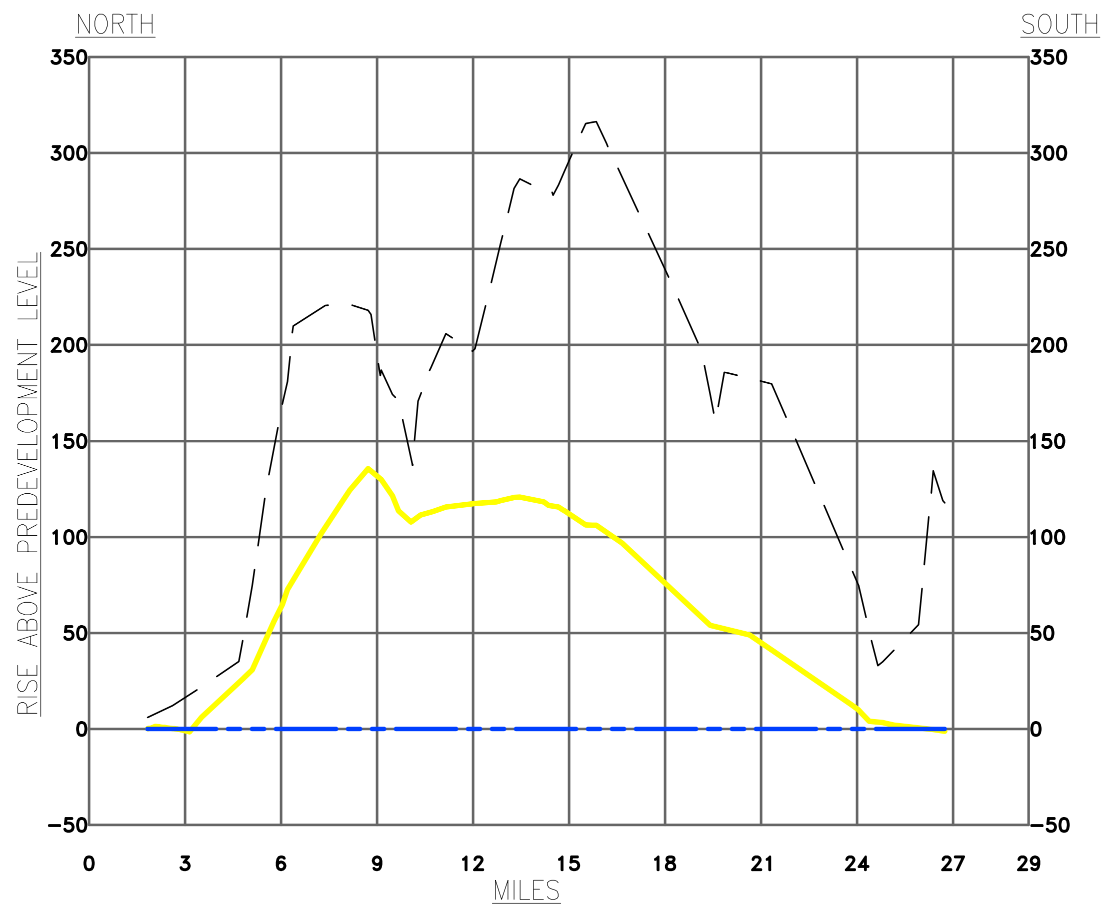
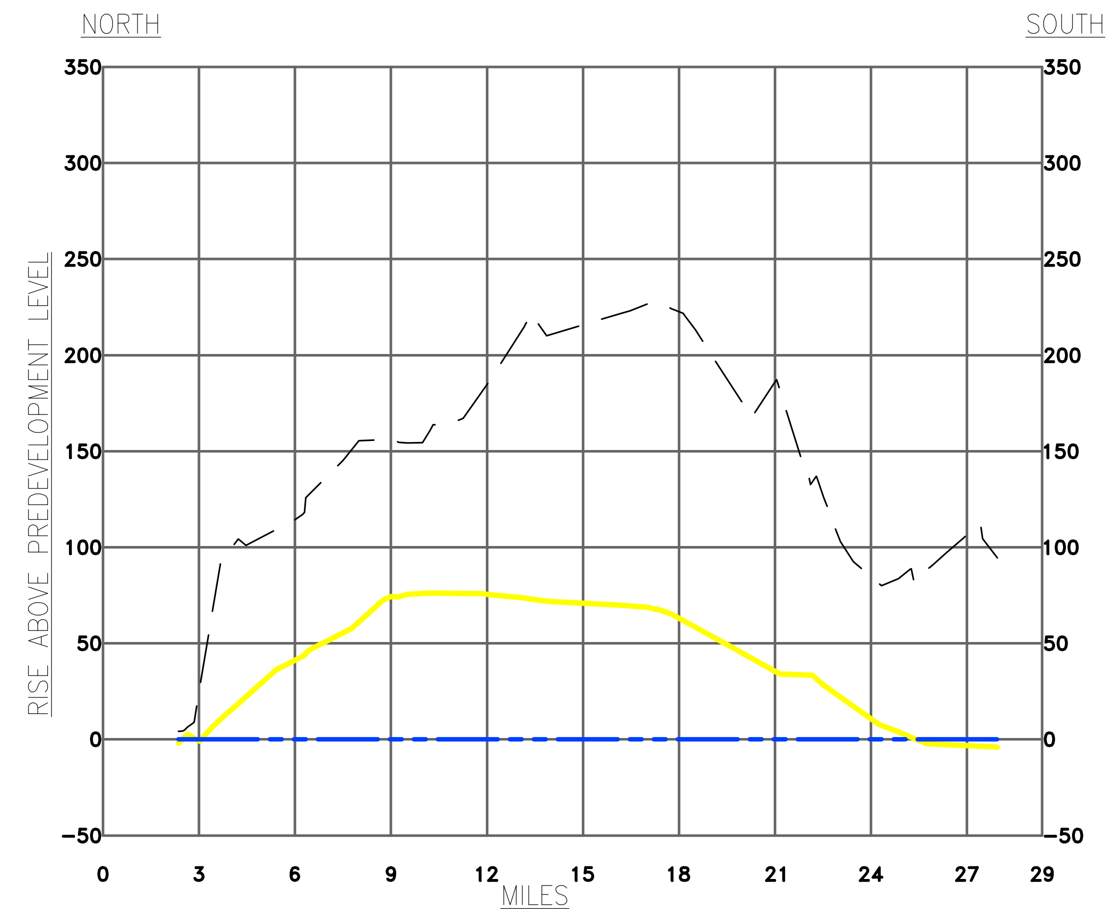


SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2003 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

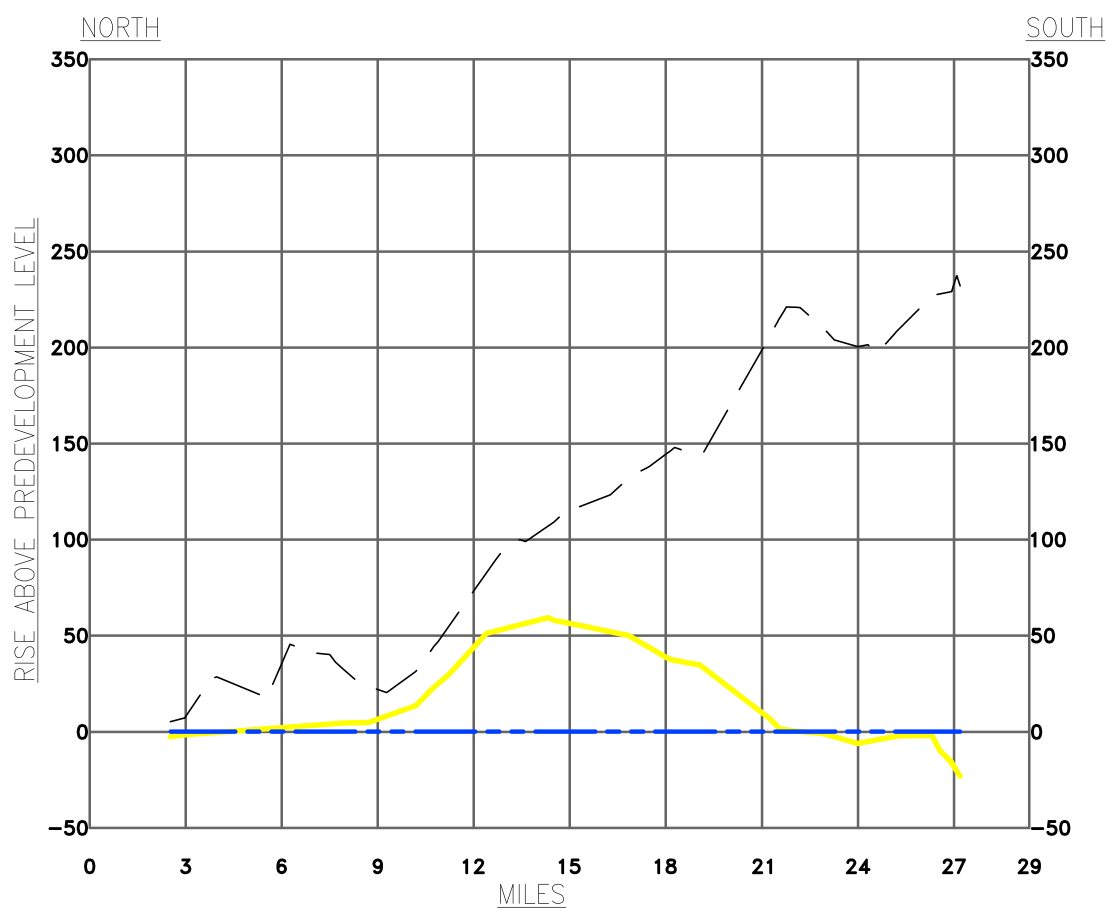
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2003 Sections.dwg
DATE:11/21/2013 TIME:17:14 DRAWN BY: cswanson

GROUNDWATER LEVELS
2003 CROSS SECTIONS

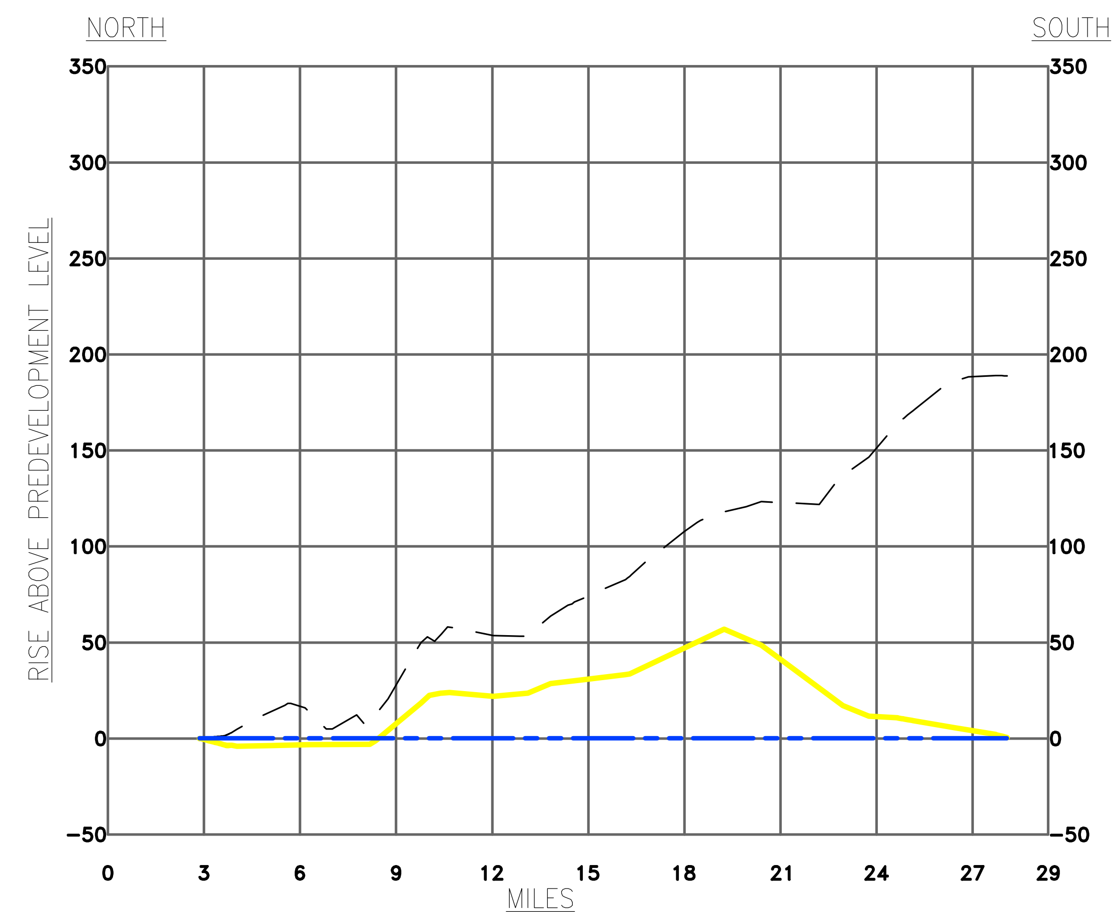
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2003-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2003 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

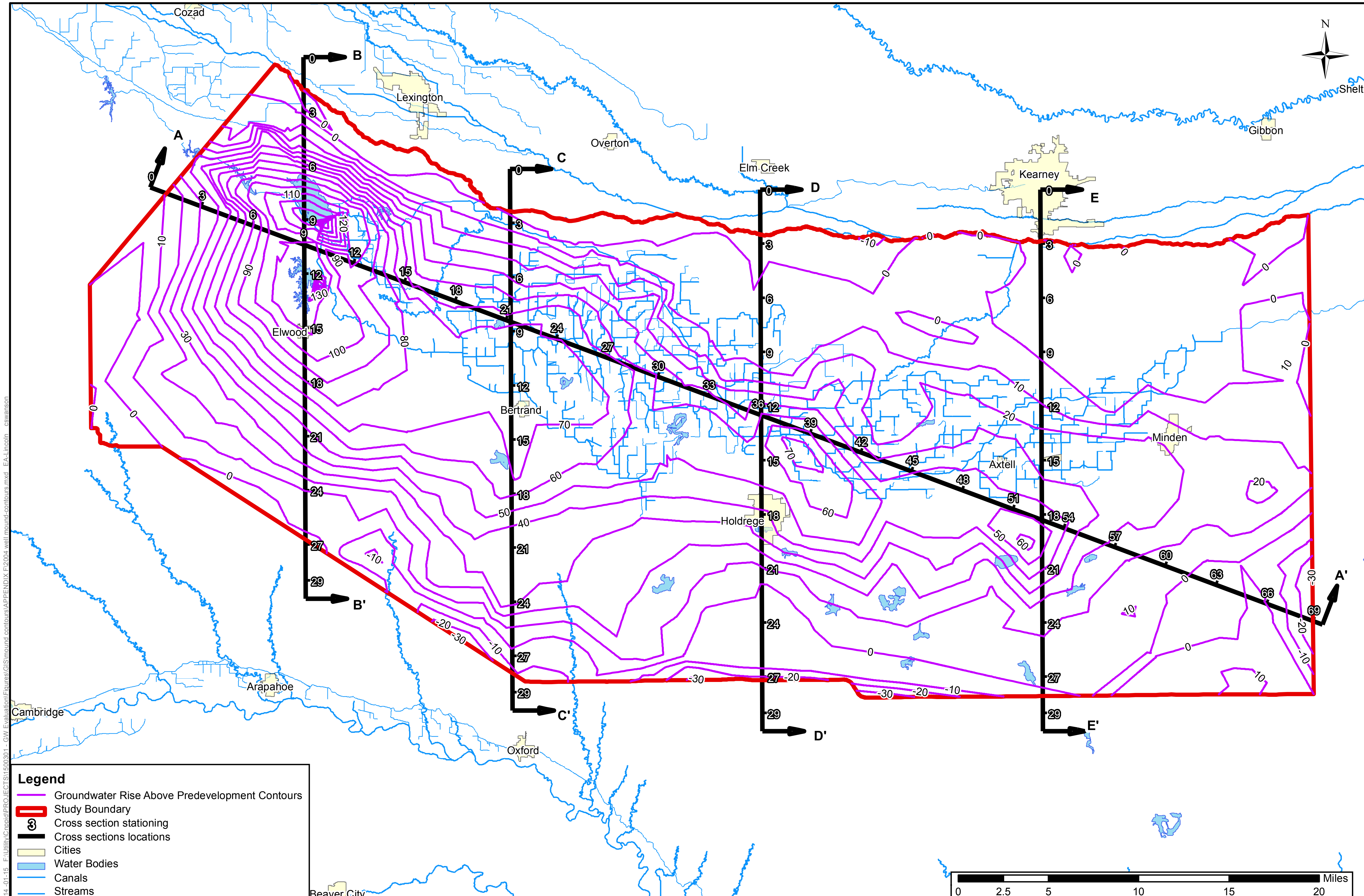
GROUNDWATER LEVELS
2003 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2003-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2003 Sections.dwg
DATE:11/21/2013 TIME:17:14 DRAWN BY:cswanson

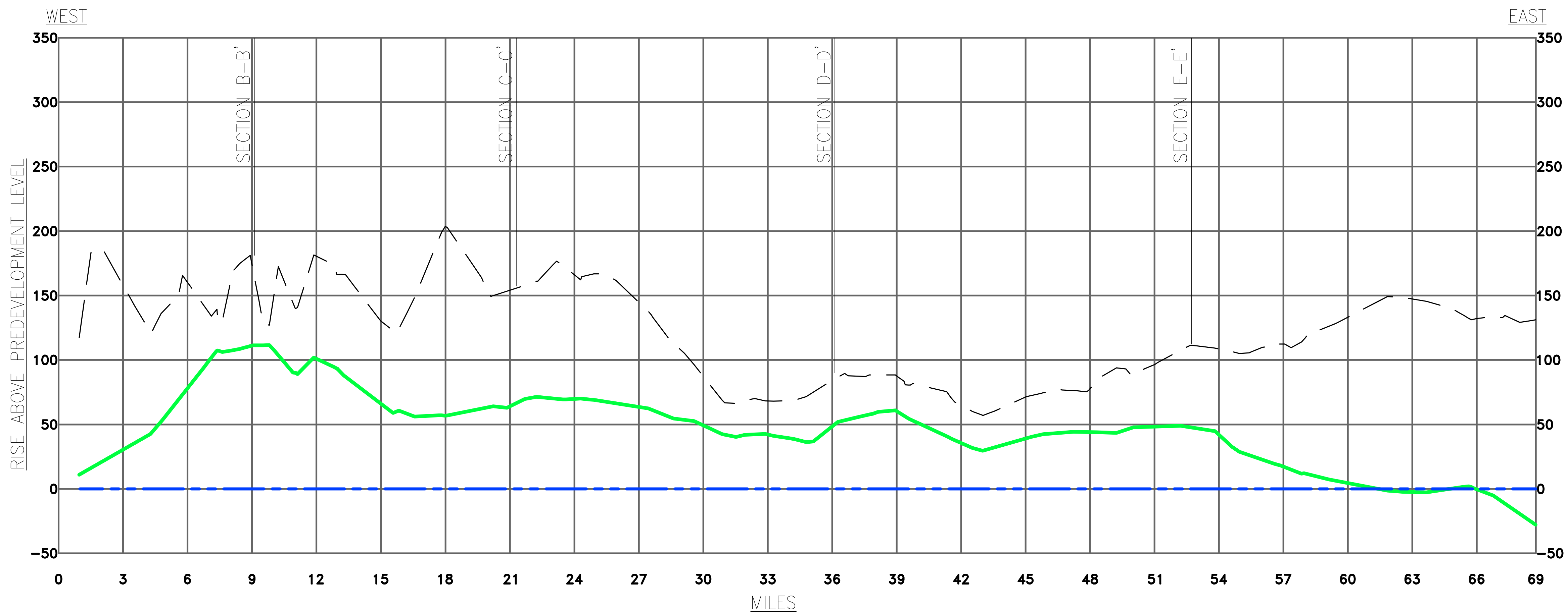


GROUNDWATER MOUND CONTOURS
2004

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2004-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2004 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2004 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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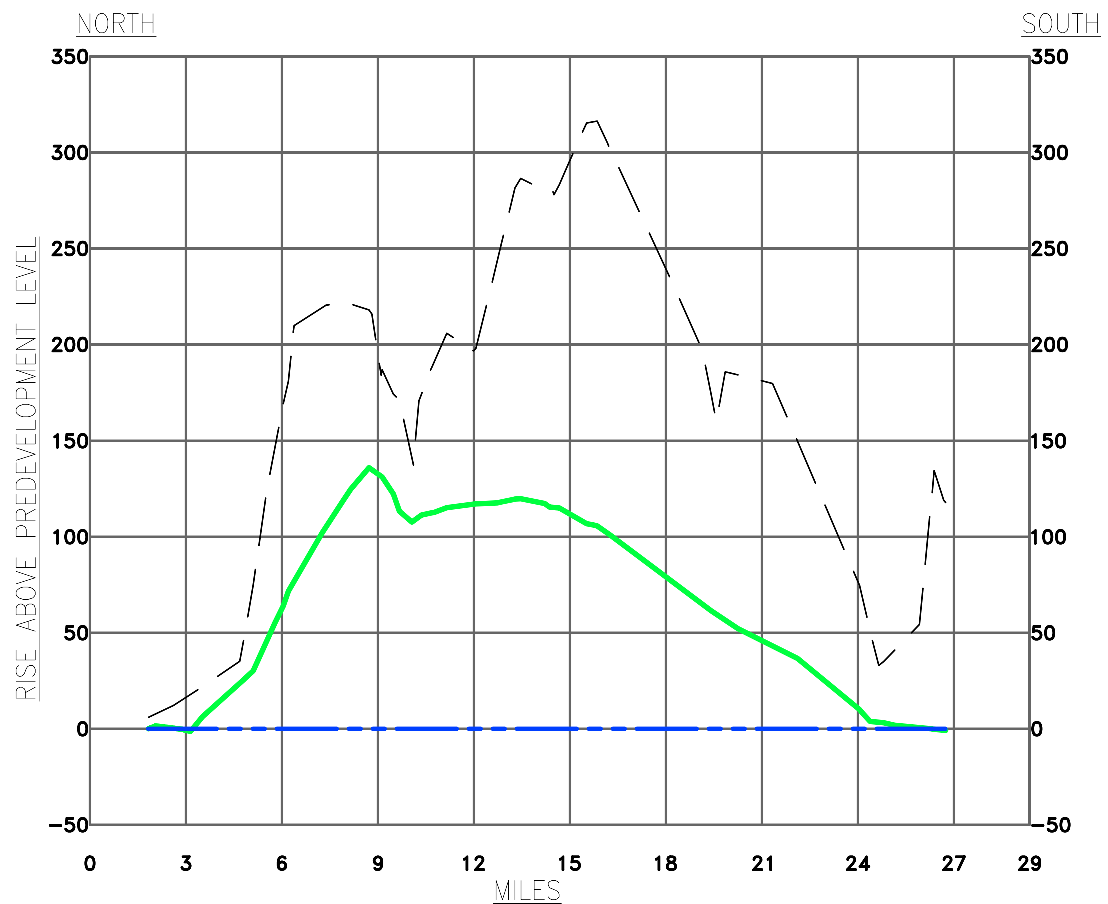
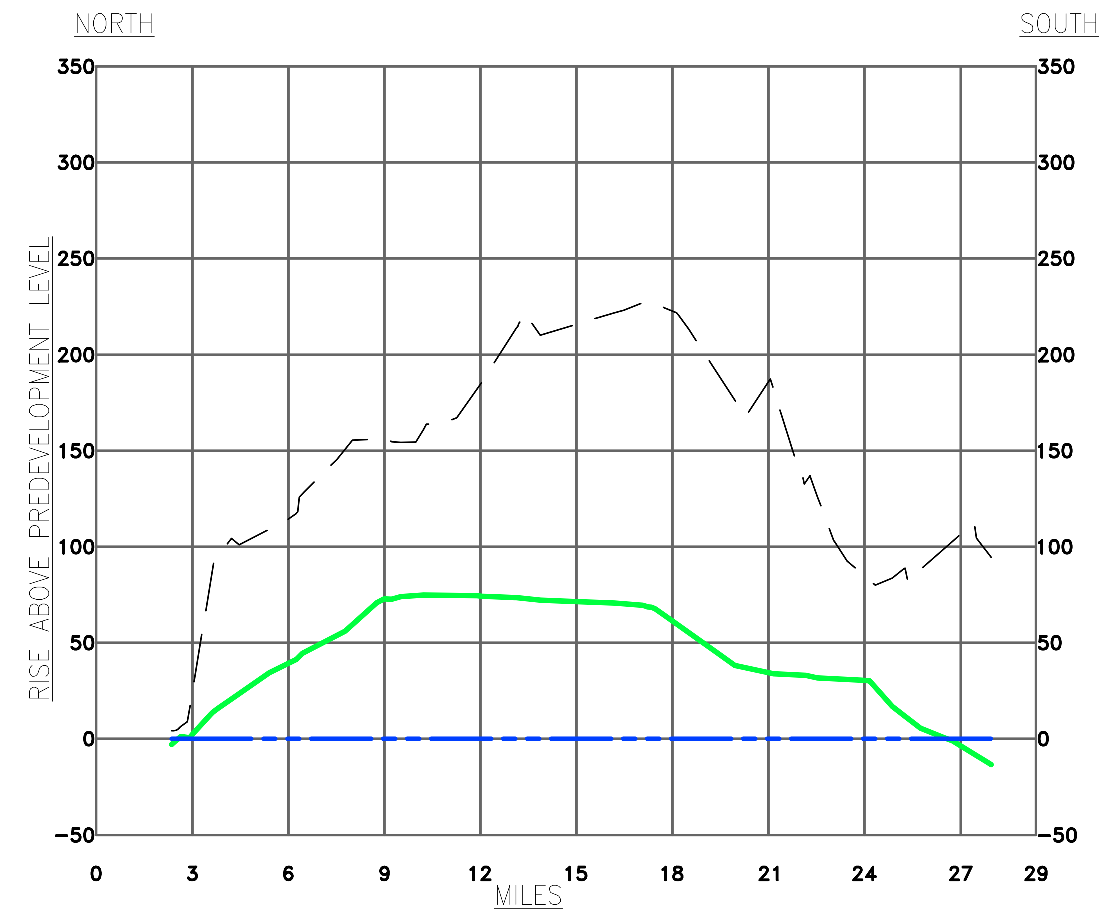
FIGURE	F2004-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2004 Sections.dwg
DATE:11/21/2013 TIME:17:20 DRAWN BY: cswanson



SECTION B-B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL
2004 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

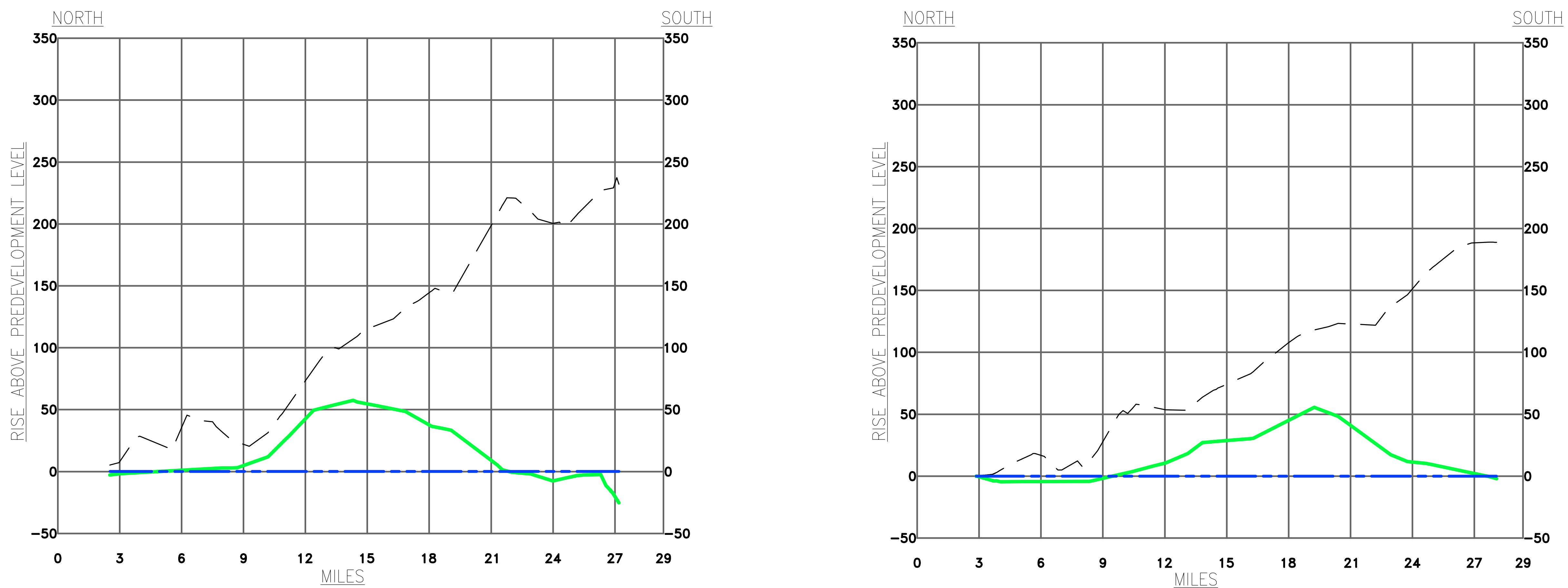
GROUNDWATER LEVELS
2004 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
F2004-3	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2004 Sections.dwg
DATE:11/21/2013 TIME:17:20 DRAWN BY: cswanson



SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2004 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

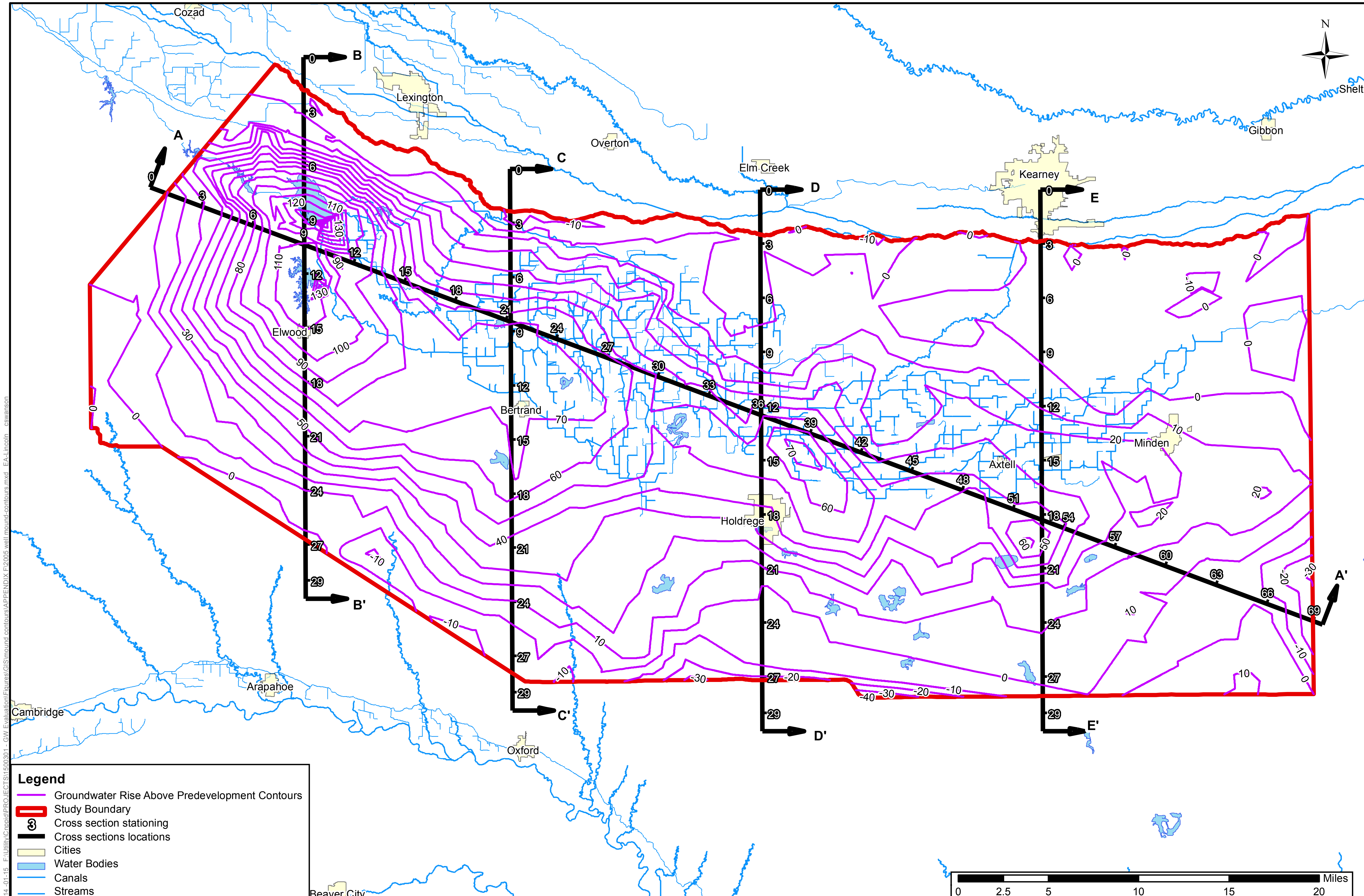
GROUNDWATER LEVELS
2004 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2004-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2004 Sections.dwg
DATE:11/21/2013 TIME:17:20 DRAWN BY:cswanson

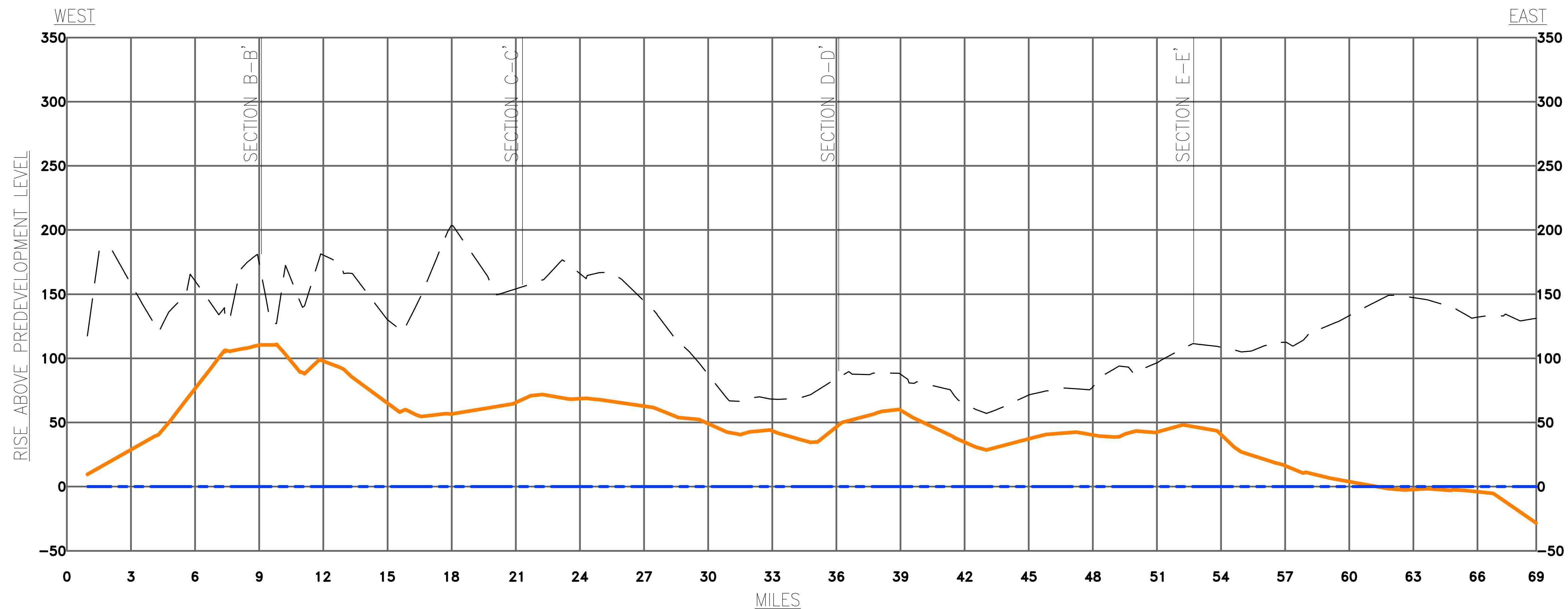


GROUNDWATER MOUND CONTOURS 2005

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2005-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2005 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2005 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
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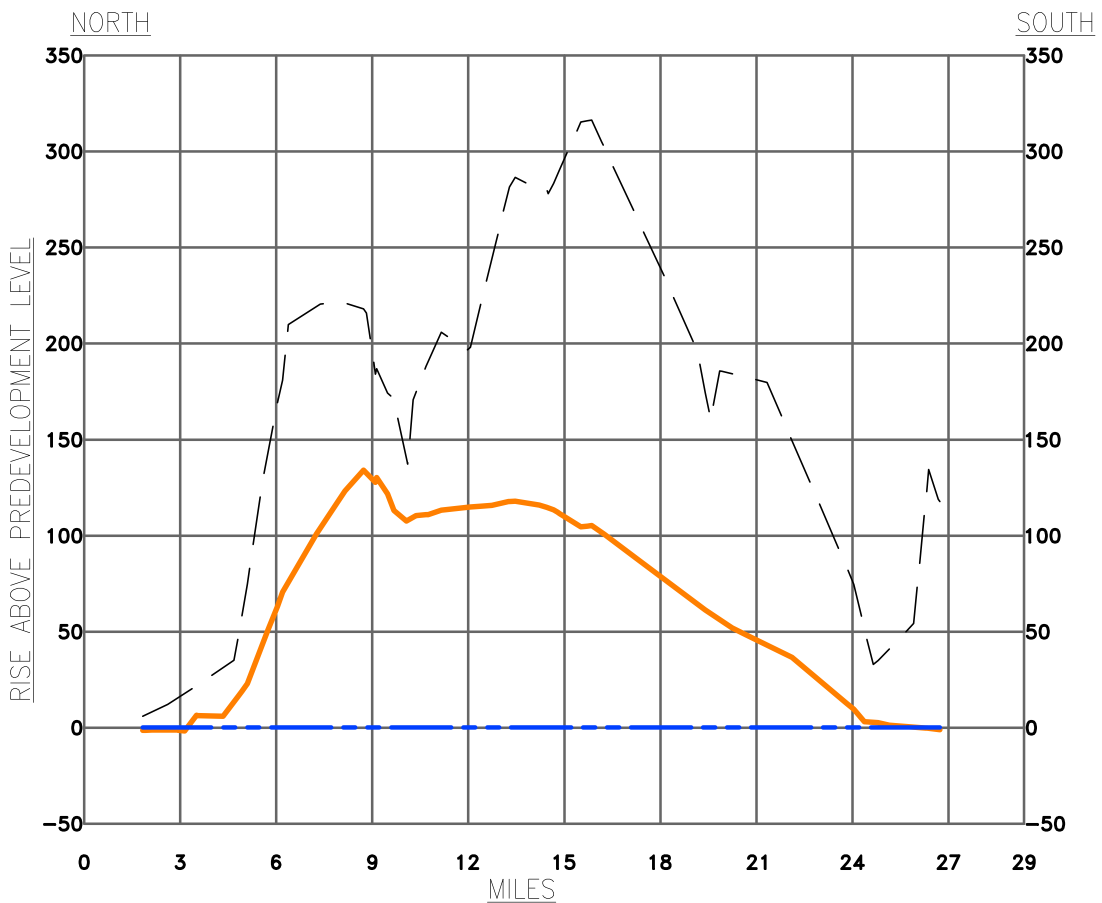
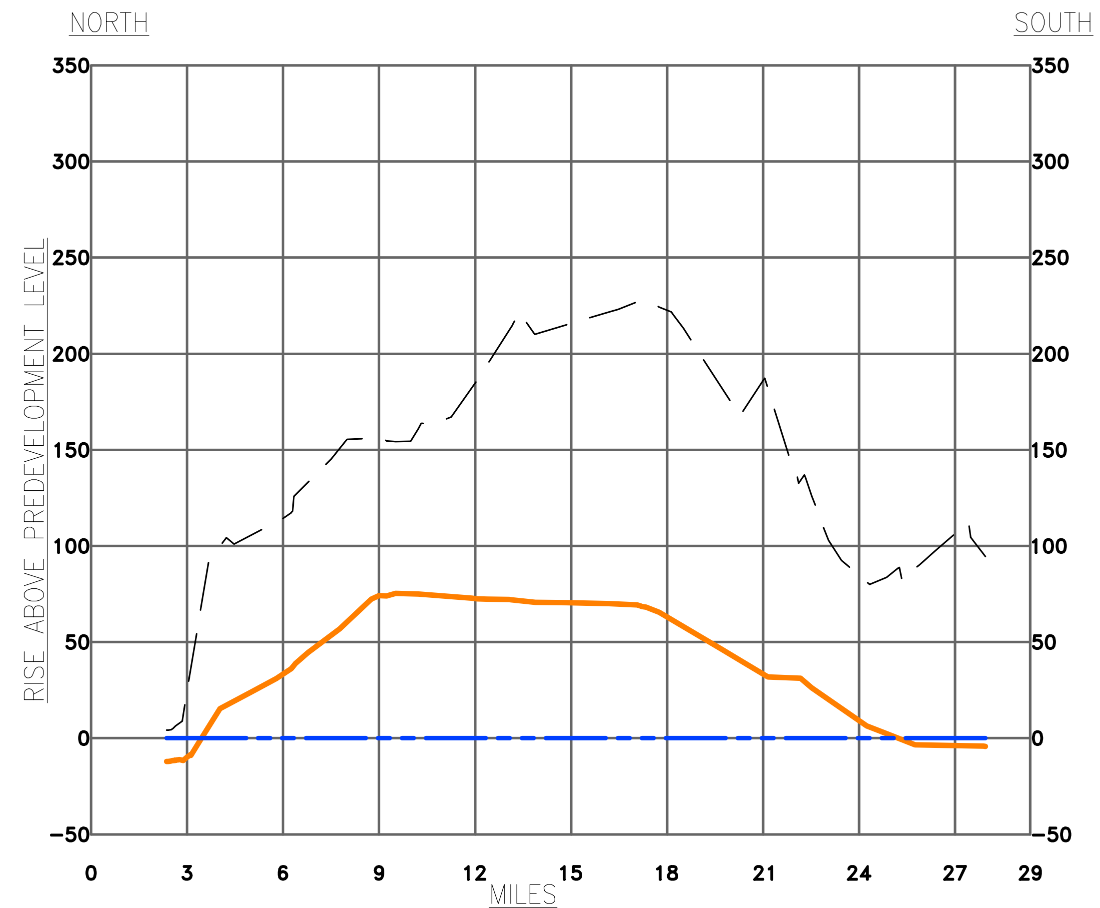
FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
F2005-2	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2005 Sections.dwg
DATE:11/21/2013 TIME:17:35 DRAWN BY: cswanson



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2005 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

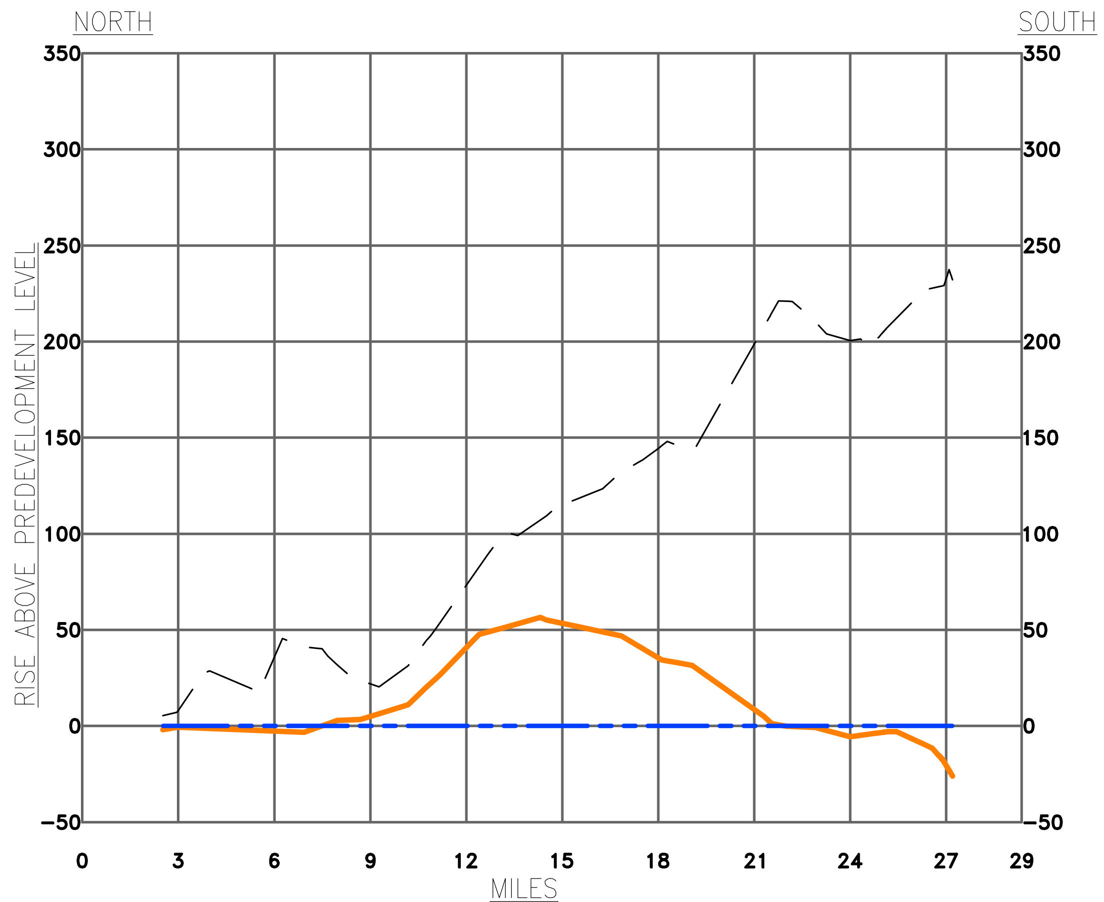
GROUNDWATER LEVELS
2005 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

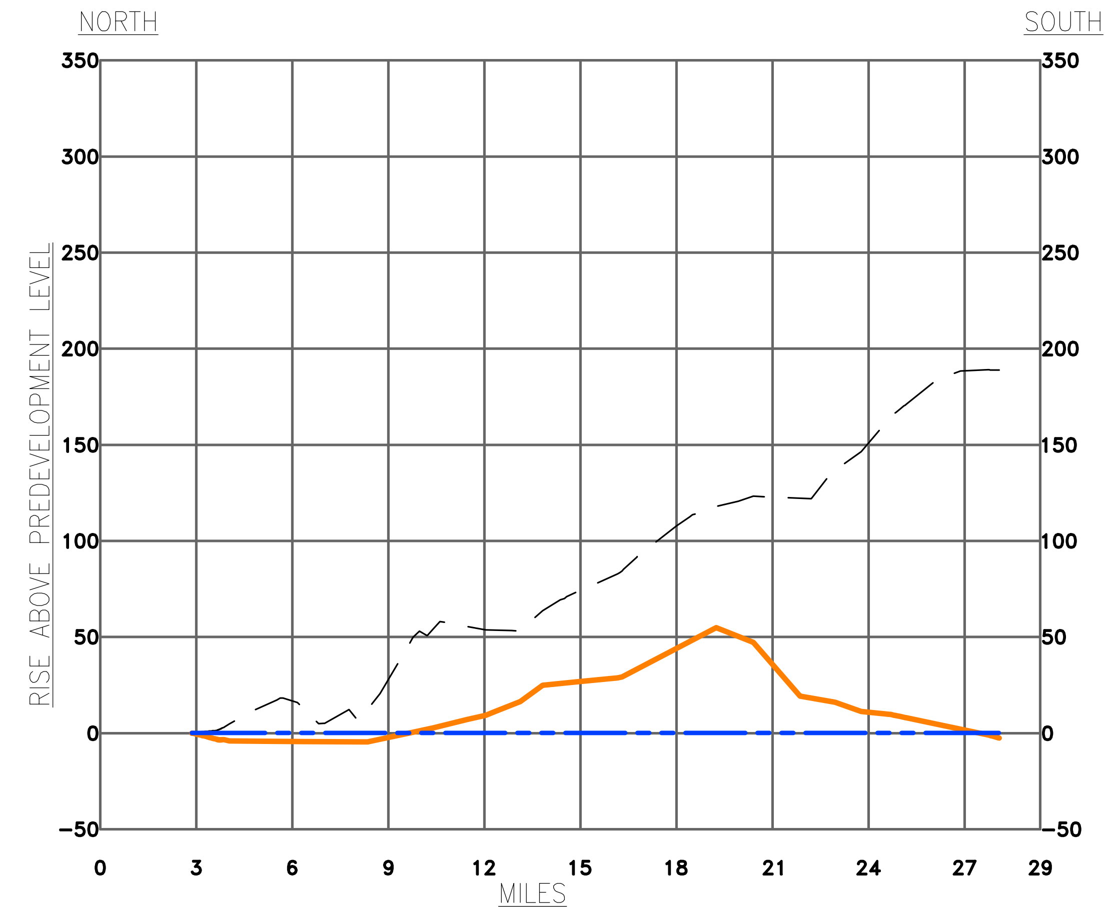
EA Engineering, Science, and Technology, Inc.®

FIGURE	F2005-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2005 Sections.dwg
DATE:11/21/2013 TIME:17:35 DRAWN BY: cswanson



SECTION D-D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E-E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2005 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

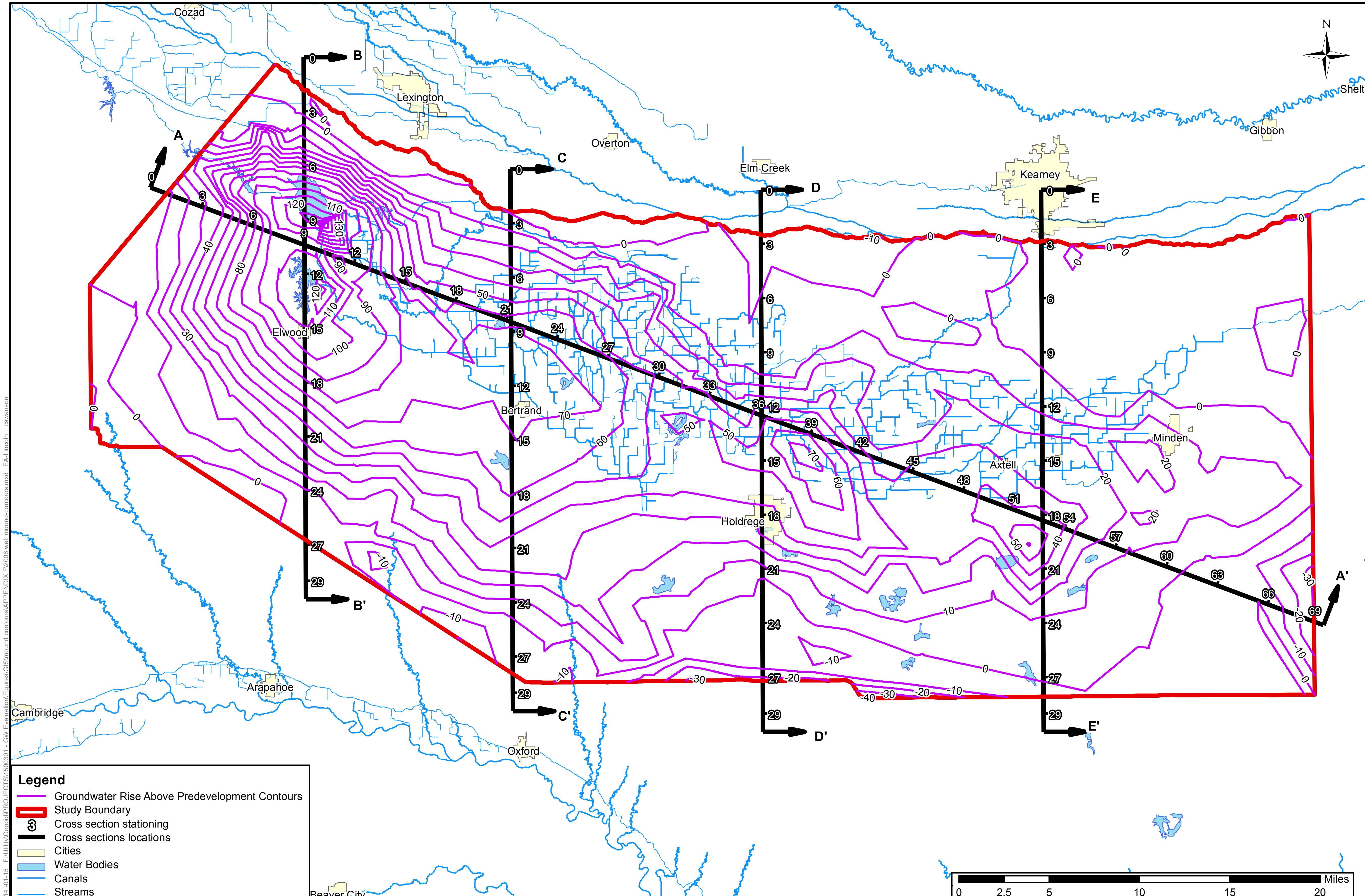
GROUNDWATER LEVELS
2005 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2005-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2005 Sections.dwg
DATE:11/21/2013 TIME:17:35 DRAWN BY:cswanson

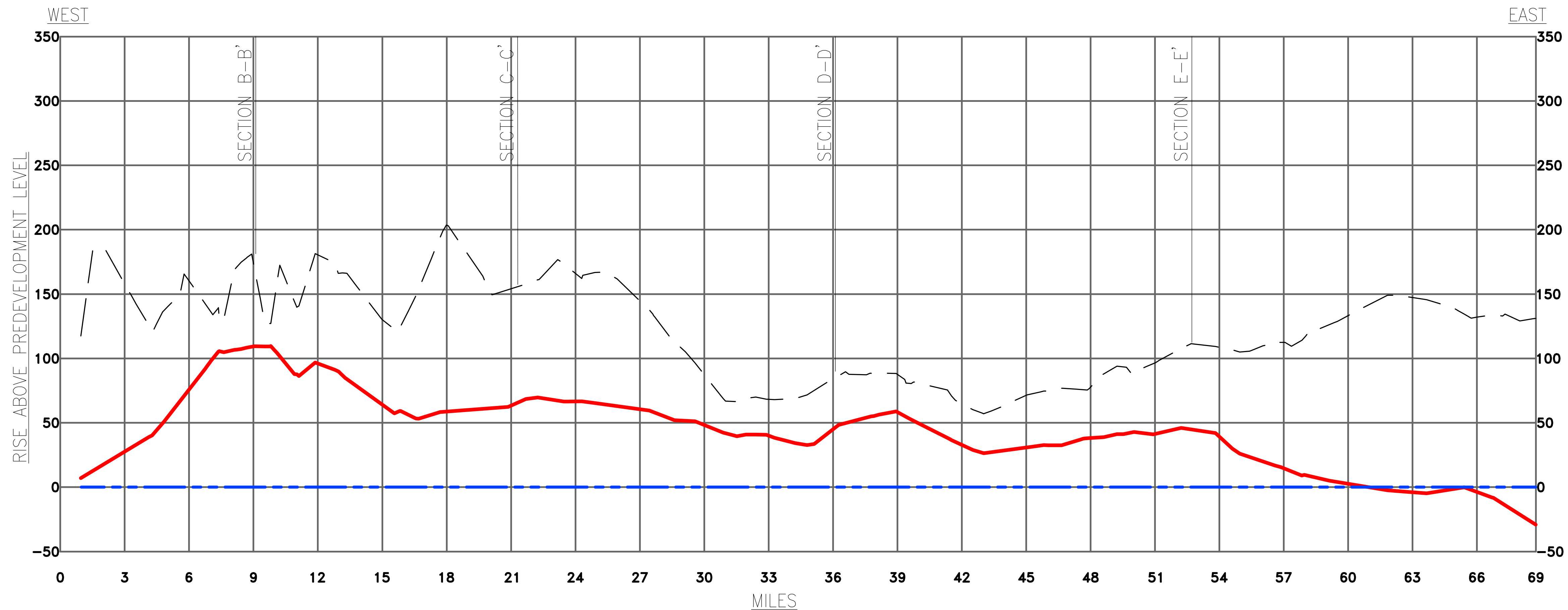


GROUNDWATER MOUND CONTOURS 2006

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2006-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2006 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

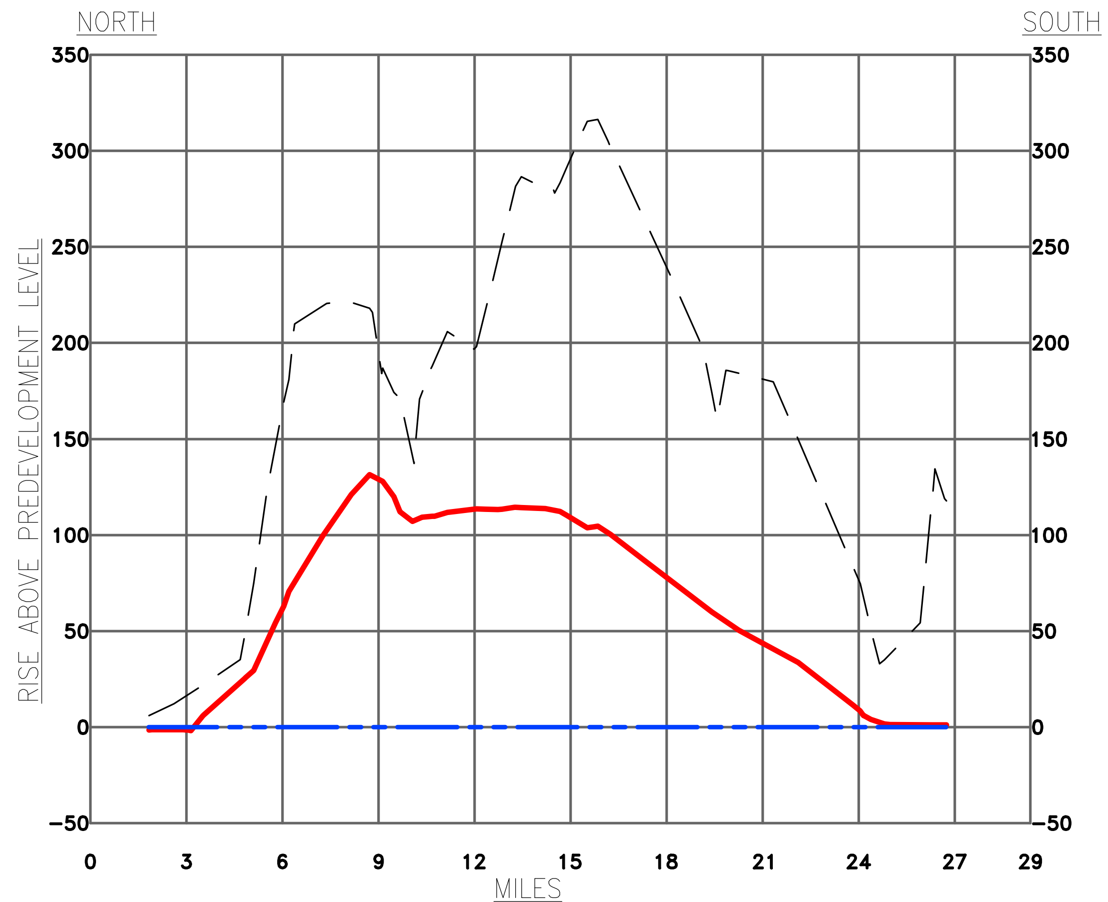
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2006 Sections.dwg
DATE:11/21/2013 TIME:18:09 DRAWN BY: cswanson

GROUNDWATER LEVELS 2006 CROSS SECTIONS

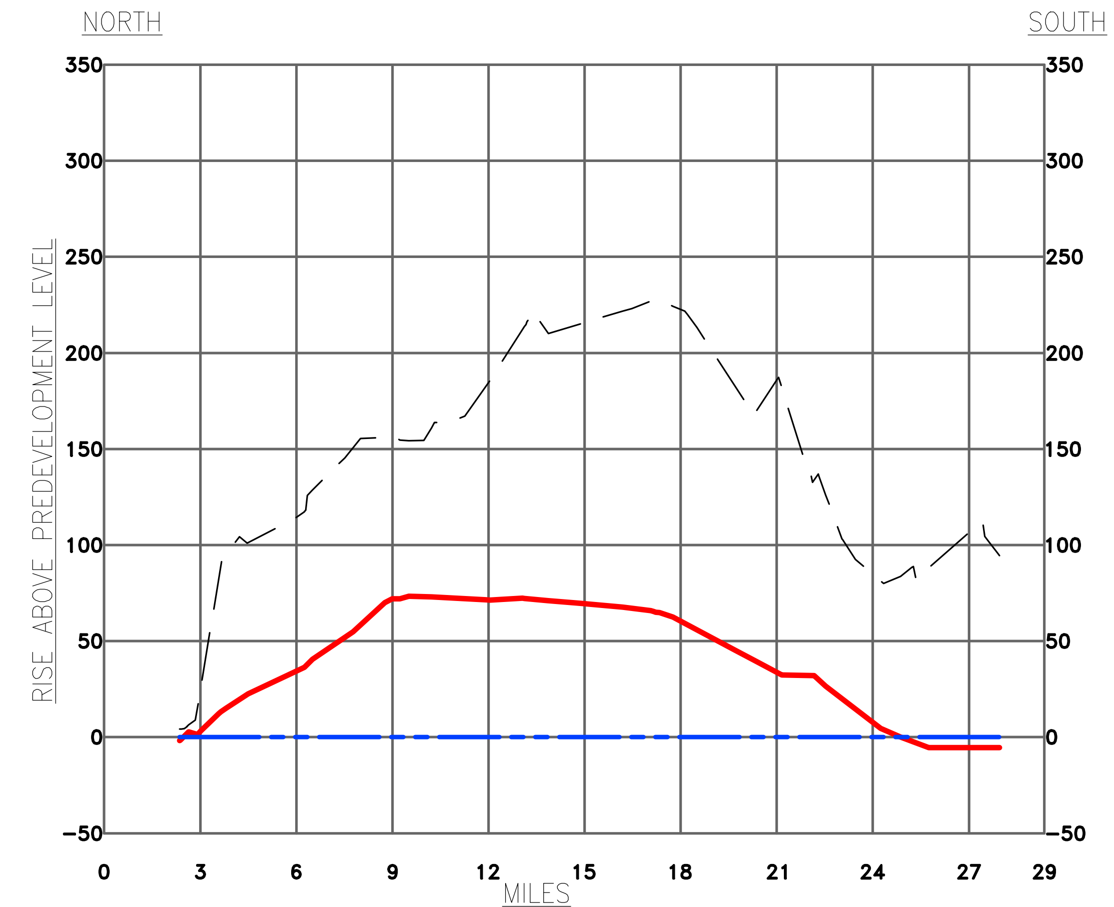
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2006-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2006 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

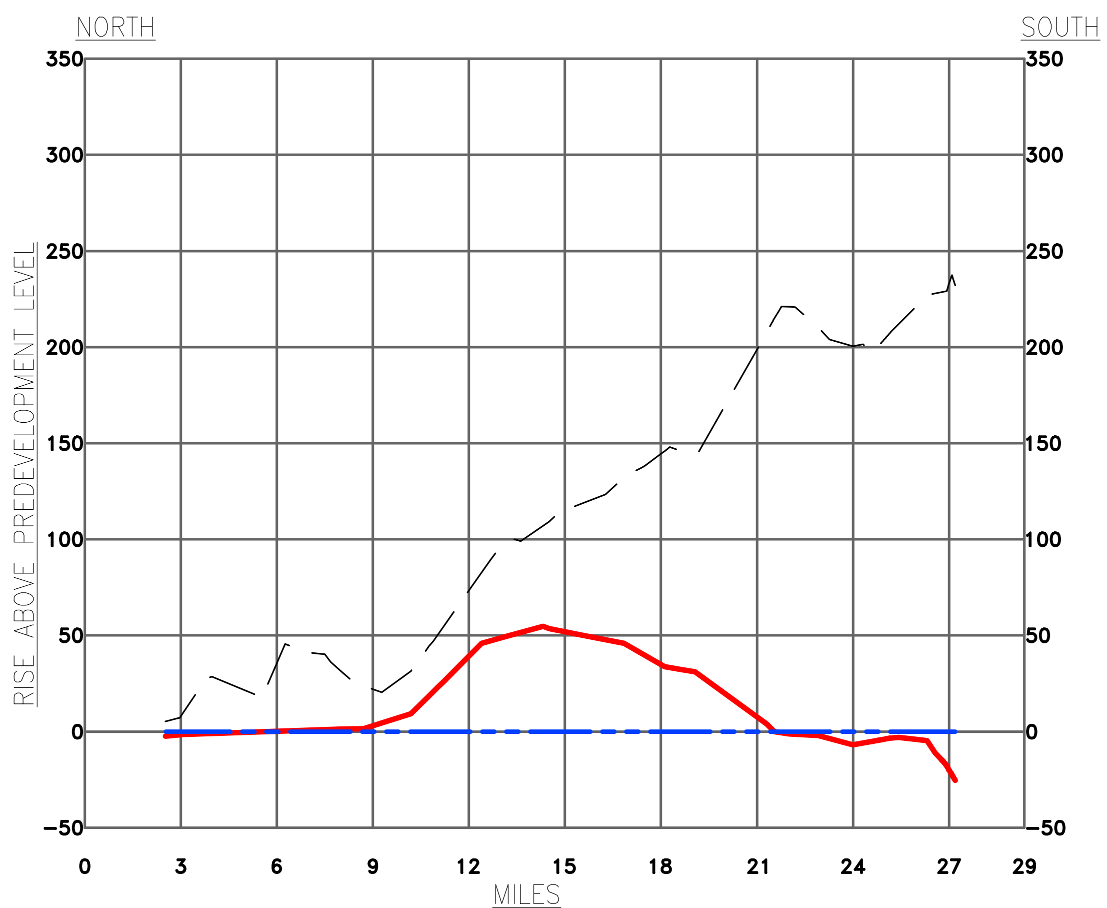
GROUNDWATER LEVELS
2006 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

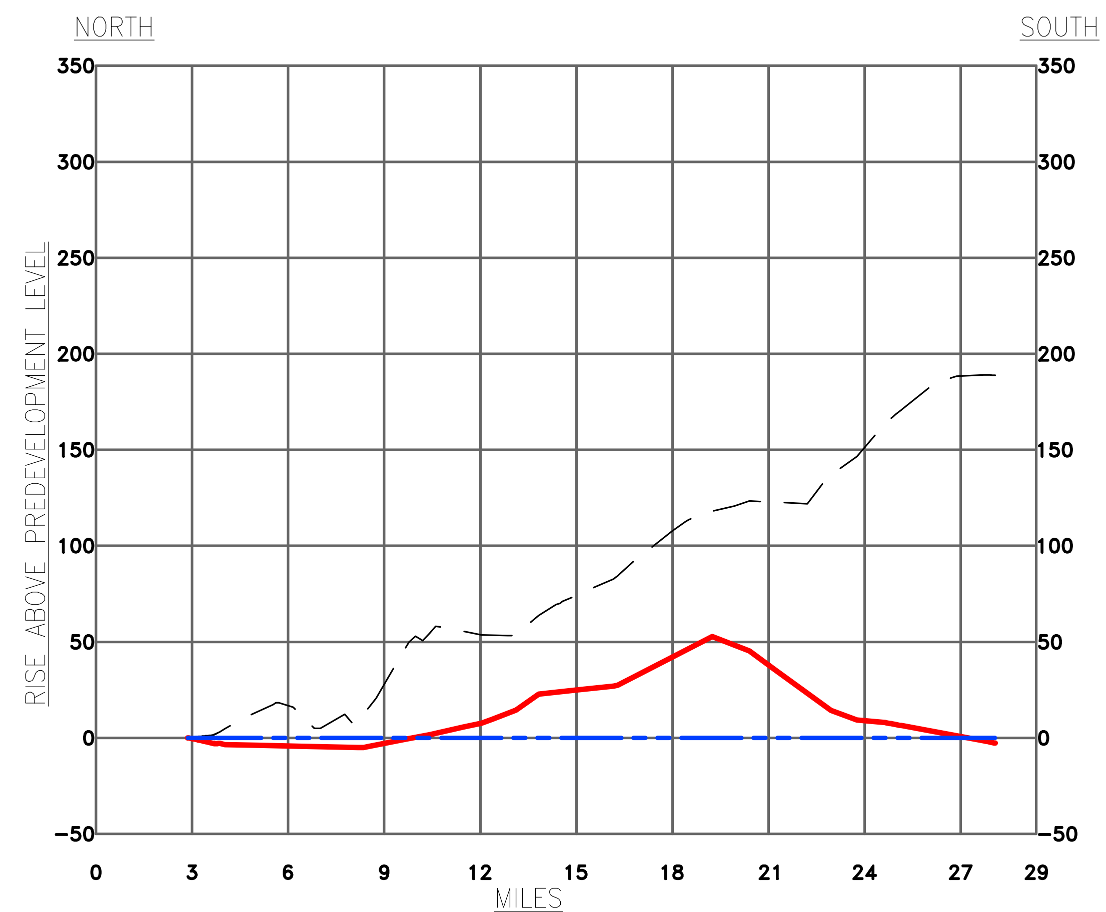
EA Engineering, Science, and Technology, Inc.®

FIGURE	F2006-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2006 Sections.dwg
DATE:11/21/2013 TIME:18:09 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2006 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2006 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
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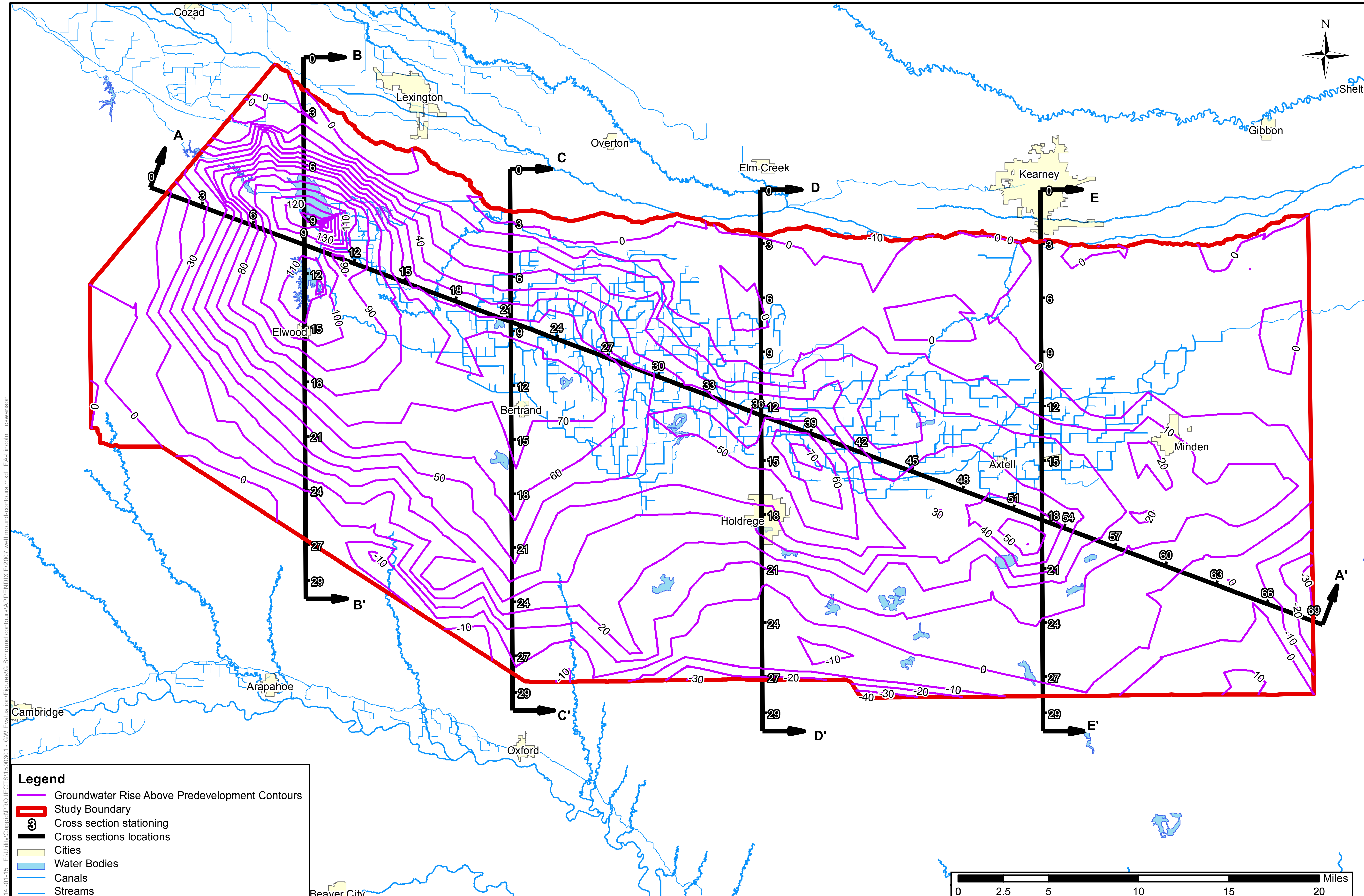
FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
F2006-4	-	-	1500301	AS SHOWN	DEC 2013	DJS	PLS	CNS	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2006 Sections.dwg
DATE:11/21/2013 TIME:18:09 DRAWN BY:cswanson

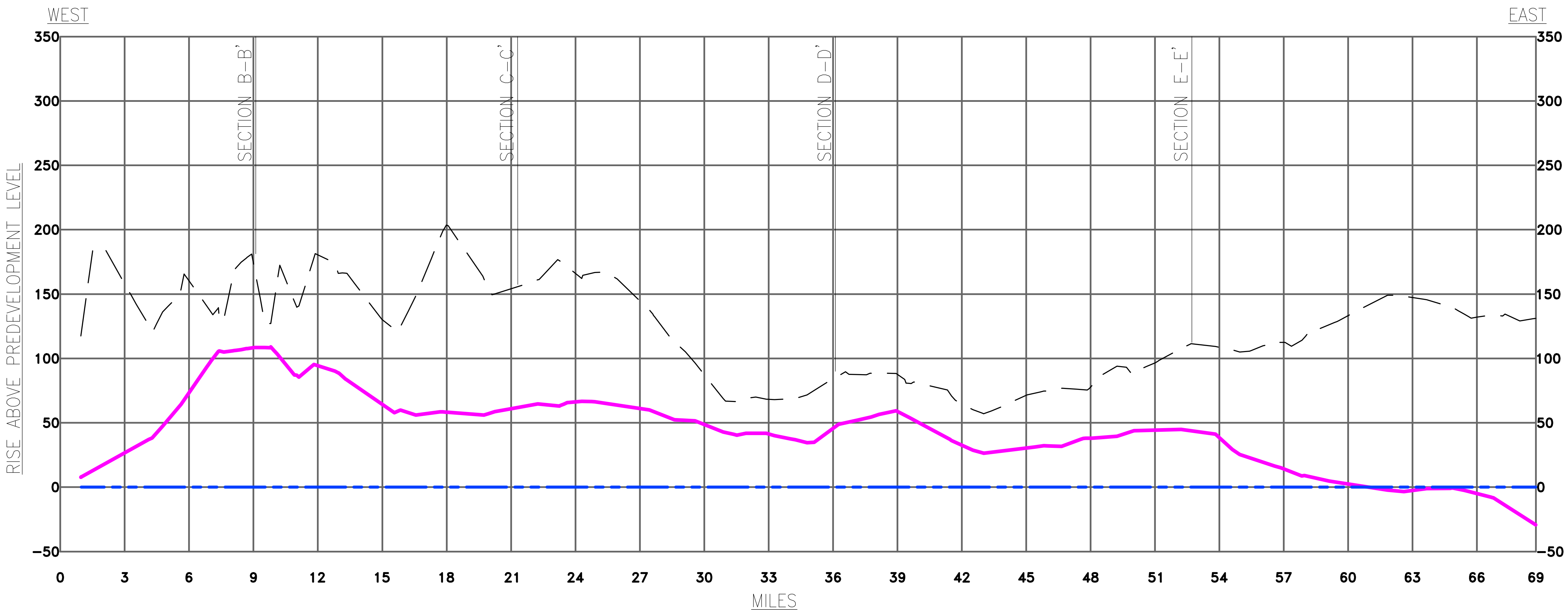


GROUNDWATER MOUND CONTOURS
2007

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2007-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2007 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

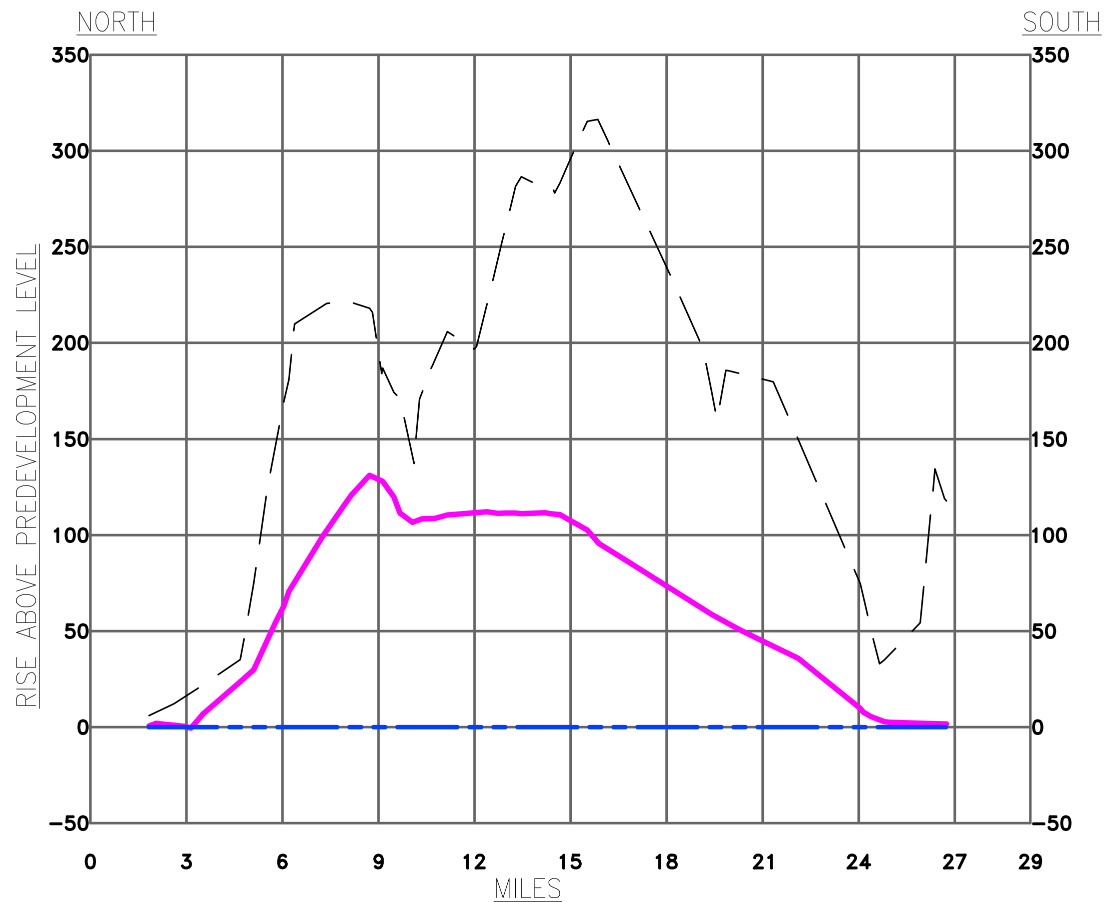
GROUNDWATER LEVELS 2007 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

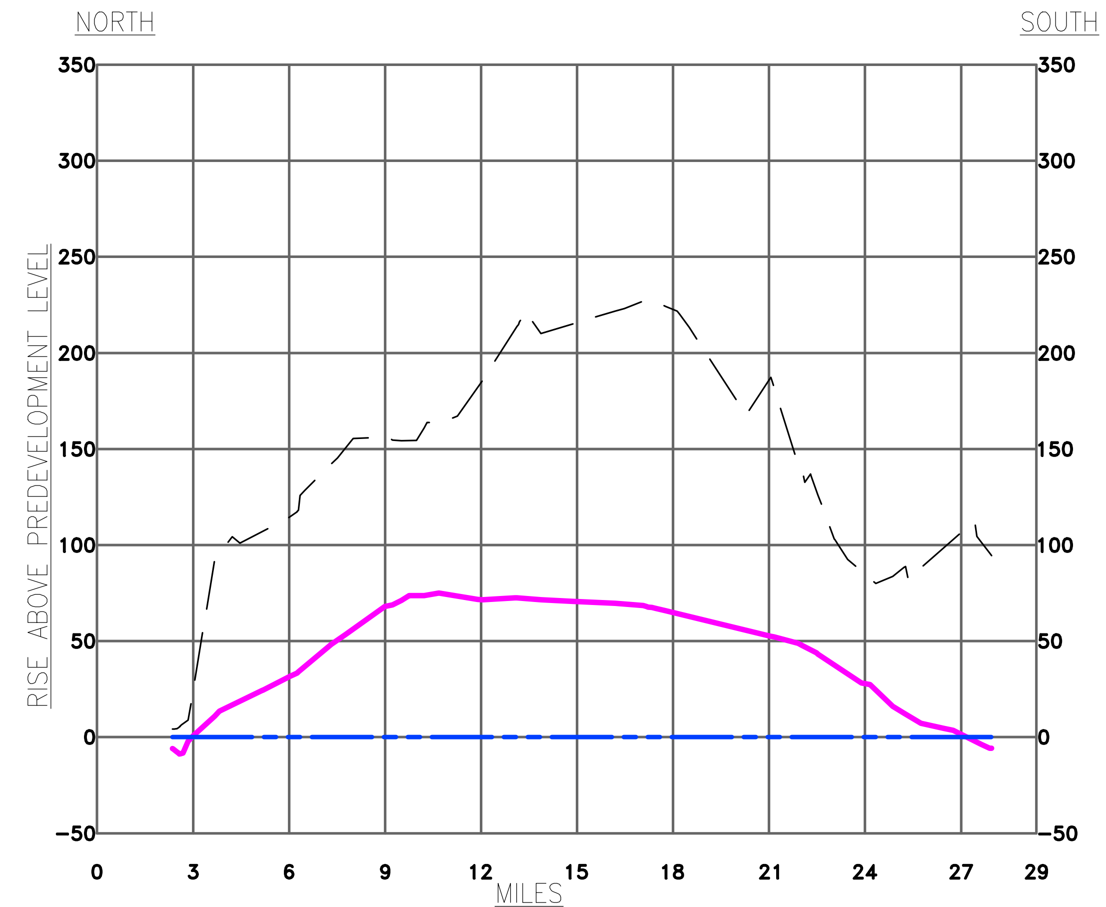
EA Engineering, Science, and Technology, Inc.

FIGURE	F2007-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2007 Sections.dwg
DATE:11/21/2013 TIME:18:20 DRAWN BY: cswanson



SECTION B-B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:
PREDEVELOPMENT GROUNDWATER LEVEL
2007 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

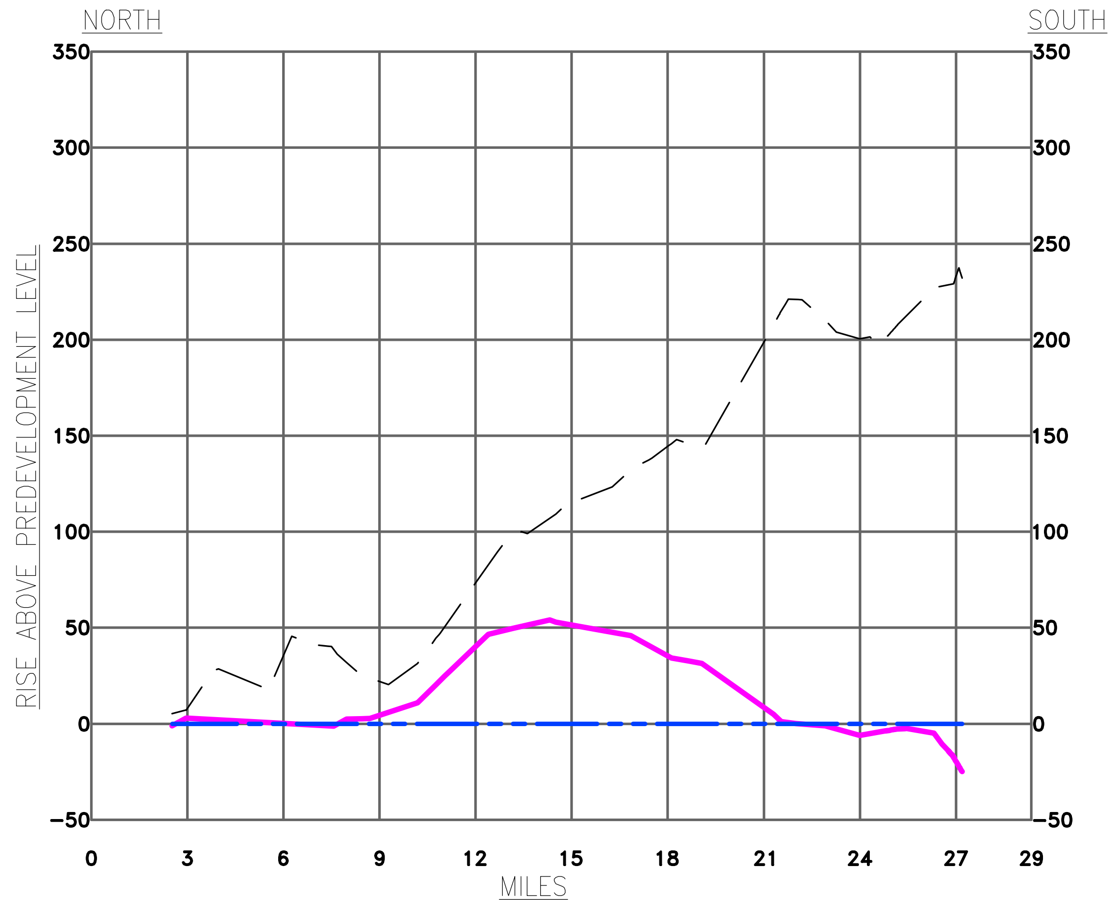
GROUNDWATER LEVELS
2007 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

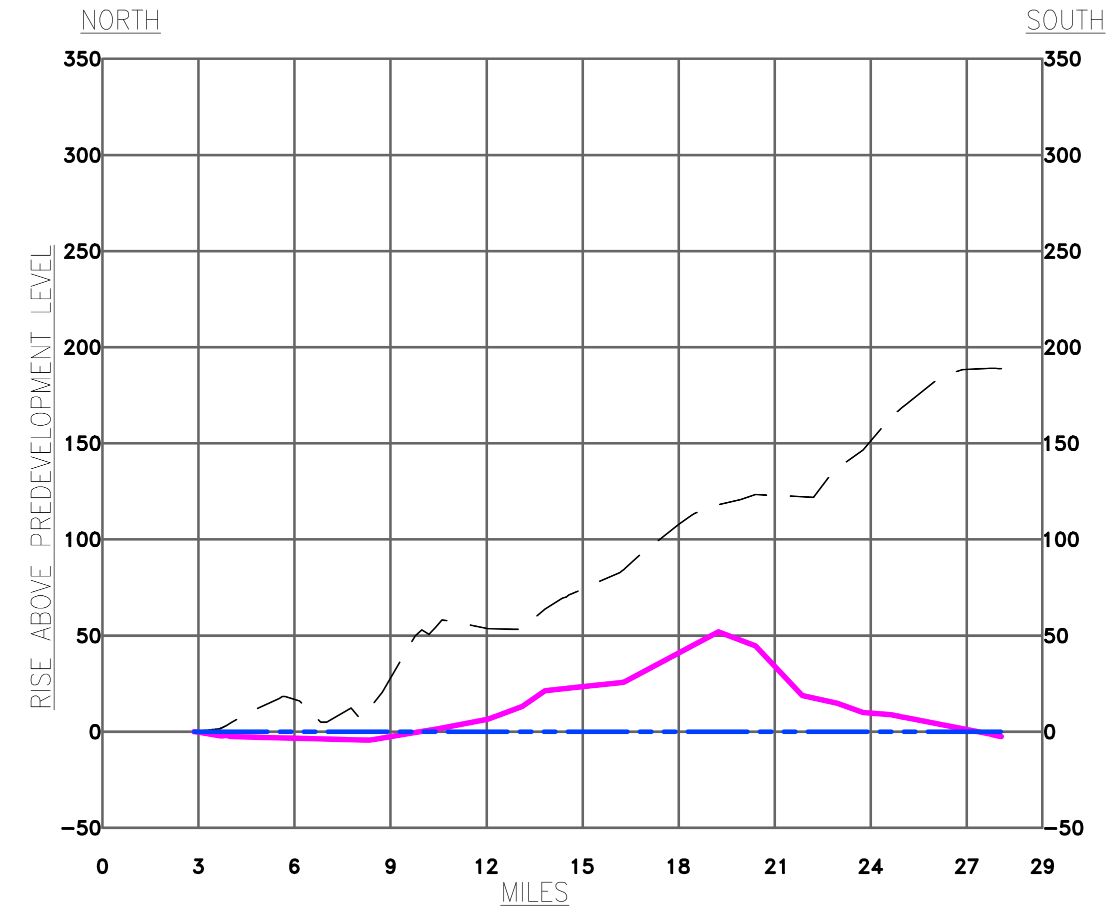
EA Engineering, Science, and Technology, Inc.®

PROJECT MGR.	DJS
DESIGNED BY	CNS
DRAWN BY	PLS
CHECKED BY	DJS
DATE	DEC 2013
SCALE	AS SHOWN
PROJECT NO.	1500301
FILE NAME	-
DRAWING NO.	-
FIGURE	F2007-3

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2007 Sections.dwg
DATE:11/21/2013 TIME:18:20 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL
2007 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

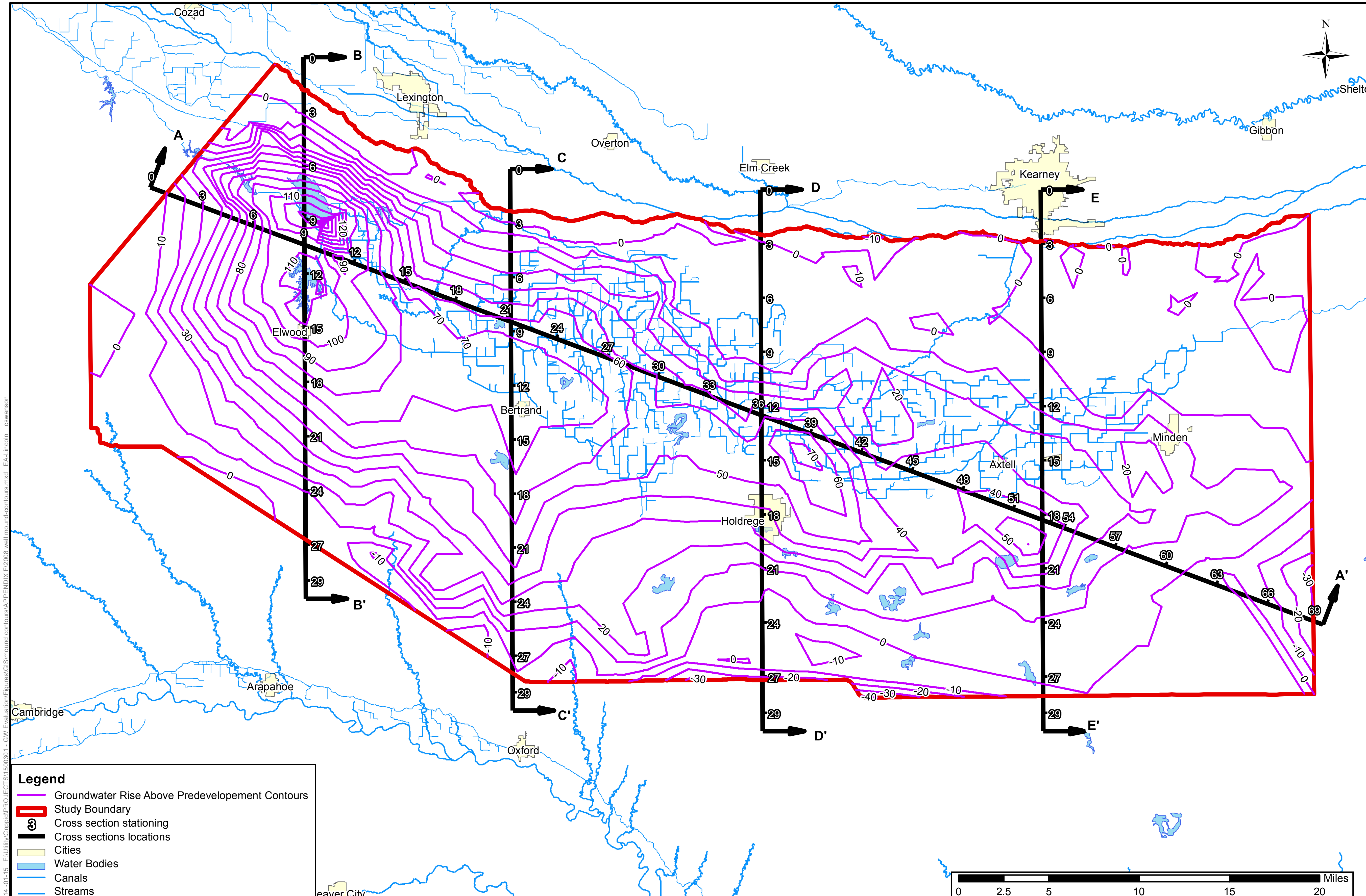
GROUNDWATER LEVELS
2007 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2007-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2007 Sections.dwg
DATE:11/21/2013 TIME:18:20 DRAWN BY:cswanson

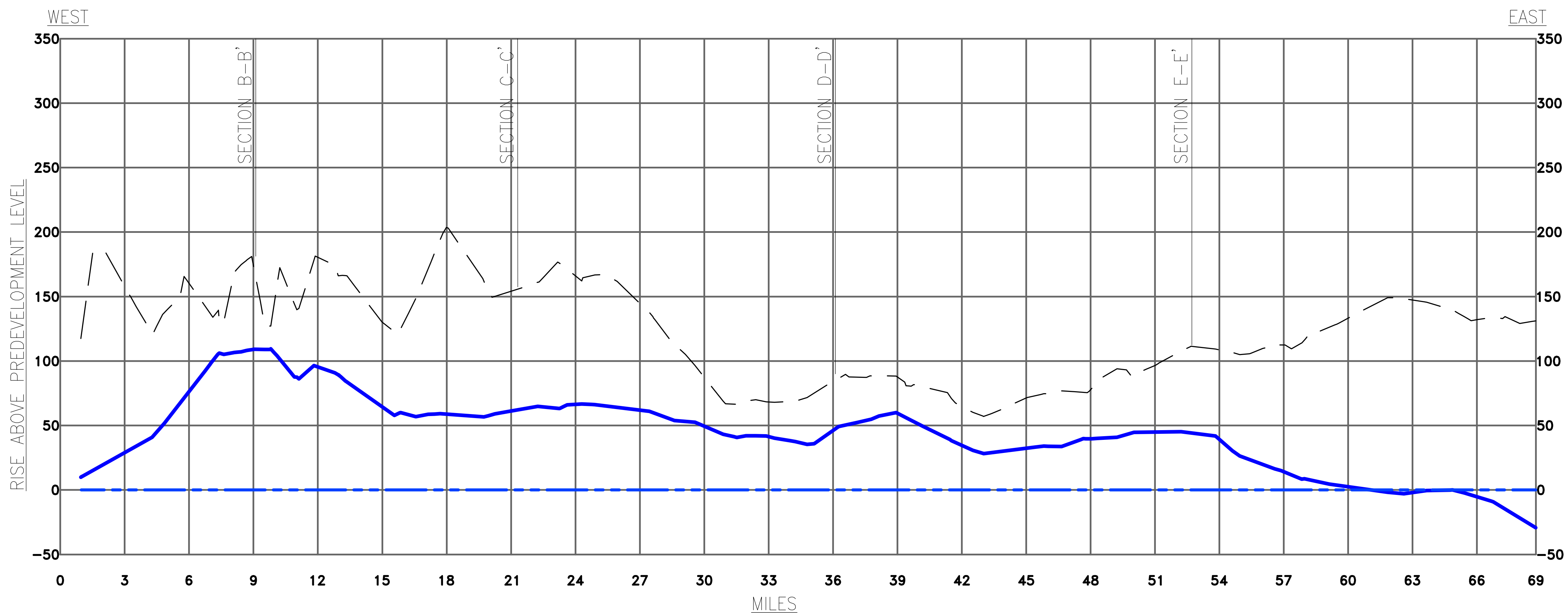


GROUNDWATER MOUND CONTOURS
2008

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2008-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2008 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

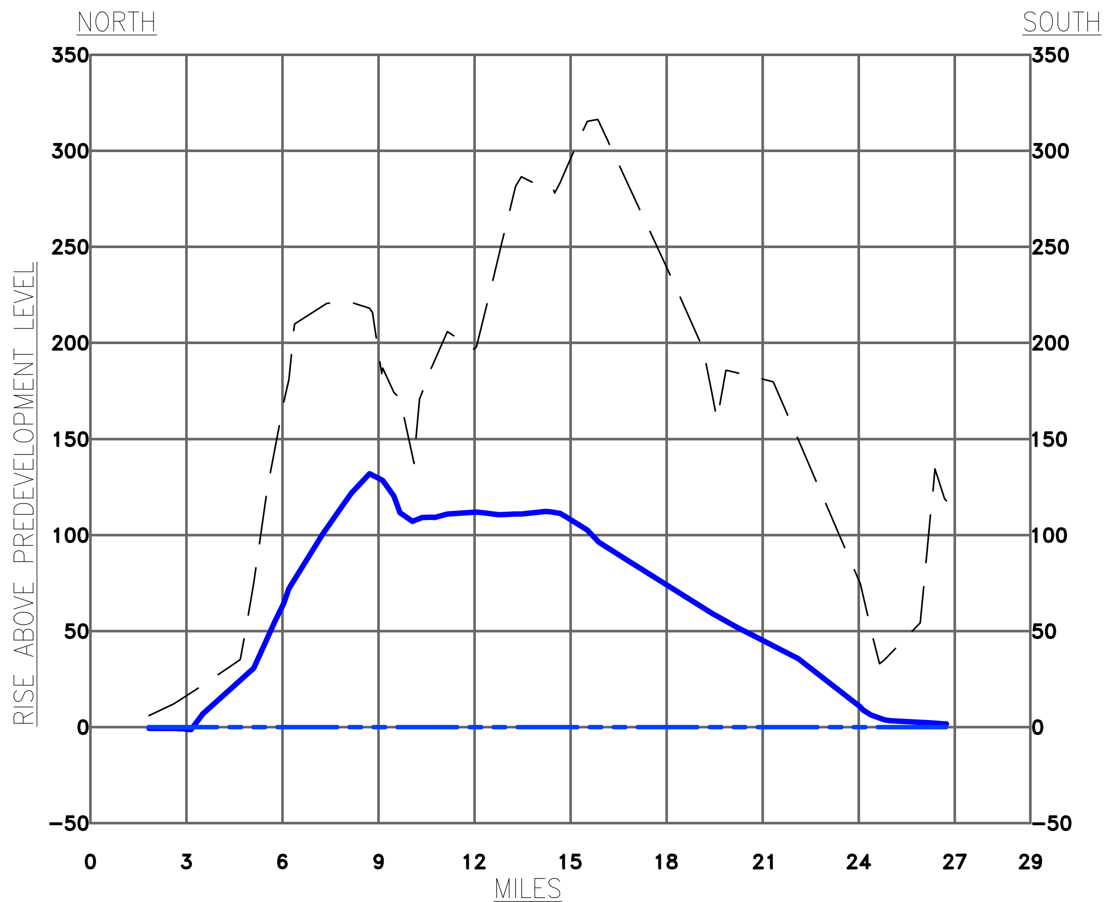
GROUNDWATER LEVELS
2008 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

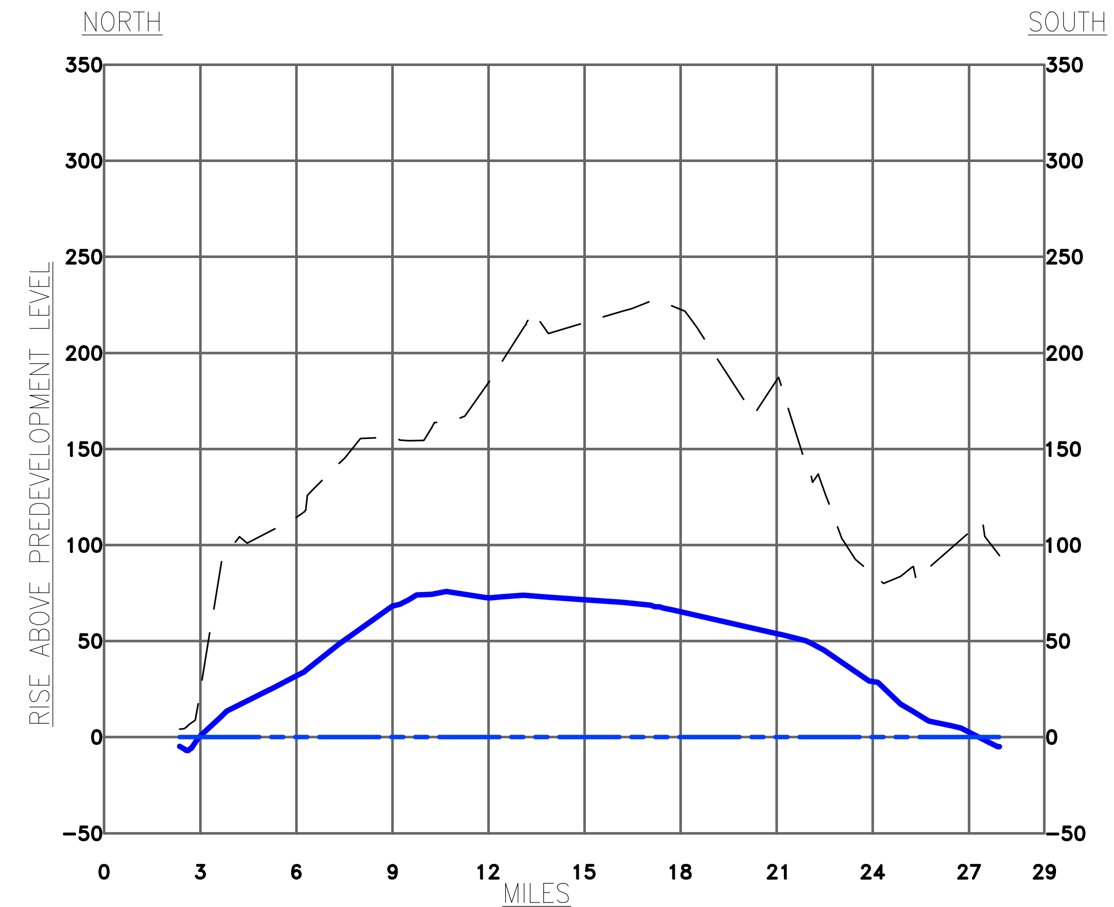
EA Engineering, Science, and Technology, Inc.®

FIGURE	F2008-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2008 Sections.dwg
DATE:11/21/2013 TIME:18:25 DRAWN BY: cswanson



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2008 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

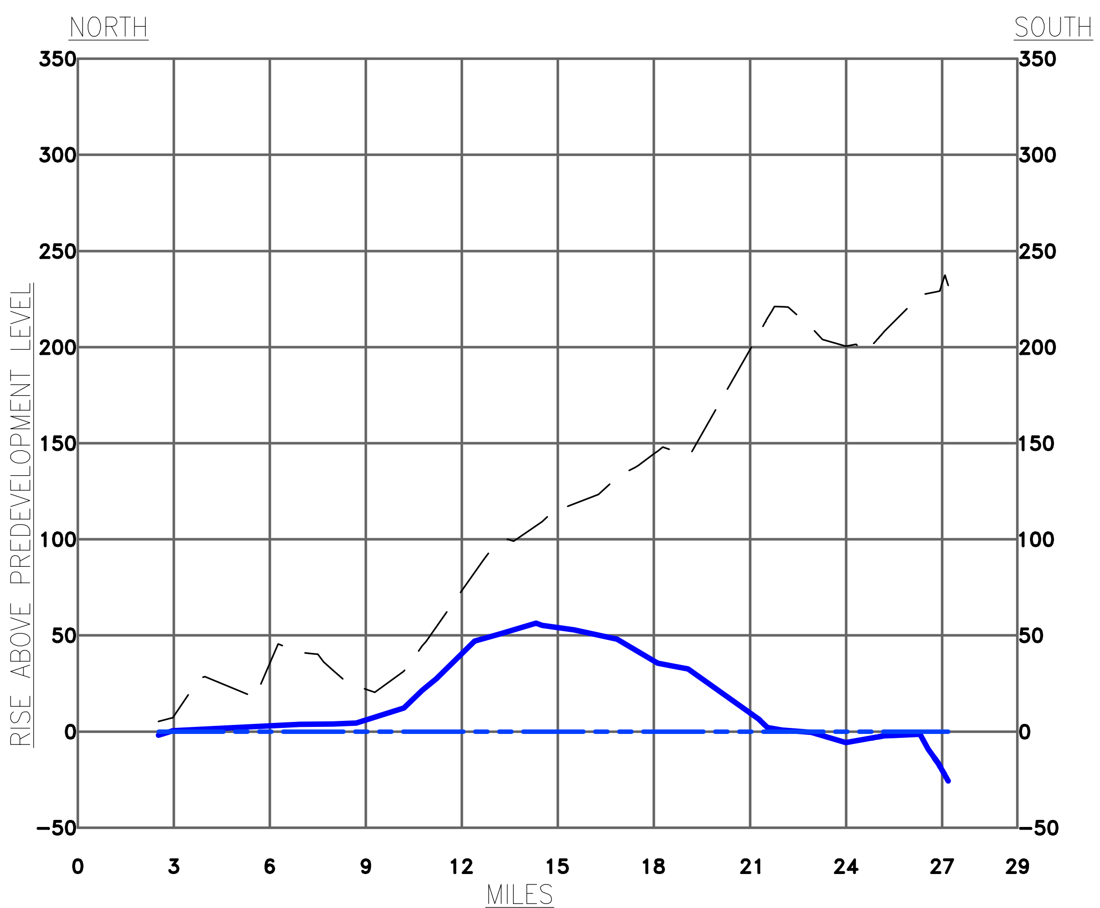
GROUNDWATER LEVELS
2008 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

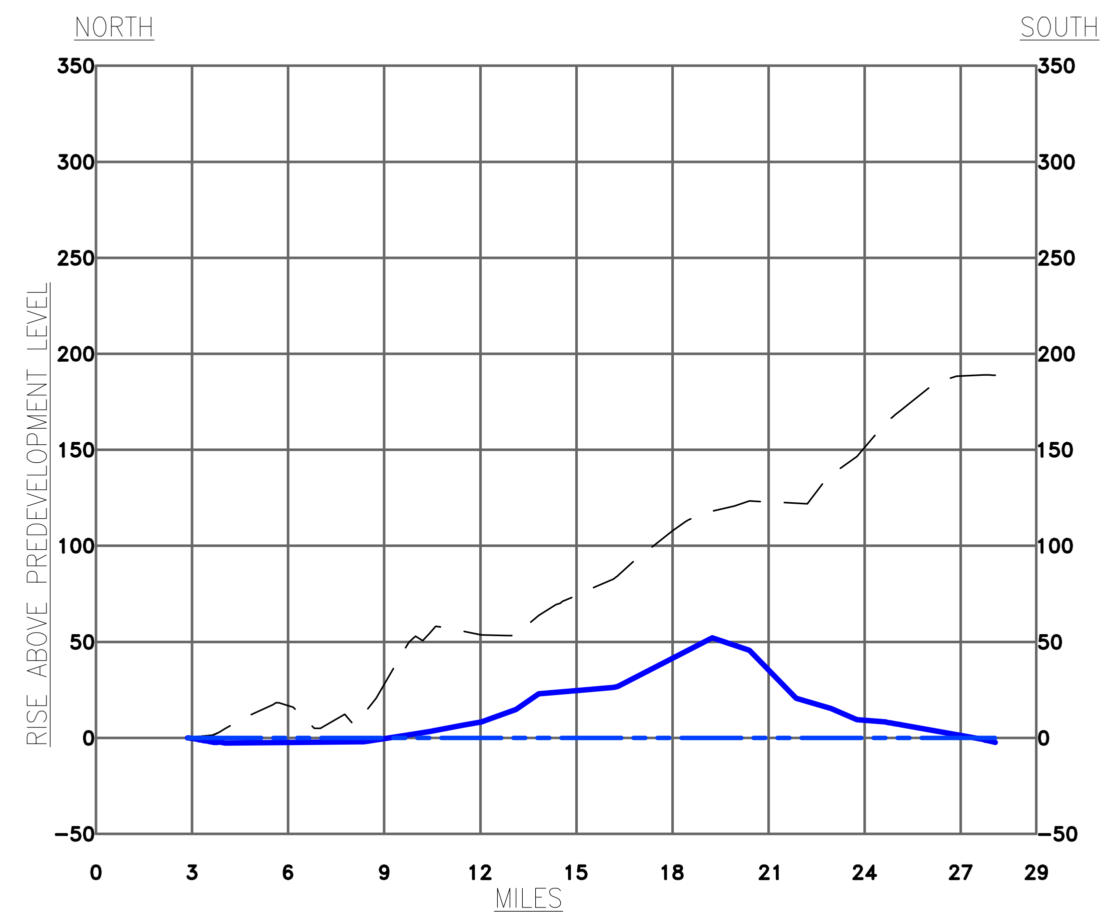
EA Engineering, Science, and Technology, Inc.®

FIGURE	F2008-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2008 Sections.dwg
DATE:11/21/2013 TIME:18:25 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

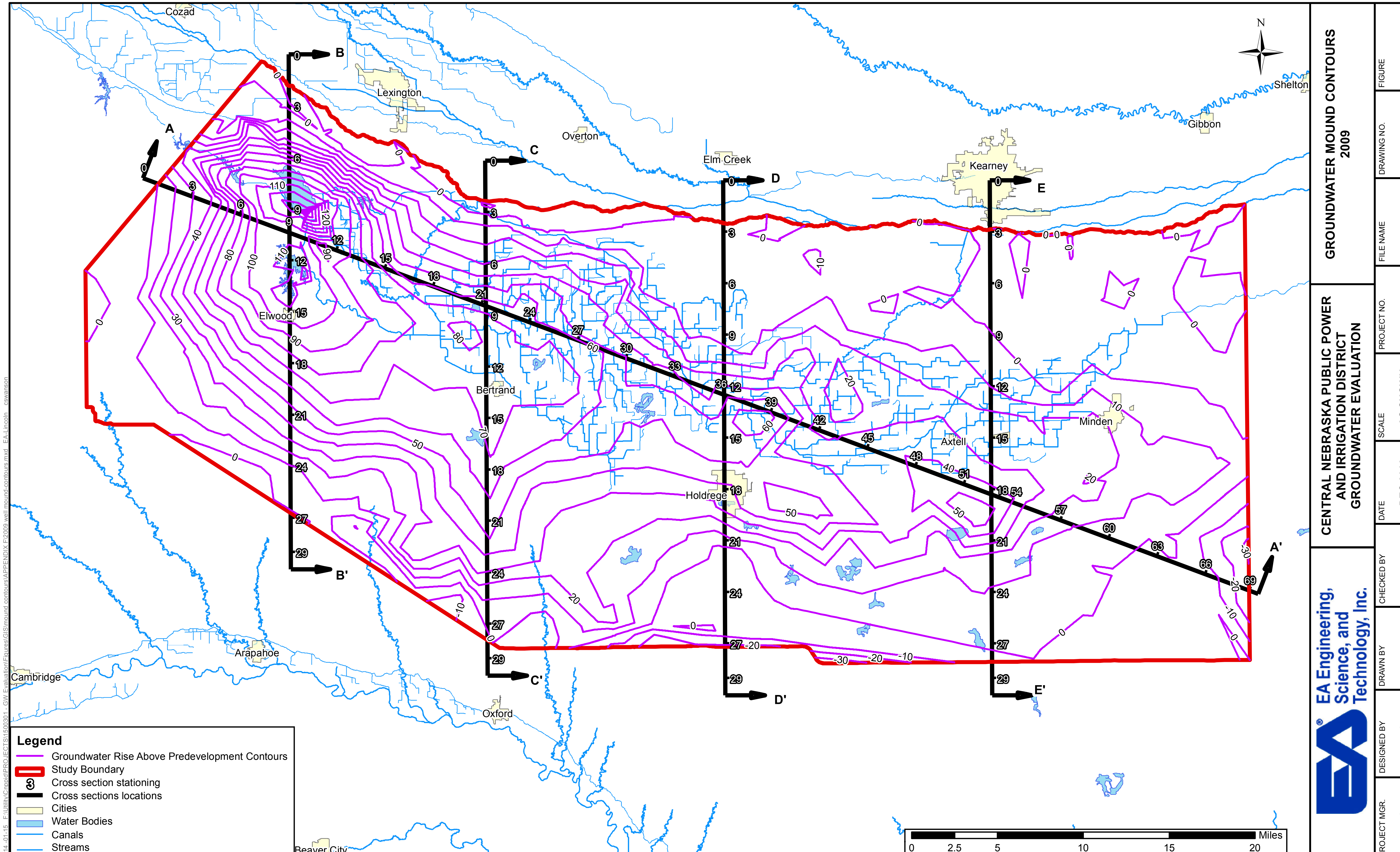
PREDEVELOPMENT GROUNDWATER LEVEL
2008 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2008 CROSS SECTIONS

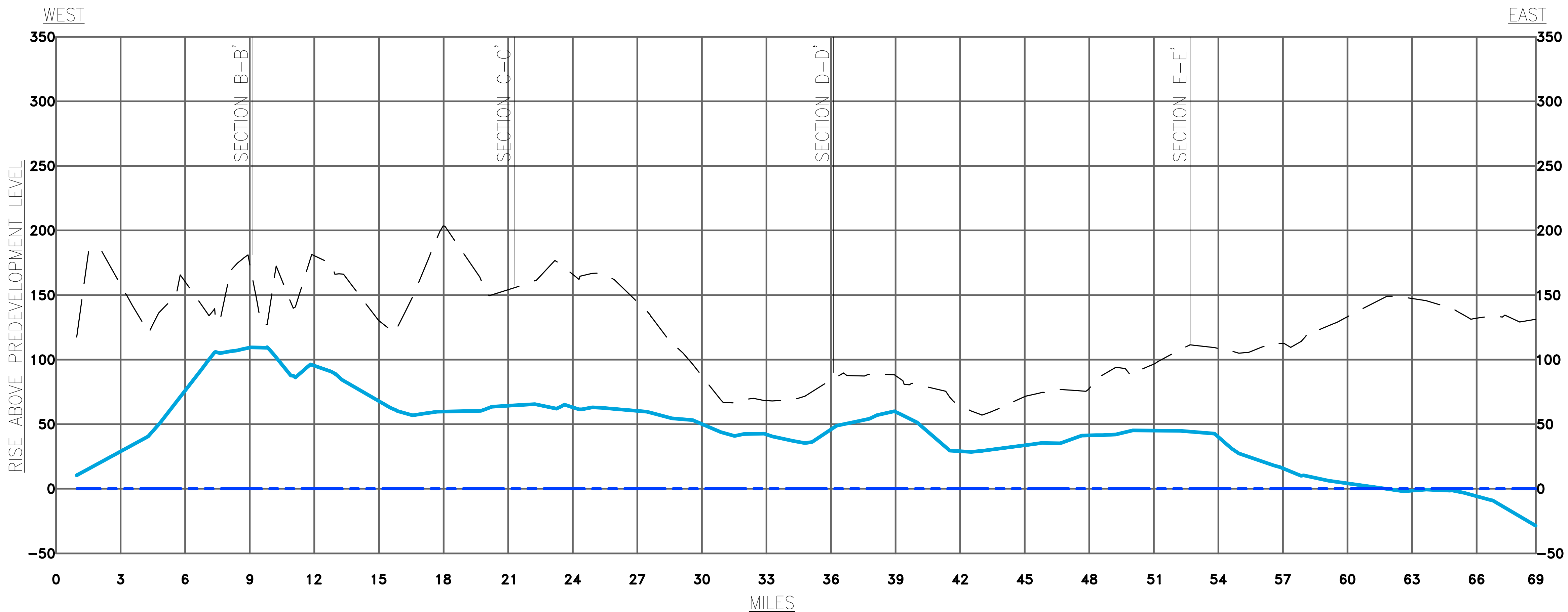
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	PLS	DJS	DEC 2013	AS SHOWN	1500301	-	-	F2008-4



GROUNDWATER MOUND CONTOURS
2009
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION
EA Engineering, Science, and Technology, Inc.
FIGURE F2009-1
DRAWING NO. –
FILE NAME –
PROJECT NO. 1500301
SCALE AS SHOWN
DATE DEC 2013
CHECKED BY DJS
DRAWN BY DMM
DESIGNED BY DJS
PROJECT MGR. DJS
Legend
Groundwater Rise Above Predevelopment Contours
Study Boundary
Cross section stationing
Cross sections locations
Cities
Water Bodies
Canals
Streams
Miles
0
2.5
5
10
15
20
N
Cozad
Lexington
Overton
Elm Creek
Kearney
Gibbon
Shelton
Elwood
Bertrand
Holdrege
Axtell
Minden
Arapahoe
Cambridge
Oxford
Beaver City
A
A'
B
B'
C
C'
D
D'
E
E'



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2009 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

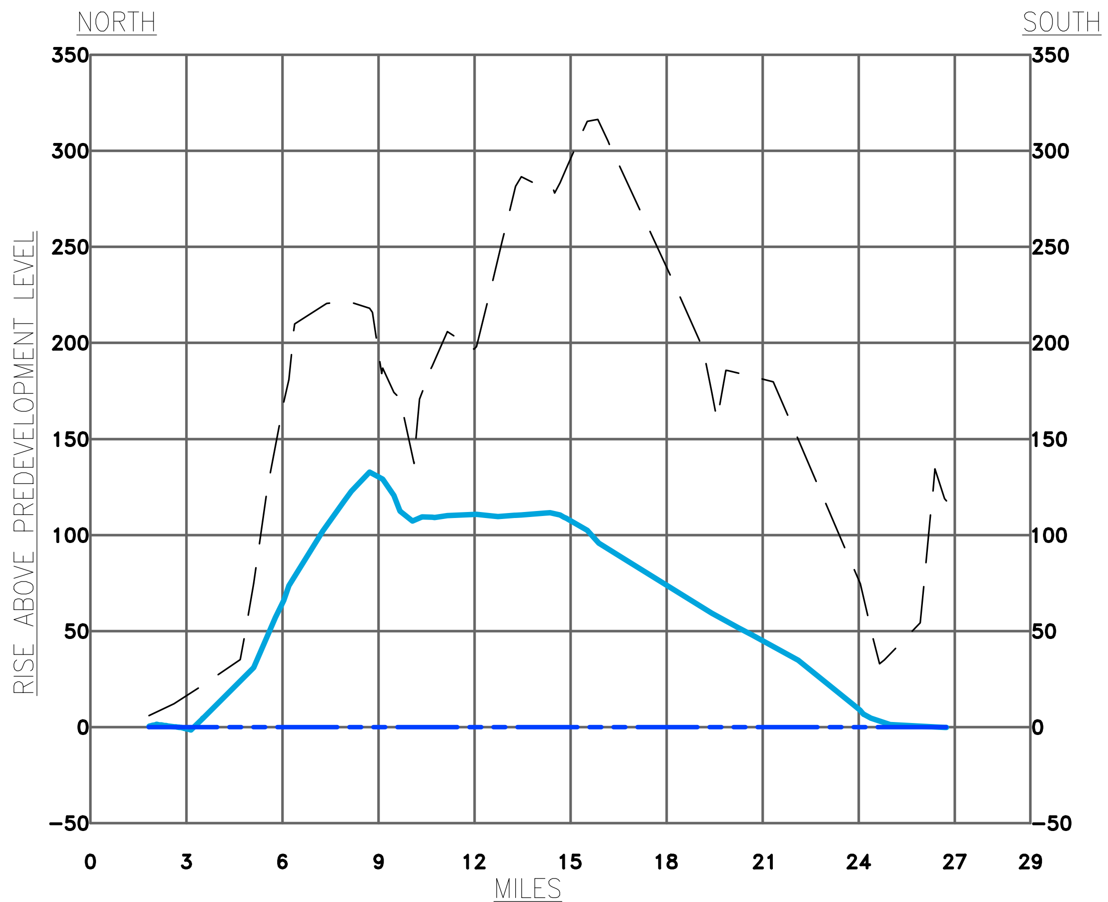
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2009 Sections.dwg
DATE:11/21/2013 TIME:18:32 DRAWN BY: cswanson

GROUNDWATER LEVELS
2009 CROSS SECTIONS

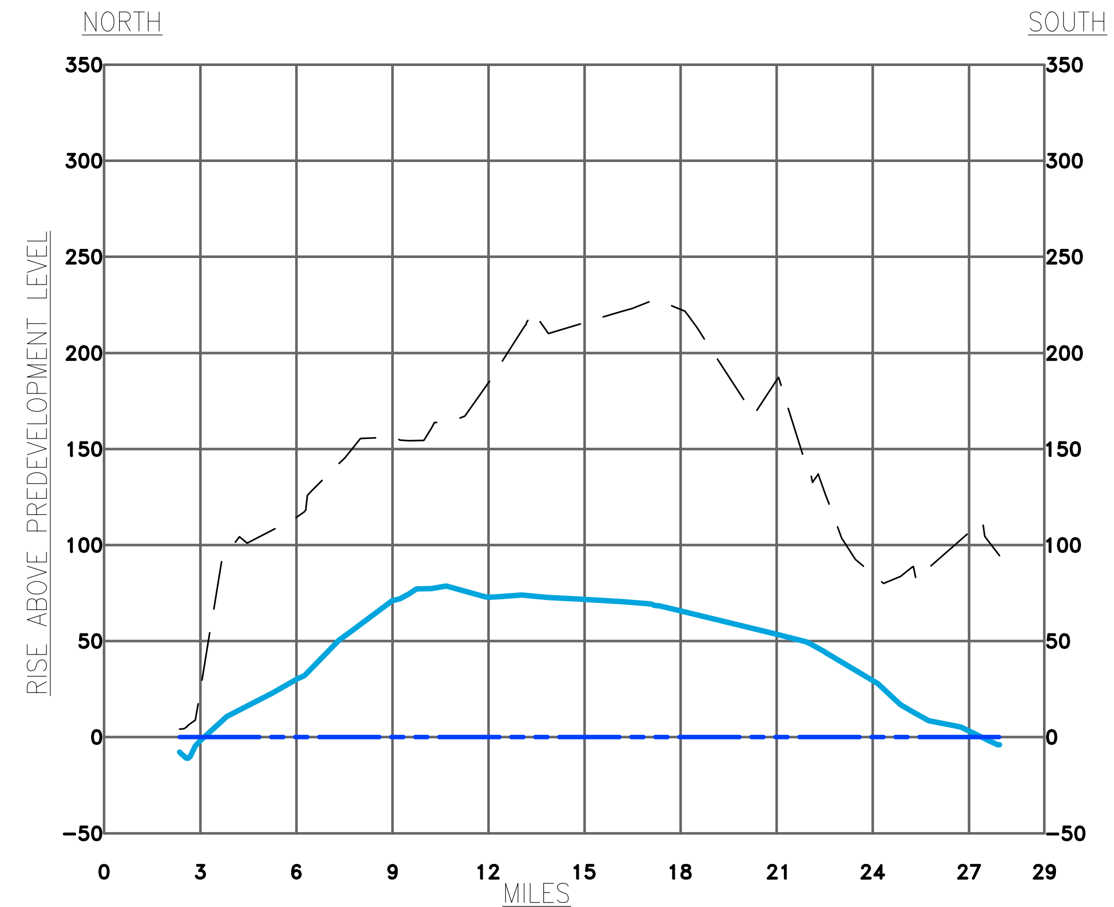
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA® **EA Engineering, Science, and Technology, Inc.**

FIGURE	F2009-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



SECTION B–B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C–C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2009 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

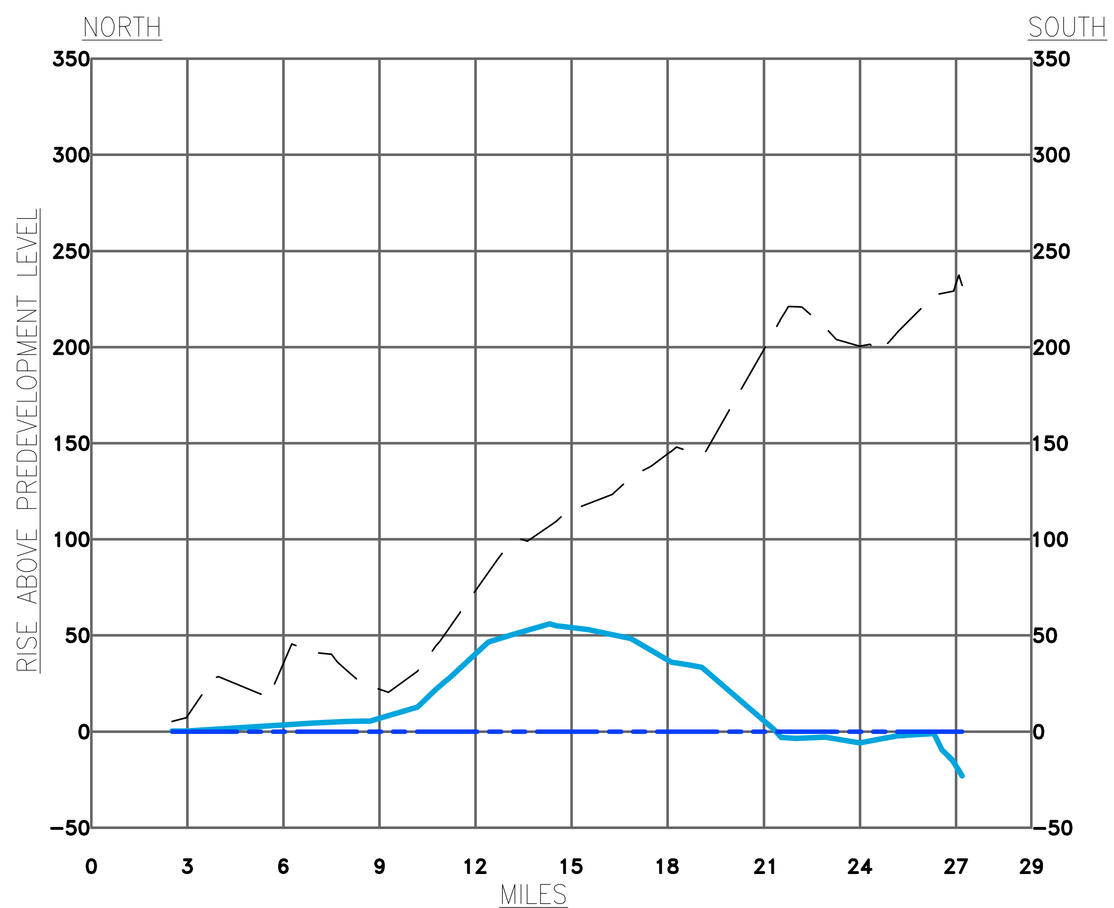
GROUNDWATER LEVELS
2009 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

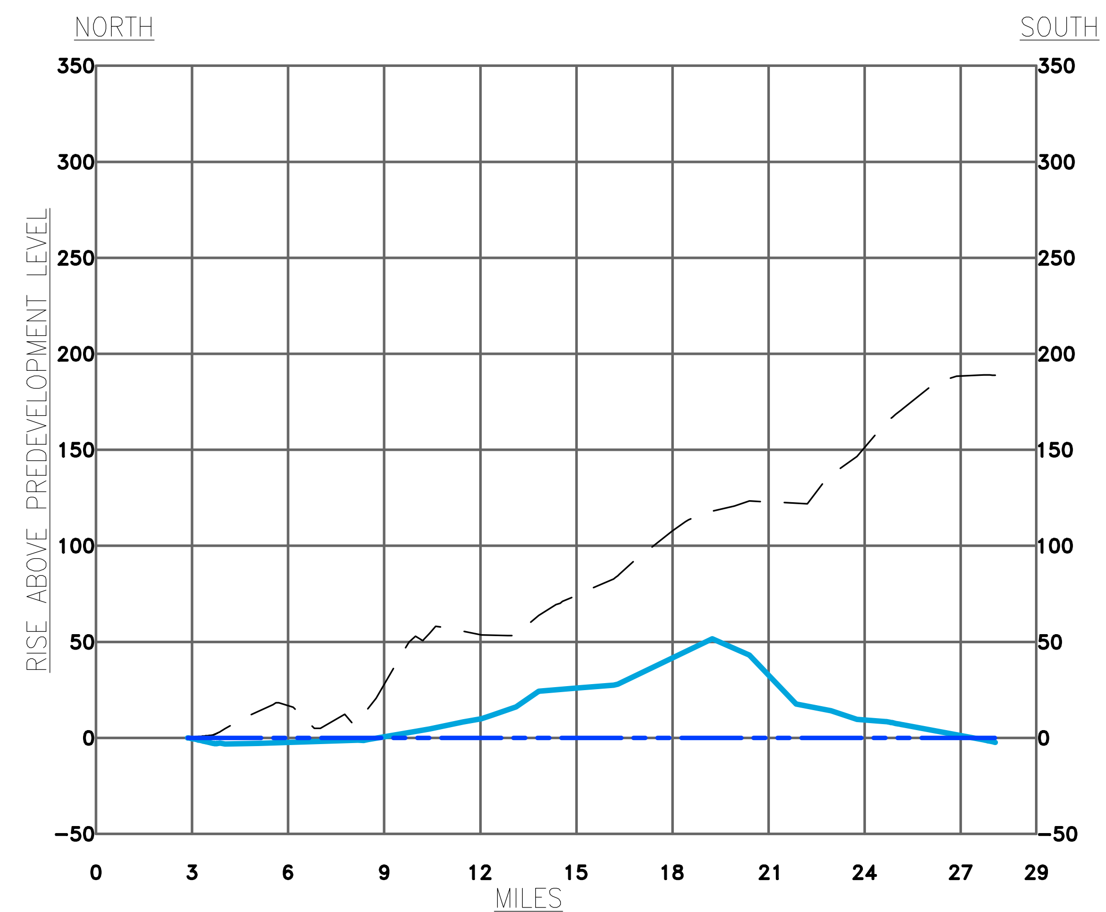
EA Engineering,
Science, and
Technology, Inc.

FIGURE	F2009-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2009 Sections.dwg
DATE:11/21/2013 TIME:18:32 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2009 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2009 Sections.dwg
DATE:11/21/2013 TIME:18:32 DRAWN BY: cswanson

GROUNDWATER LEVELS
2009 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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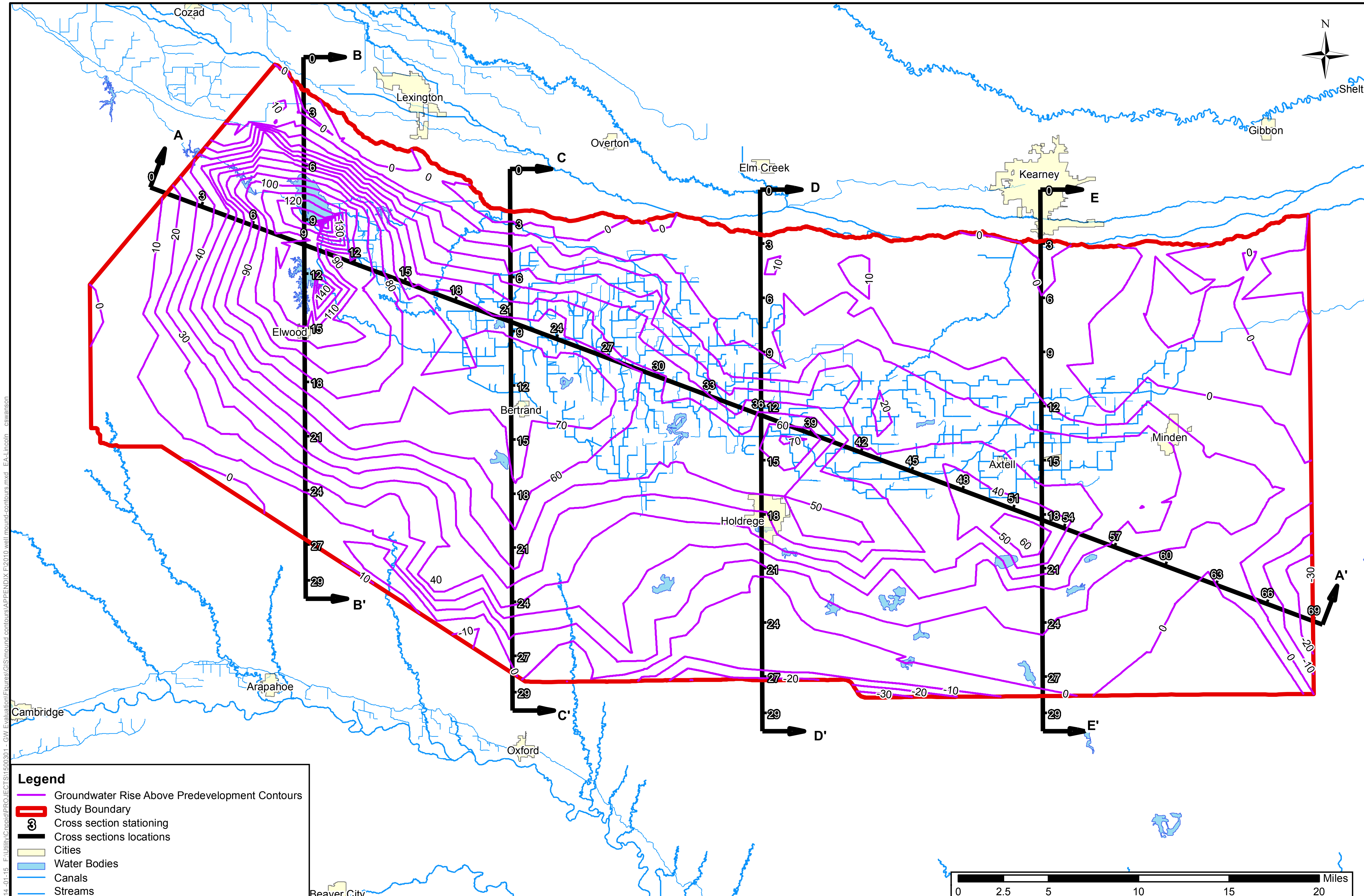
FIGURE	F2009-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

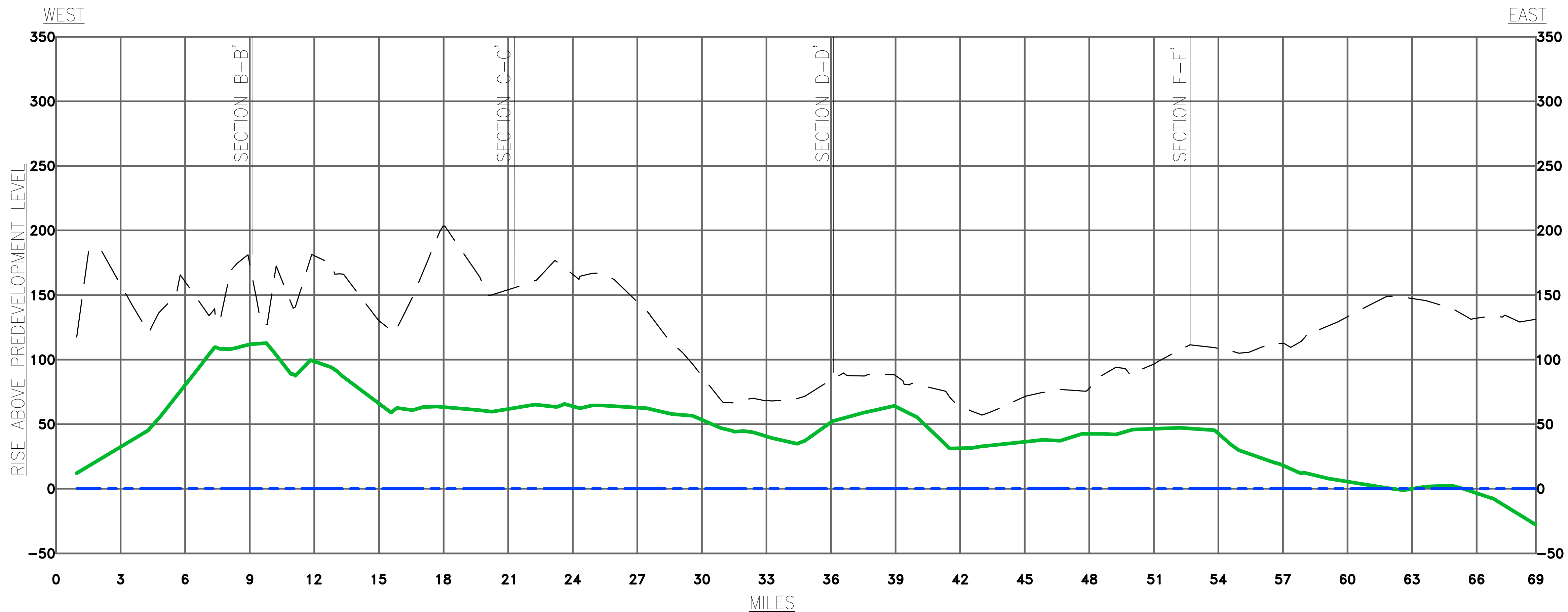


GROUNDWATER MOUND CONTOURS
2010

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2010-1
DRAWING NO.	–
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2010 GROUNDWATER RISE

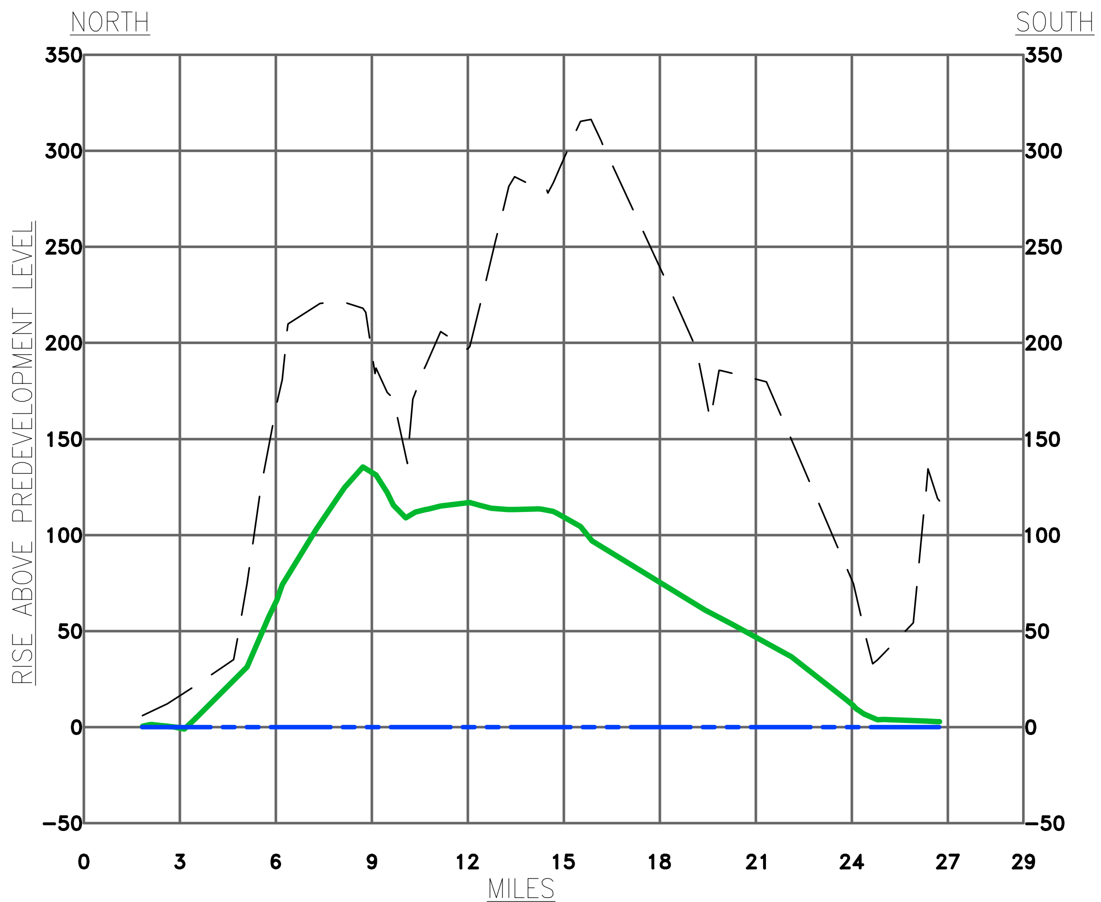
APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2010 CROSS SECTIONS

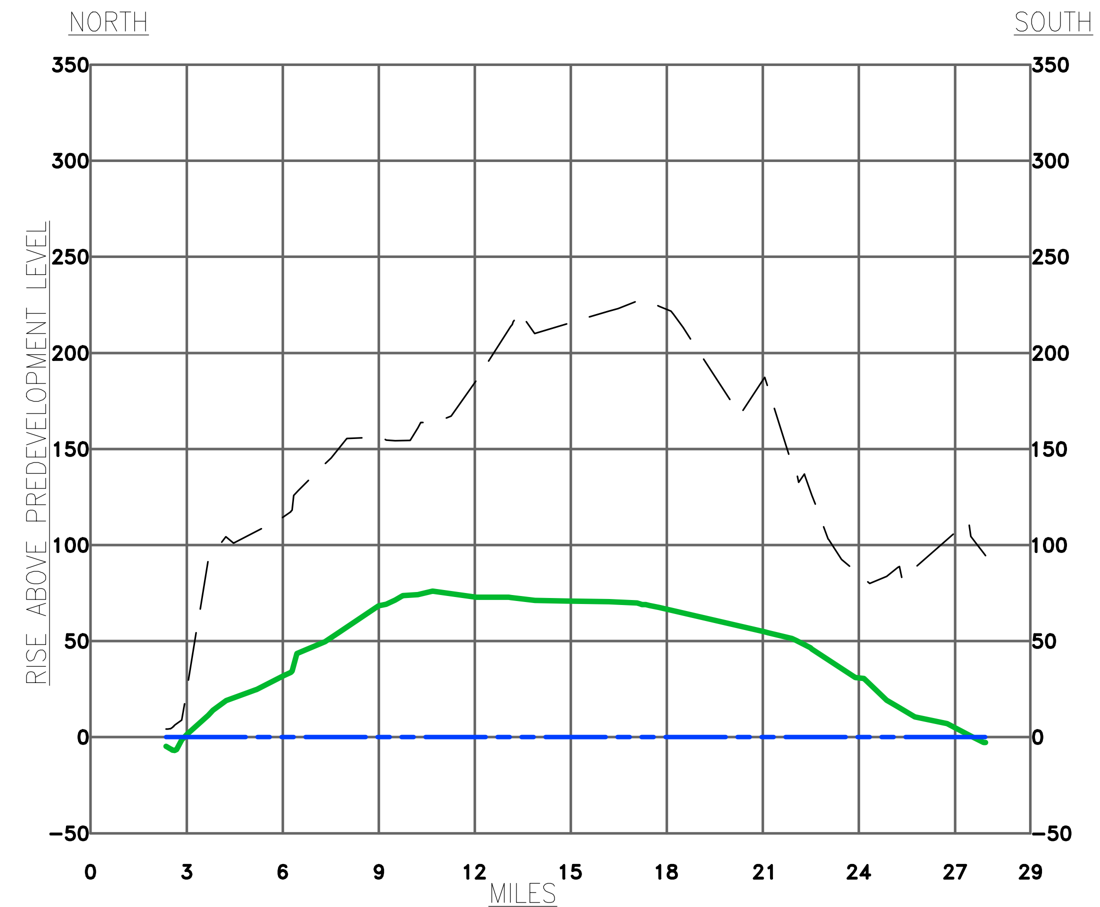
CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2010-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



SECTION B-B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2010 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2010 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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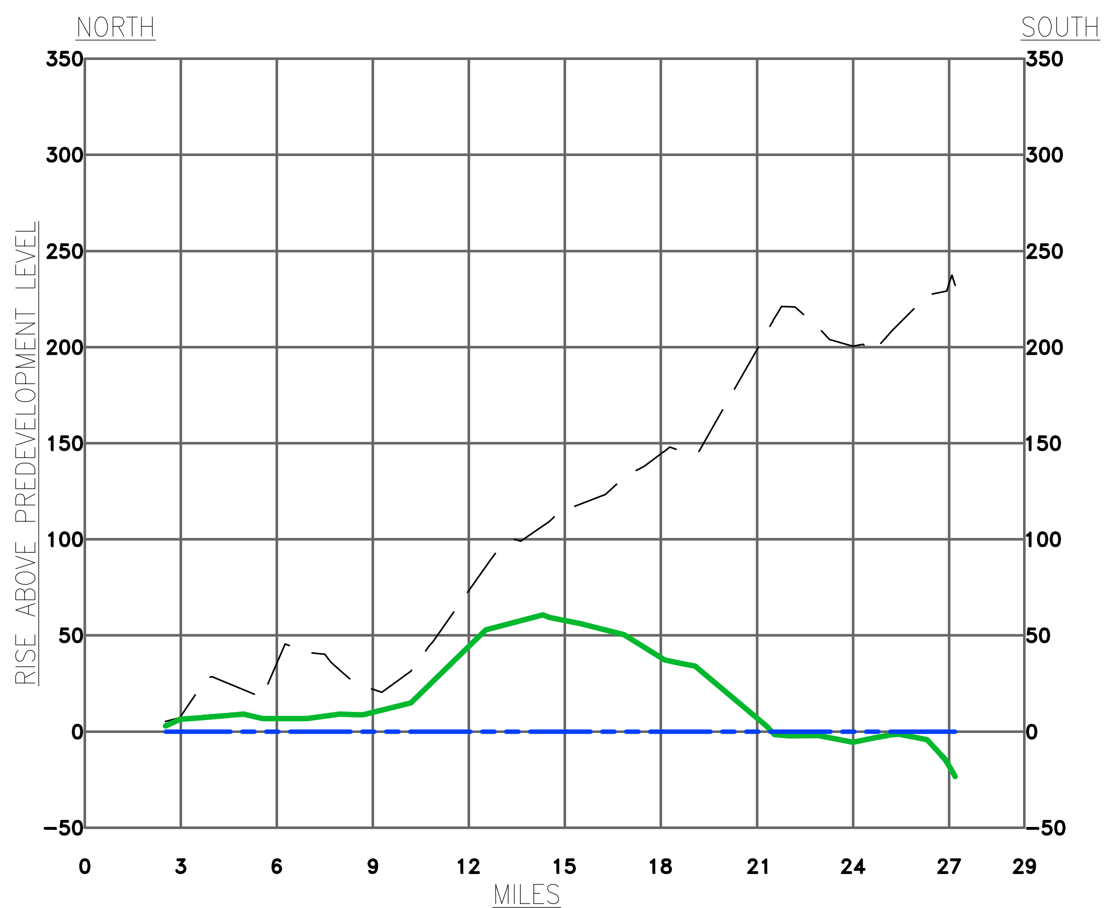
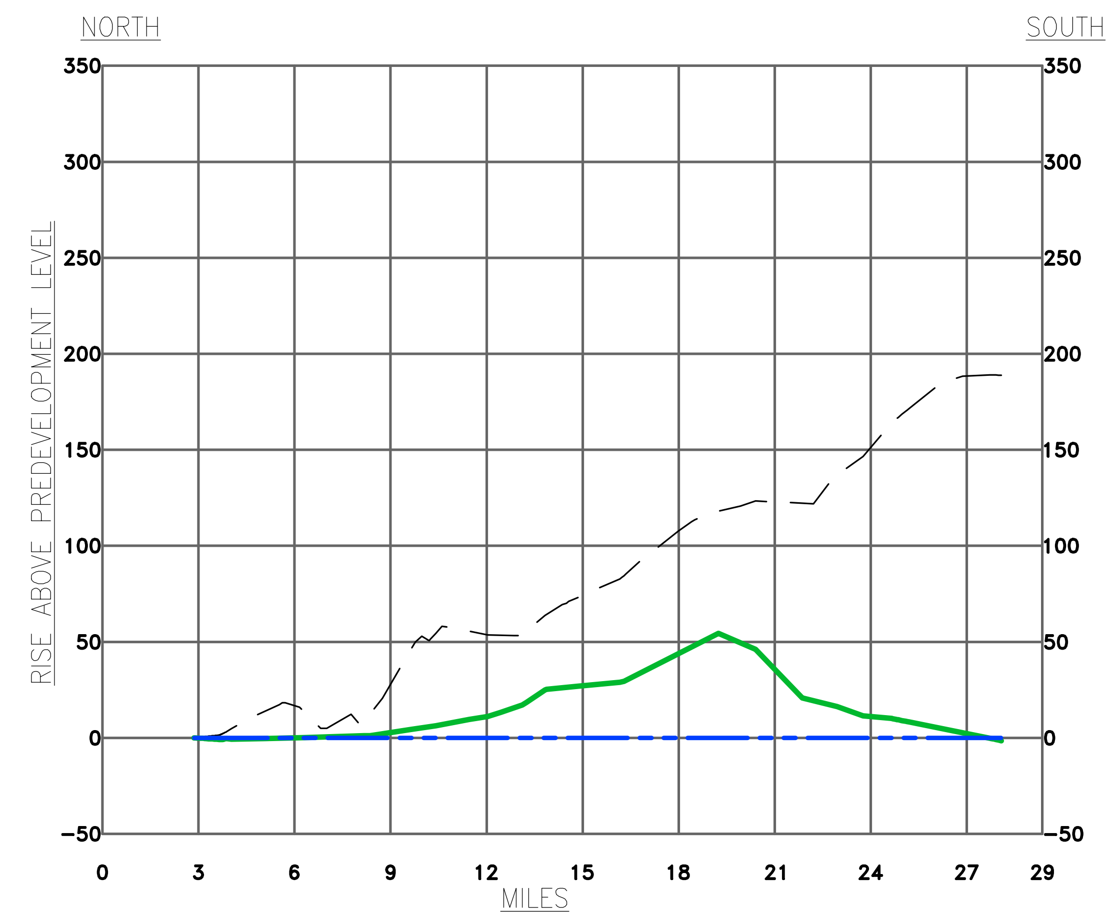


SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

- PREDEVELOPMENT GROUNDWATER LEVEL
- 2010 GROUNDWATER RISE
- APPROXIMATE GROUND SURFACE

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2010 Sections.dwg
DATE:11/21/2013 TIME:18:38 DRAWN BY:cswanson

GROUNDWATER LEVELS
2010 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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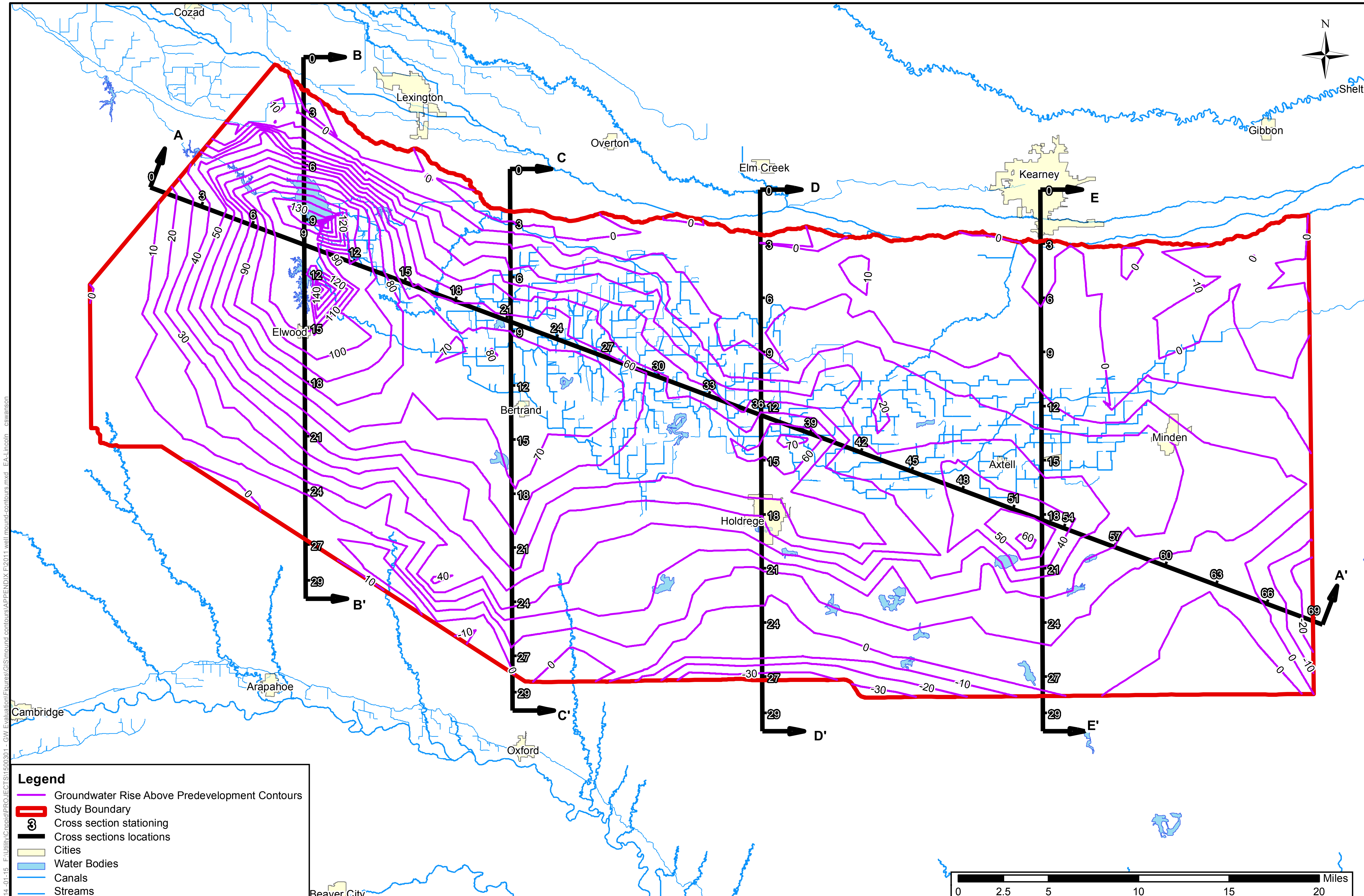

GROUNDWATER MOUND CONTOURS 2011

CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

FIGURE	F2011-1
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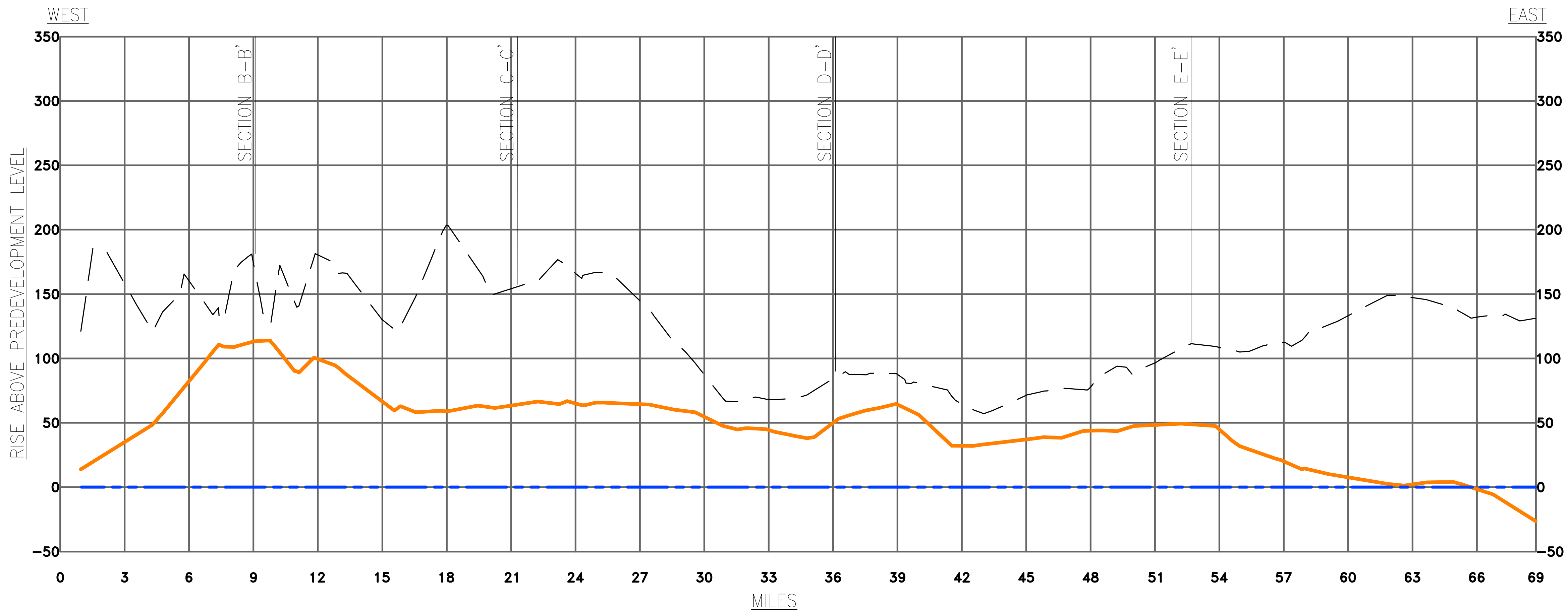
FILE NAME	–
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	DMM
DESIGNED BY	DJS
PROJECT MGR.	DJS



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2011 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2011 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
Science, and
Technology, Inc.

FIGURE	DRAWING NO.	FILE NAME	PROJECT NO.	SCALE	DATE	CHECKED BY	DRAWN BY	DESIGNED BY	PROJECT MGR.
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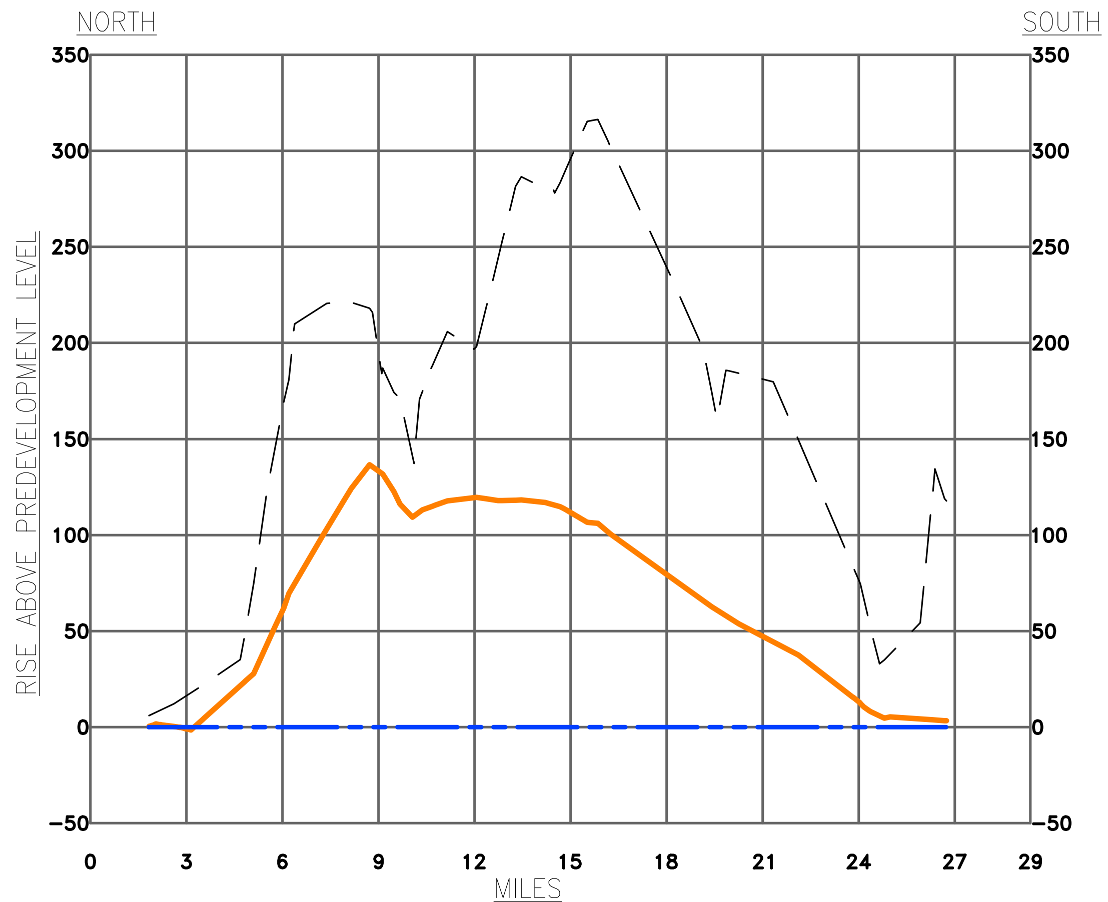

SECTION B-B'
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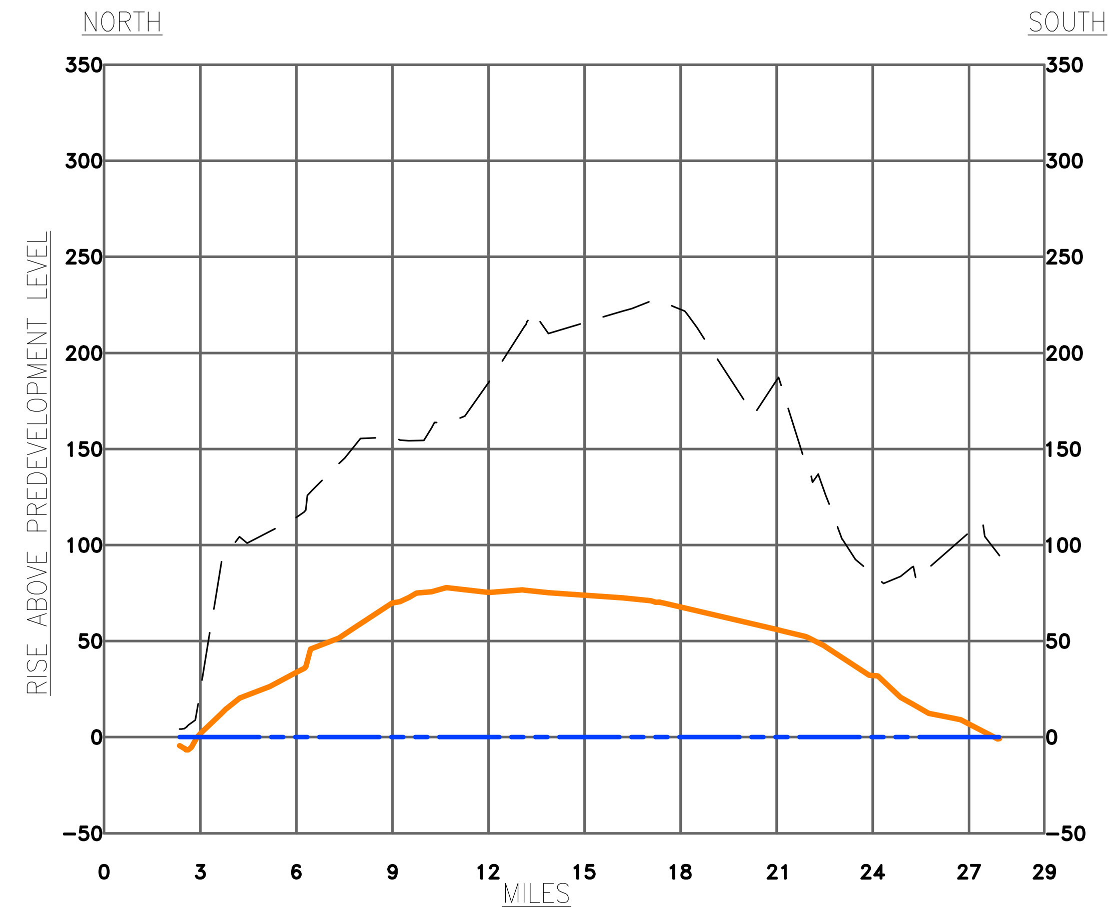
VERTICAL SCALE: 1"=100'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2011 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2011 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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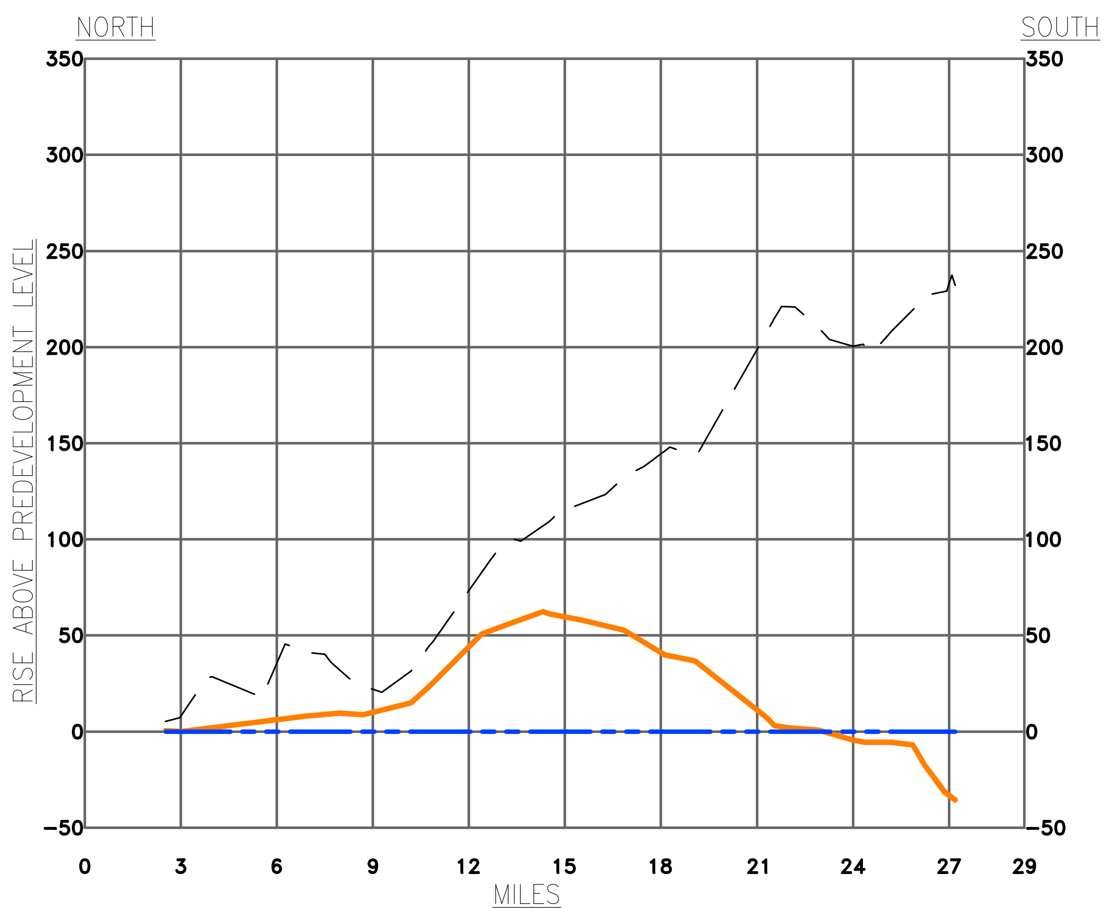
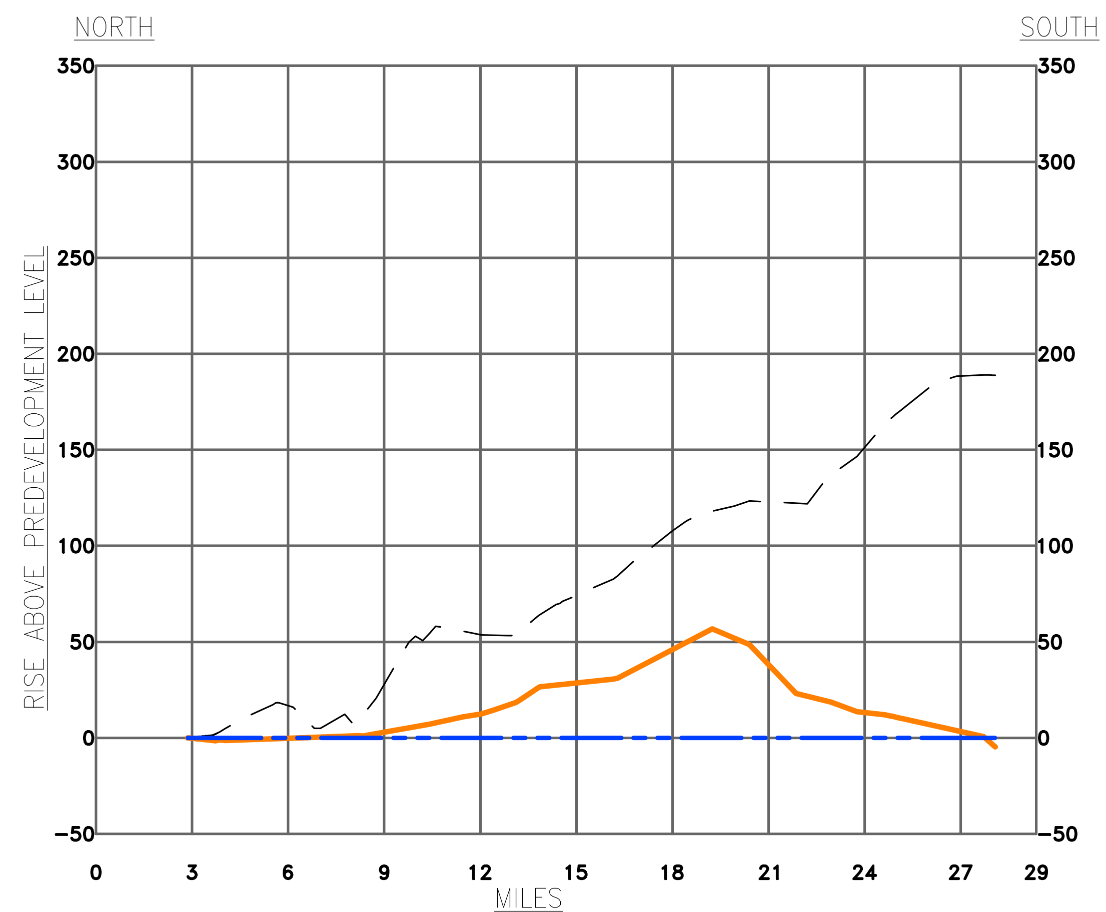
FIGURE	F2011-3
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2011 Sections.dwg
DATE:11/21/2013 TIME:18:45 DRAWN BY: cswanson



SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL
2011 GROUNDWATER RISE
APPROXIMATE GROUND SURFACE

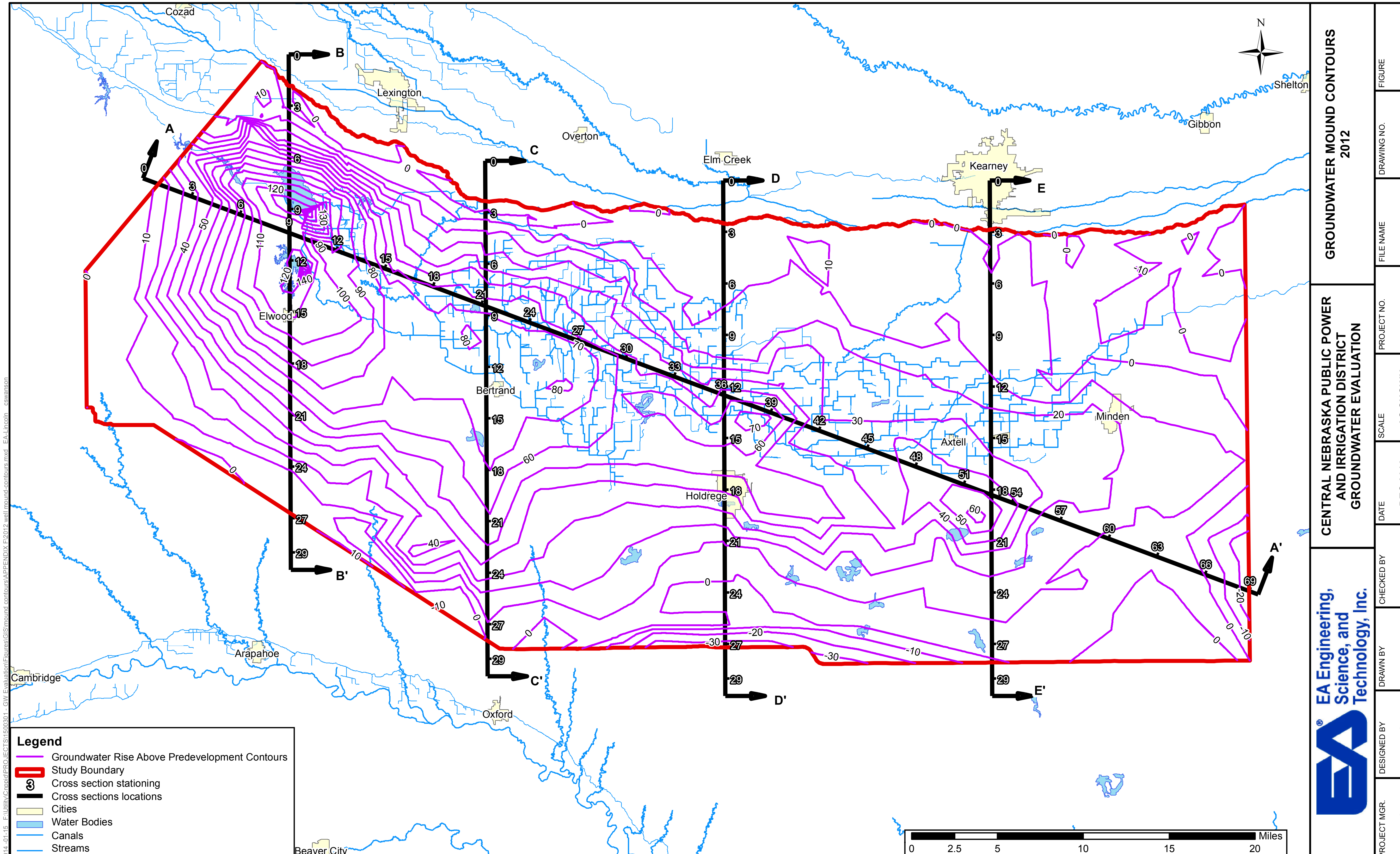
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2011 Sections.dwg
DATE:11/21/2013 TIME:18:45 DRAWN BY: cswanson

GROUNDWATER LEVELS
2011 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2011-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



GROUNDWATER MOUND CONTOURS
2012
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION
EA Engineering, Science, and Technology, Inc.
FIGURE F2012-1
DRAWING NO. –
FILE NAME –
PROJECT NO. 1500301
SCALE AS SHOWN
DATE DEC 2013
CHECKED BY DJS
DRAWN BY DMM
DESIGNED BY DJS
PROJECT MGR. DJS
Legend
Groundwater Rise Above Predevelopment Contours
Study Boundary
Cross section stationing
Cross sections locations
Cities
Water Bodies
Canals
Streams
Miles
0 2.5 5 10 15 20
N
Cozad
Lexington
Overton
Elm Creek
Kearney
Gibbon
Shelton
Elwood
Bertrand
Holdrege
Axtell
Minden
Arapahoe
Cambridge
Oxford
Beaver City
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A'
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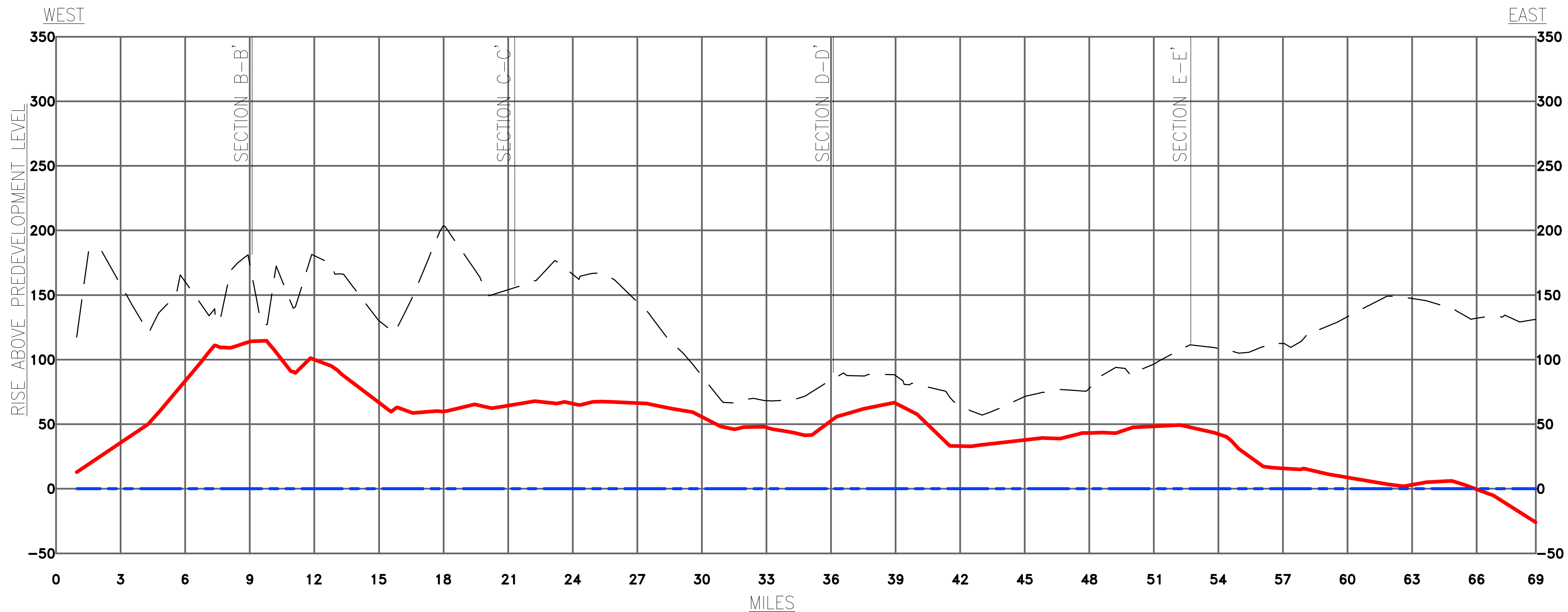
B'
C
C'
D
D'
E
E'



SECTION A–A'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2012 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2012 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
Science, and
Technology, Inc.

FIGURE	F2012-2
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

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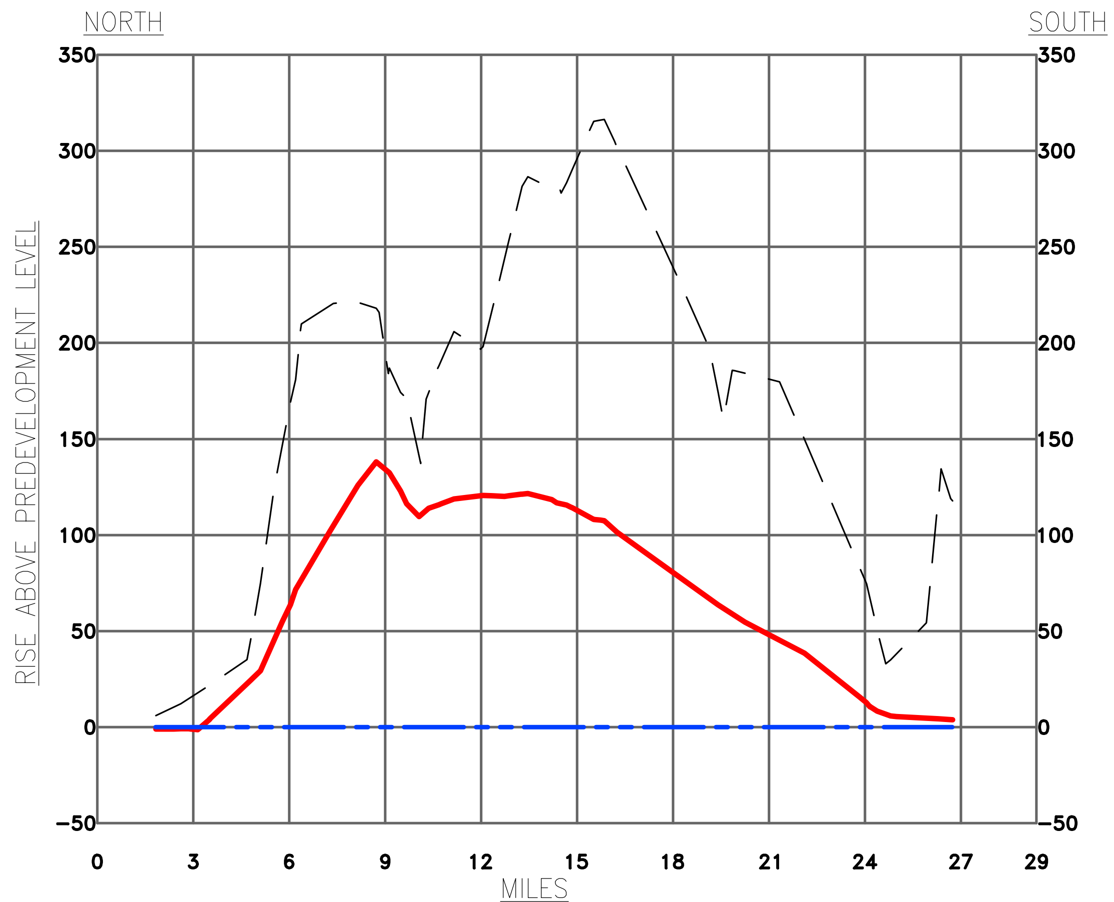
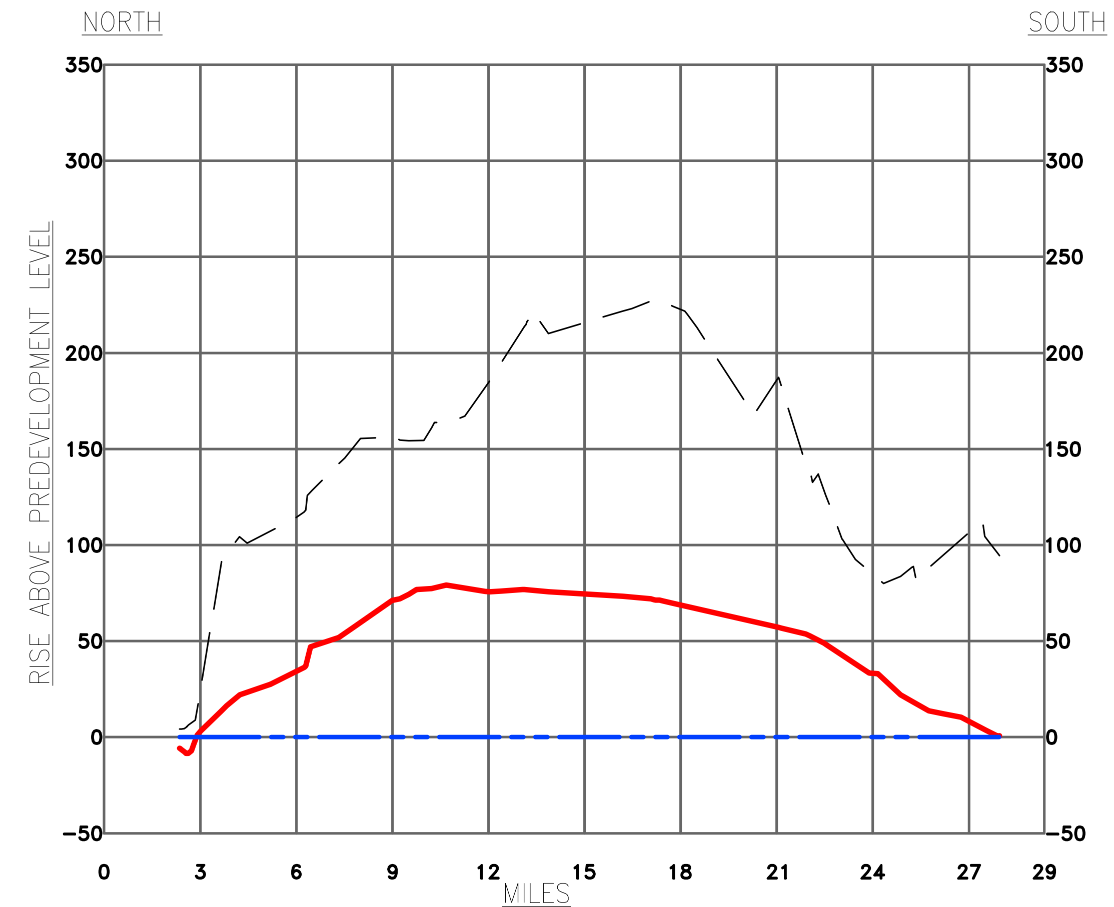


SECTION B-B'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION C-C'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2012 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2012 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.®

PROJECT MGR.	DJS
DESIGNED BY	CNS
DRAWN BY	PLS
CHECKED BY	DJS
DATE	DEC 2013
SCALE	AS SHOWN
PROJECT NO.	1500301
FILE NAME	-
DRAWING NO.	-
FIGURE	F2012-3

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2012 Sections.dwg
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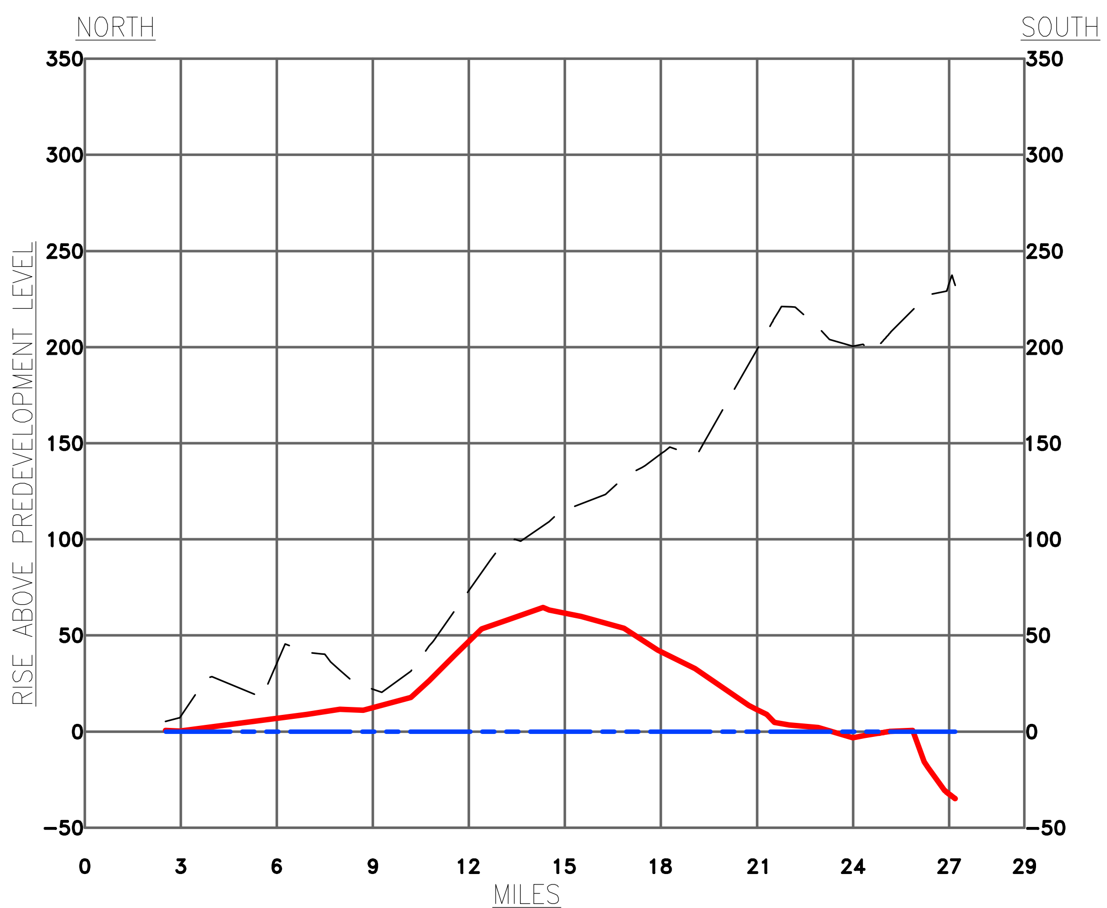
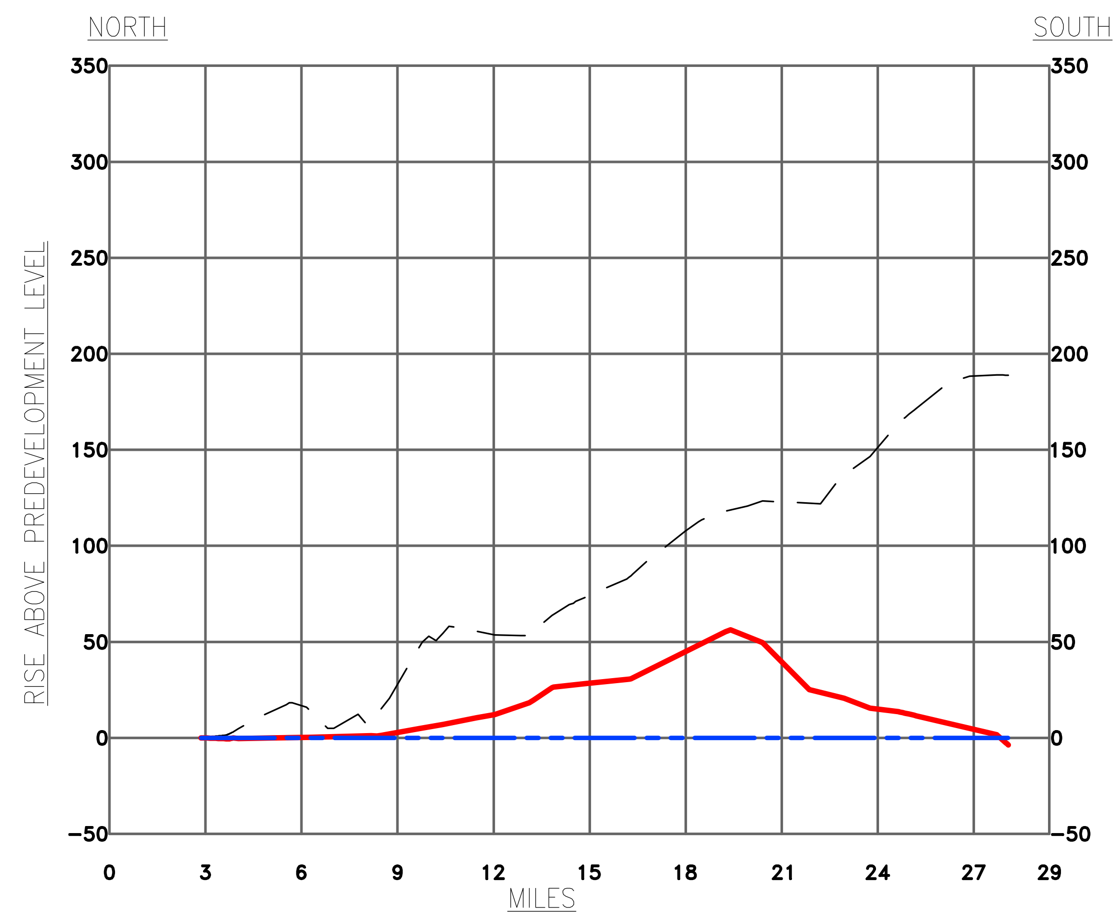


SECTION D–D'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'



SECTION E–E'
HORIZONTAL SCALE: 1"=6 MILES
VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2012 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2012 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

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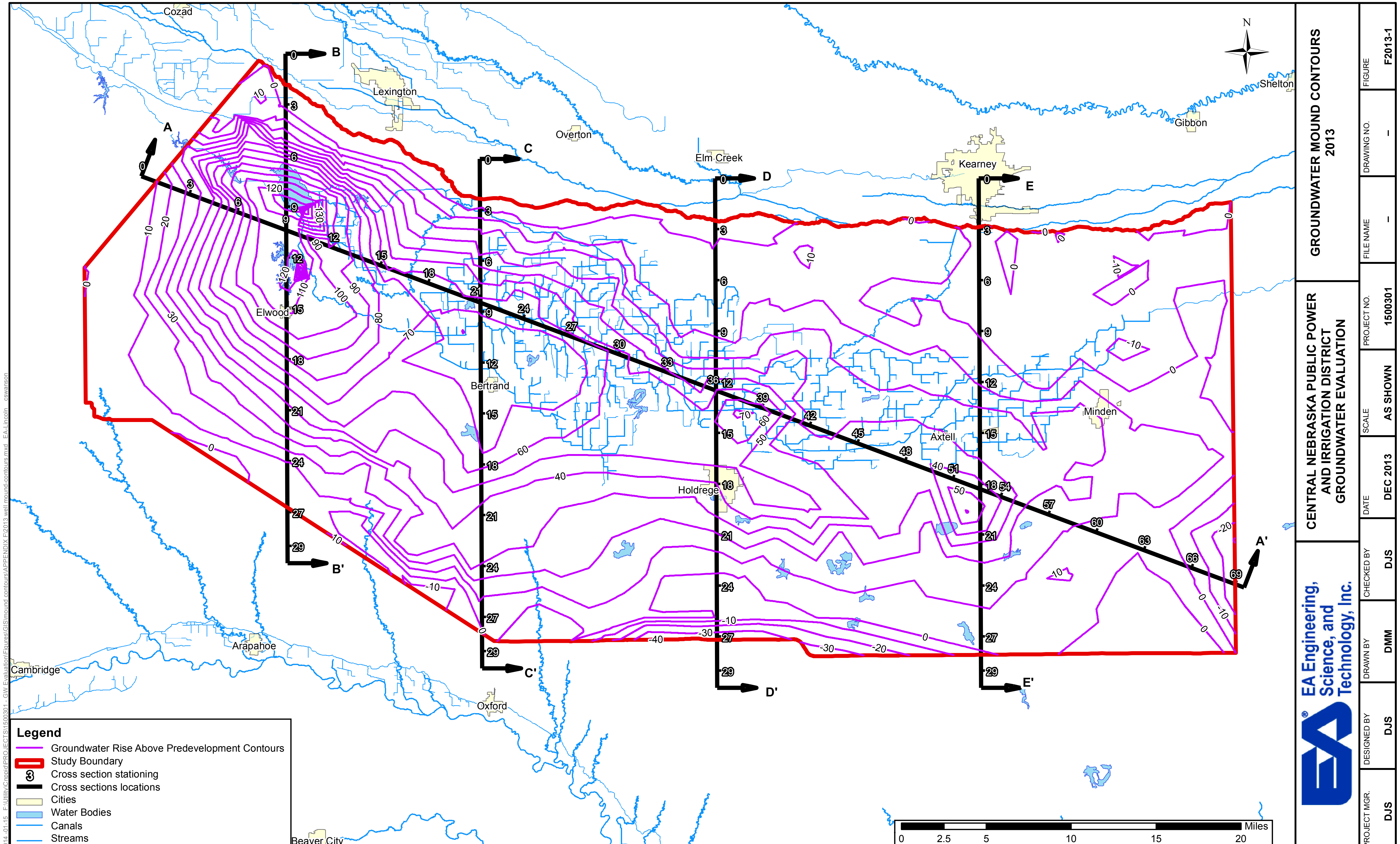
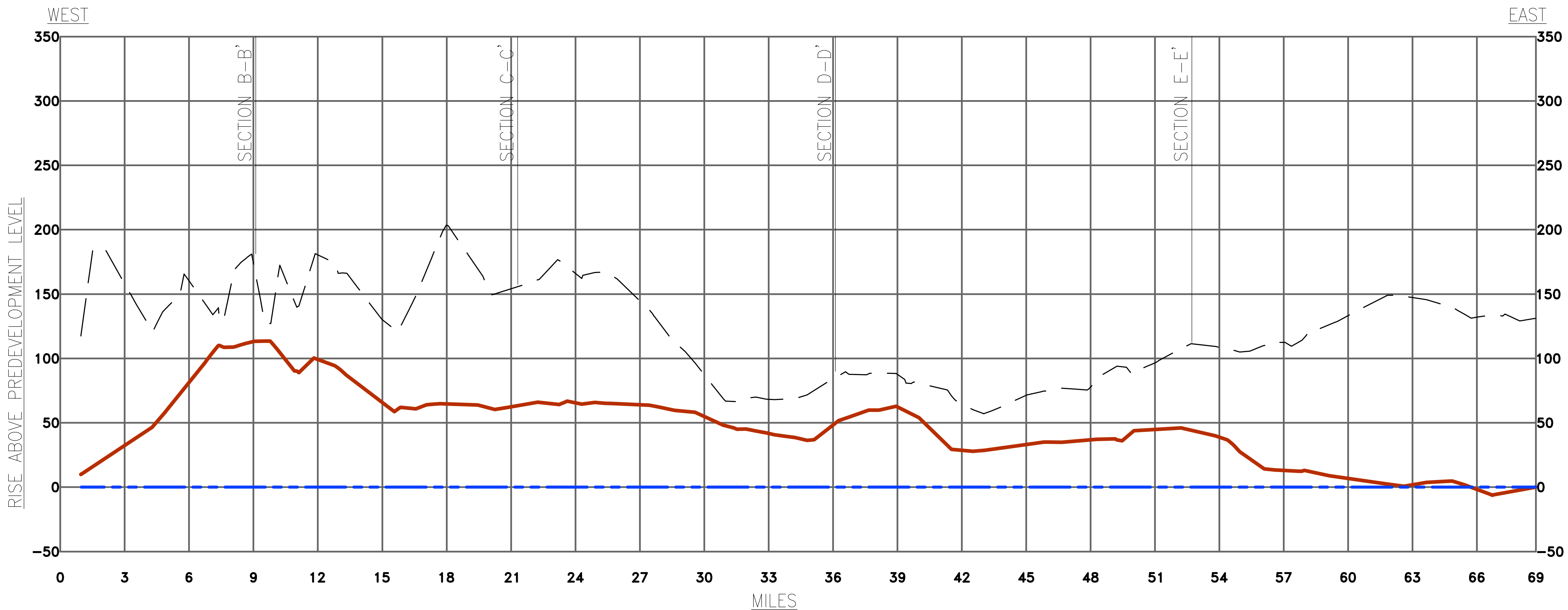
Technology, Inc.

FIGURE	F2012-4
DRAWING NO.	-
FILE NAME	-
PROJECT NO.	1500301
SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS


GROUNDWATER MOUND CONTOURS
2013
CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION
EA Engineering, Science, and Technology, Inc.
FIGURE F2013-1
DRAWING NO. –
FILE NAME –
PROJECT NO. 1500301
SCALE AS SHOWN
DATE DEC 2013
CHECKED BY DJS
DRAWN BY DMM
DESIGNED BY DJS
PROJECT MGR. DJS
Legend
Groundwater Rise Above Predevelopment Contours
Study Boundary
Cross section stationing
Cross sections locations
Cities
Water Bodies
Canals
Streams
Miles
0 2.5 5 10 15 20
N
Cozad
Lexington
Overton
Elm Creek
Kearney
Shelton
Gibbon
Elwood
Bertrand
Holdrege
Axtell
Minden
Arapahoe
Cambridge
Oxford
Beaver City
A
A'
B
B'
C
C'
D
D'
E
E'
2014-01-15 F:\UtilityCropping\PROJECTS\1500301 - GW Evaluation\Figures\GIS\mound contours\APPENDIX F\2013 well mound-contours.mxd EA-Lincoln csswanson



SECTION A–A'
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VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2013 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

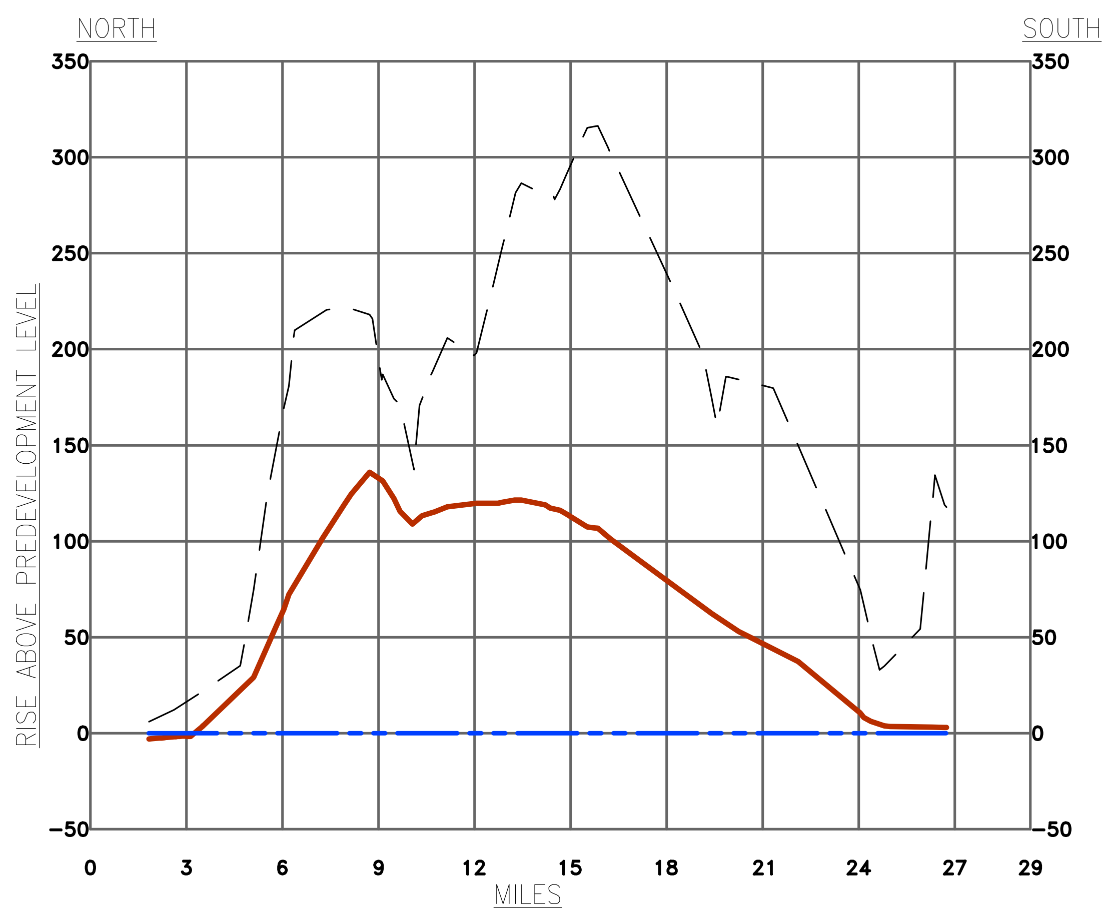
DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2013 Sections.dwg
DATE:11/21/2013 TIME:19:02 DRAWN BY: cswanson

GROUNDWATER LEVELS
2013 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering,
Science, and
Technology, Inc.

PROJECT MGR.	DESIGNED BY	DRAWN BY	CHECKED BY	DATE	SCALE	PROJECT NO.	FILE NAME	DRAWING NO.	FIGURE
DJS	CNS	PLS	DJS	DEC 2013	AS SHOWN	1500301	-	-	F2013-2



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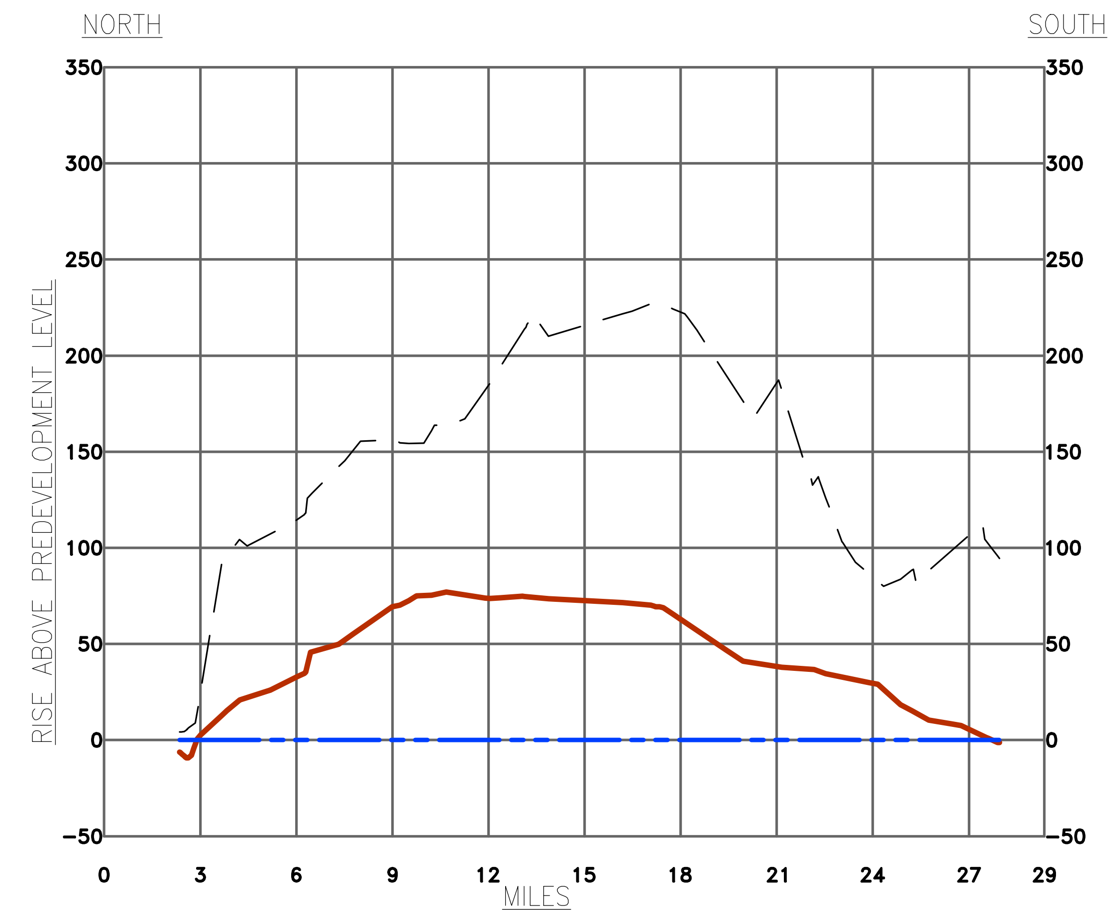

SECTION C–C'
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VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2013 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 – GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2013 Sections.dwg
DATE:11/21/2013 TIME:19:02 DRAWN BY: cswanson

GROUNDWATER LEVELS
2013 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2013-3
DRAWING NO.	-
FILE NAME	-
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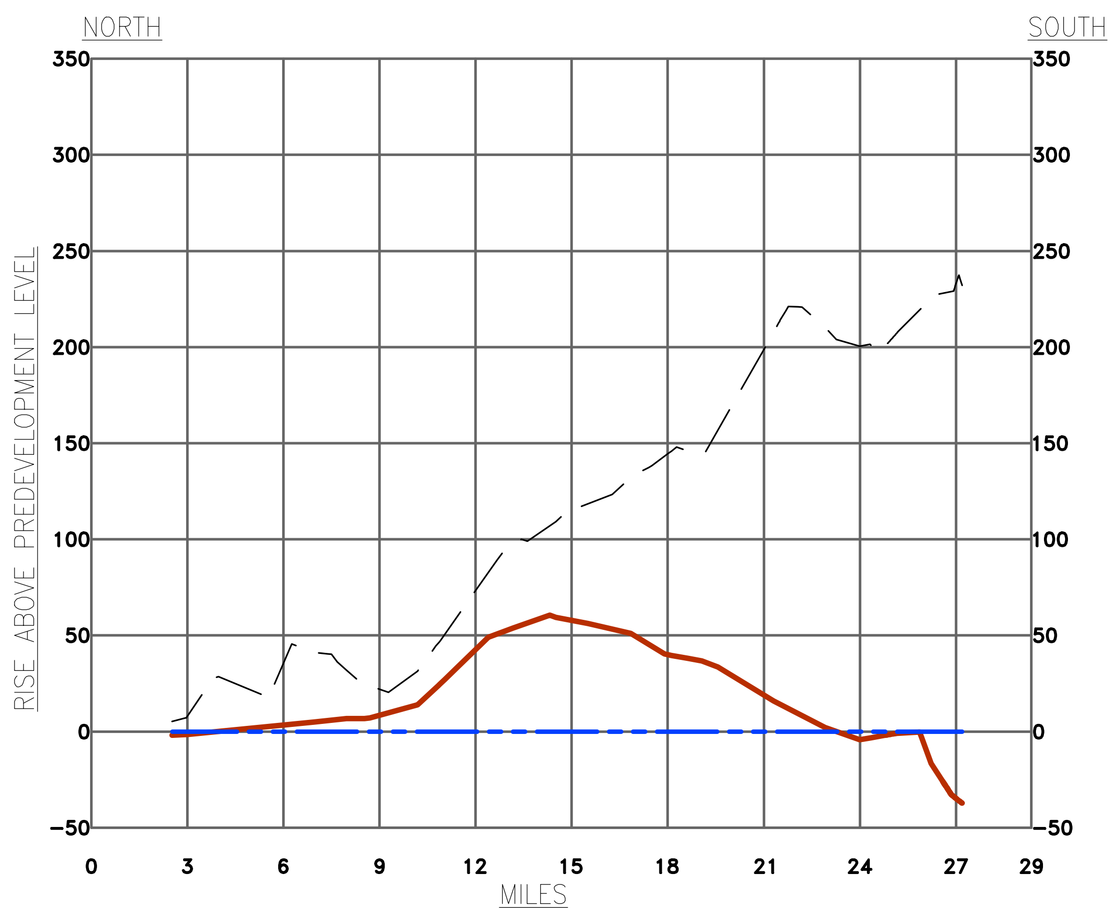
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS



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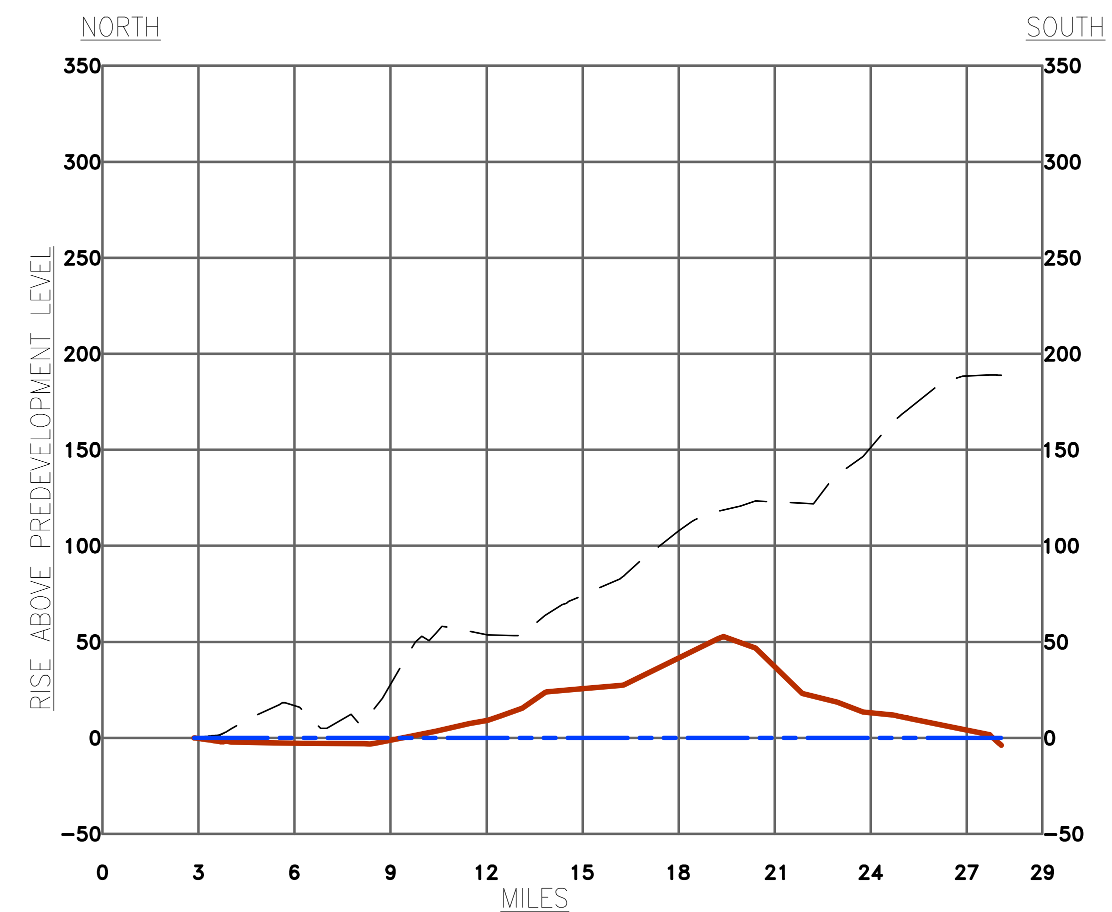

SECTION E–E'
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VERTICAL SCALE: 1"=100'

LEGEND:

PREDEVELOPMENT GROUNDWATER LEVEL

2013 GROUNDWATER RISE

APPROXIMATE GROUND SURFACE

GROUNDWATER LEVELS
2013 CROSS SECTIONS

CENTRAL NEBRASKA PUBLIC POWER
AND IRRIGATION DISTRICT
GROUNDWATER EVALUATION

EA Engineering, Science, and Technology, Inc.

FIGURE	F2013-4
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FILE NAME	-
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SCALE	AS SHOWN
DATE	DEC 2013
CHECKED BY	DJS
DRAWN BY	PLS
DESIGNED BY	CNS
PROJECT MGR.	DJS

DRAWING NAME: F:\Utility\Cnppid\PROJECTS\1500301 - GW Evaluation\Figures\CAD\Wells\WELL SECTION FIGURES\2013 Sections.dwg
DATE:11/21/2013 TIME:19:02 DRAWN BY:cswanson

Appendix G

Relationships Utilized to Extrapolate COHYST's CROPSIM and MODFLOW Data

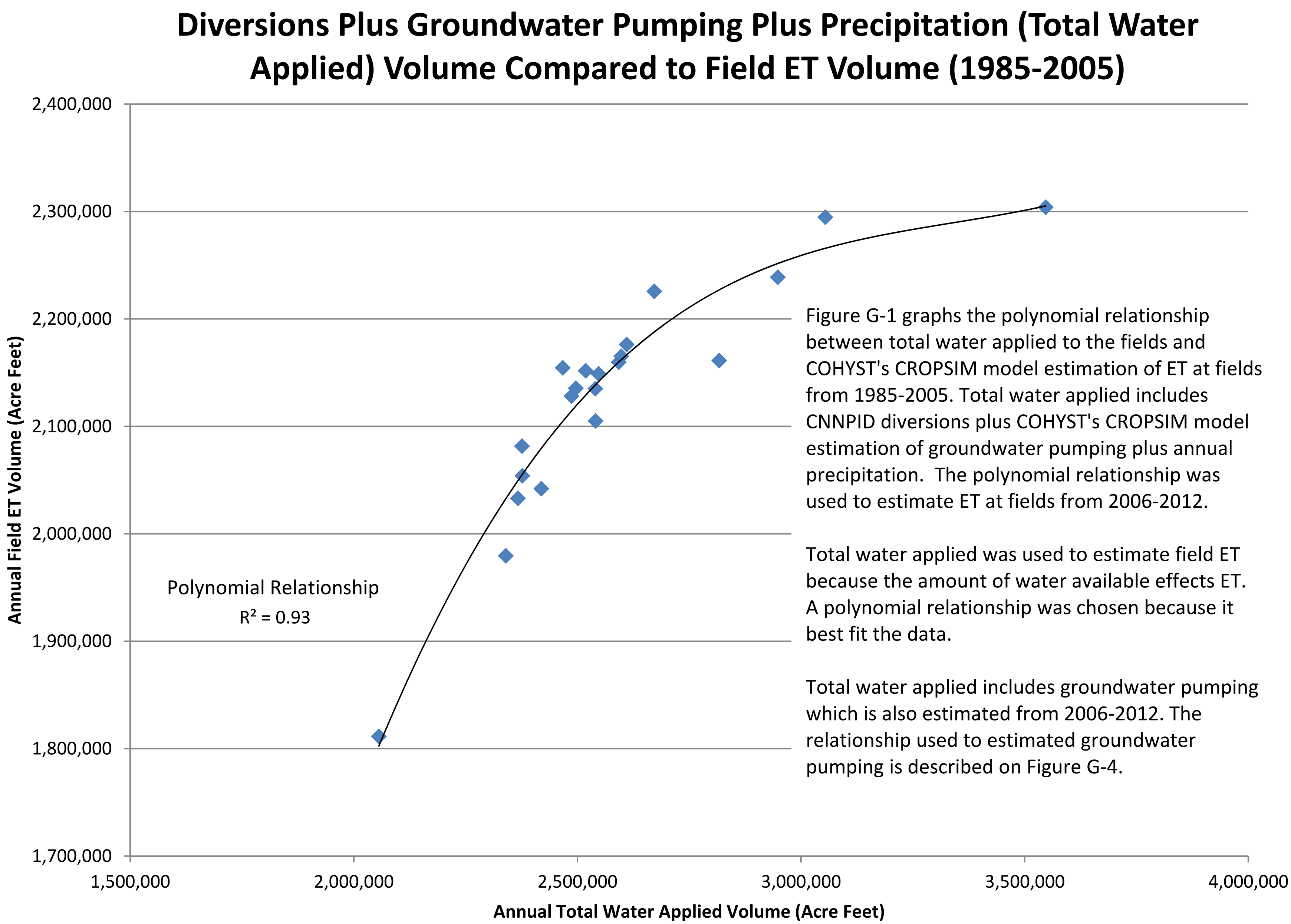

Figure G-1 graphs the polynomial relationship between total water applied to the fields and COHYST's CROPSIM model estimation of ET at fields from 1985-2005. Total water applied includes CNNPID diversions plus COHYST's CROPSIM model estimation of groundwater pumping plus annual precipitation. The polynomial relationship was used to estimate ET at fields from 2006-2012.

Total water applied was used to estimate field ET because the amount of water available effects ET. A polynomial relationship was chosen because it best fit the data.

Total water applied includes groundwater pumping which is also estimated from 2006-2012. The relationship used to estimated groundwater pumping is described on Figure G-4.

Figure G-1. Relationship between annual field ET volume and annual total water applied volume

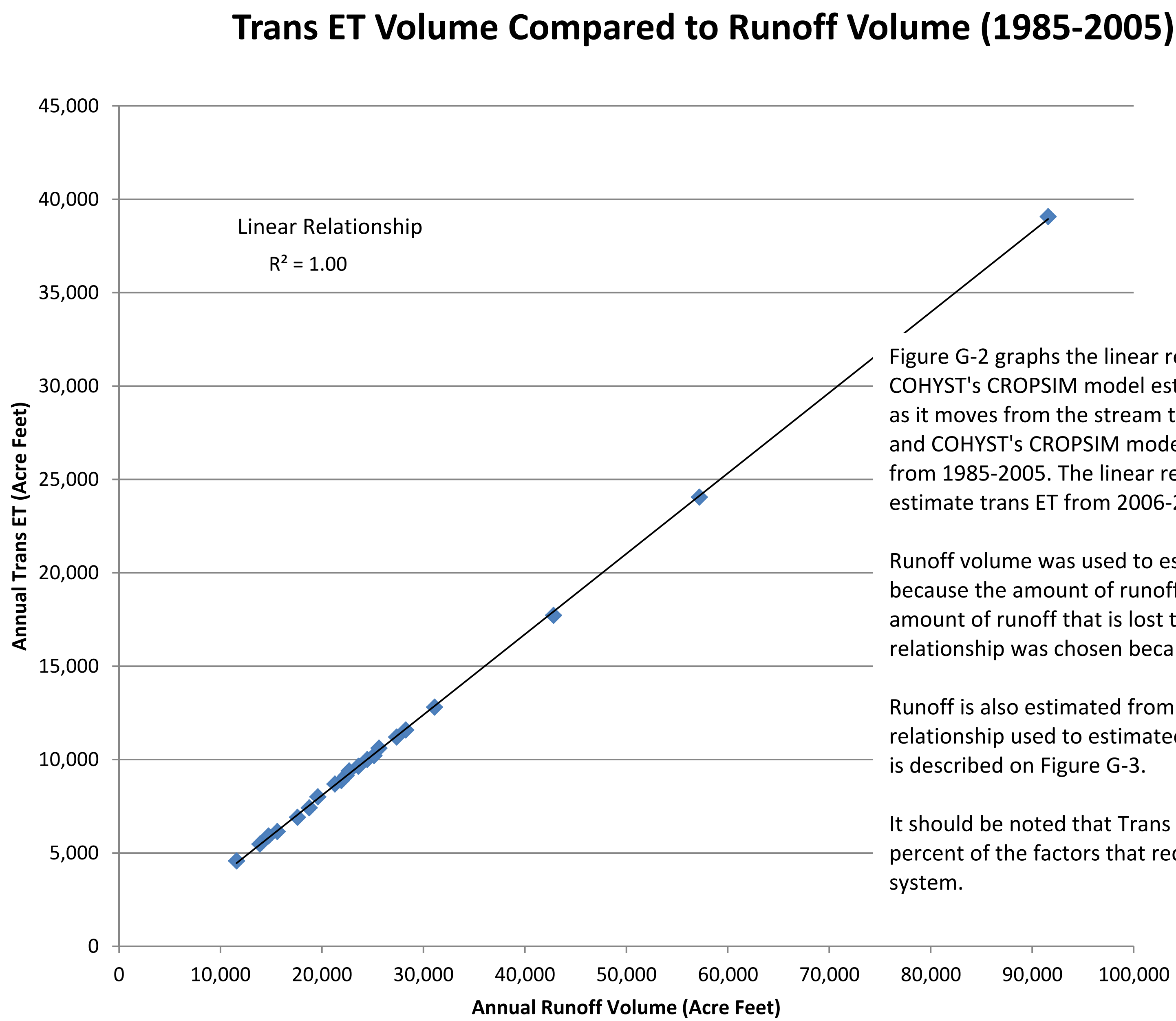

Figure G-2 graphs the linear relationship between COHYST's CROPSIM model estimation of ET of runoff as it moves from the stream to the field (trans ET) and COHYST's CROPSIM model estimation of runoff from 1985-2005. The linear relationship is used to estimate trans ET from 2006-2012.

Runoff volume was used to estimate trans ET because the amount of runoff directly effects the amount of runoff that is lost to ET. A linear relationship was chosen because it best fit the data.

Runoff is also estimated from 2006-2012. The relationship used to estimated groundwater pumping is described on Figure G-3.

It should be noted that Trans ET only comprises 0.5 percent of the factors that reduce water into the system.

Figure G-2. Relationship between annual trans ET volume and annual runoff volume

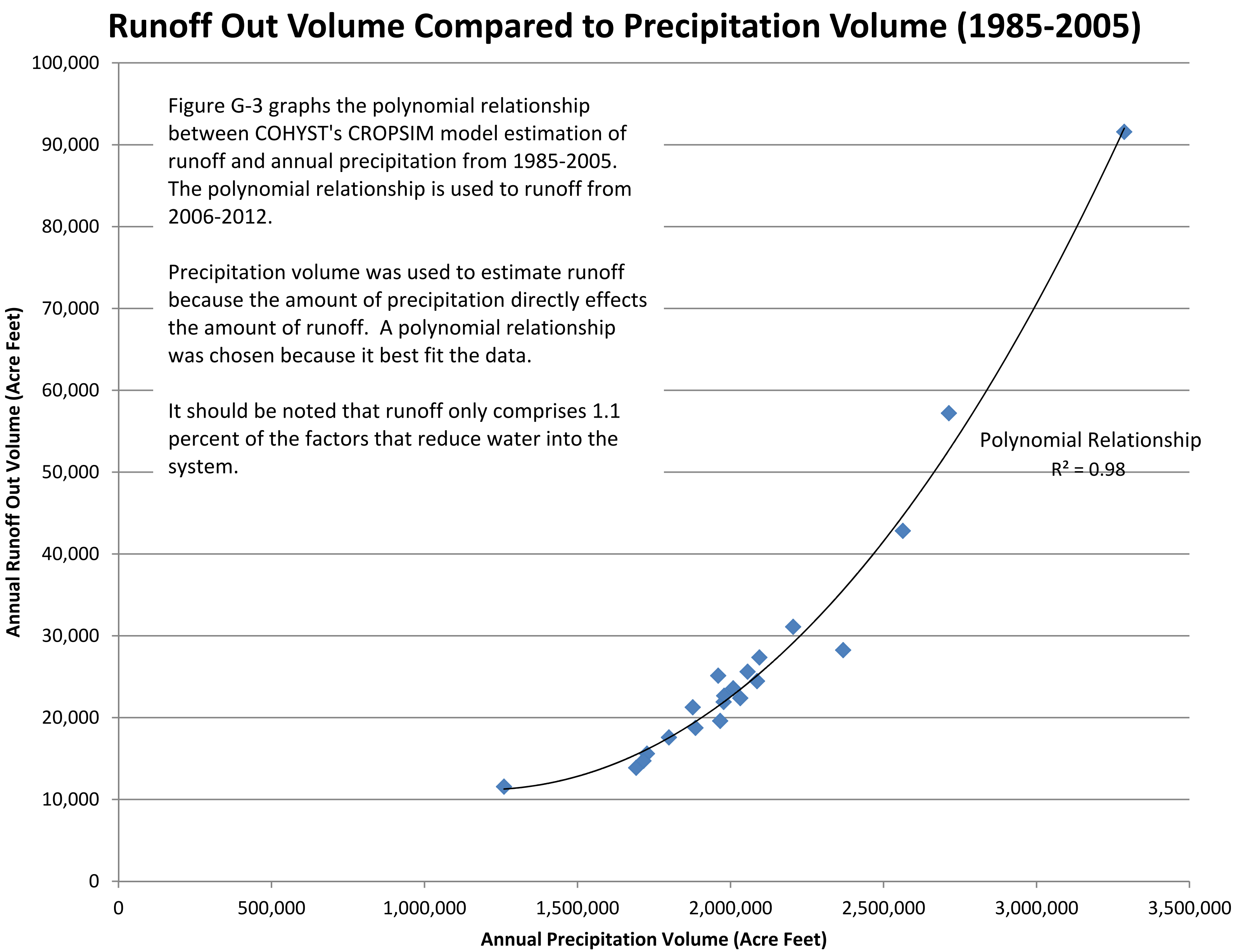

Figure G-3. Relationship between annual runoff out volume and annual precipitation volume

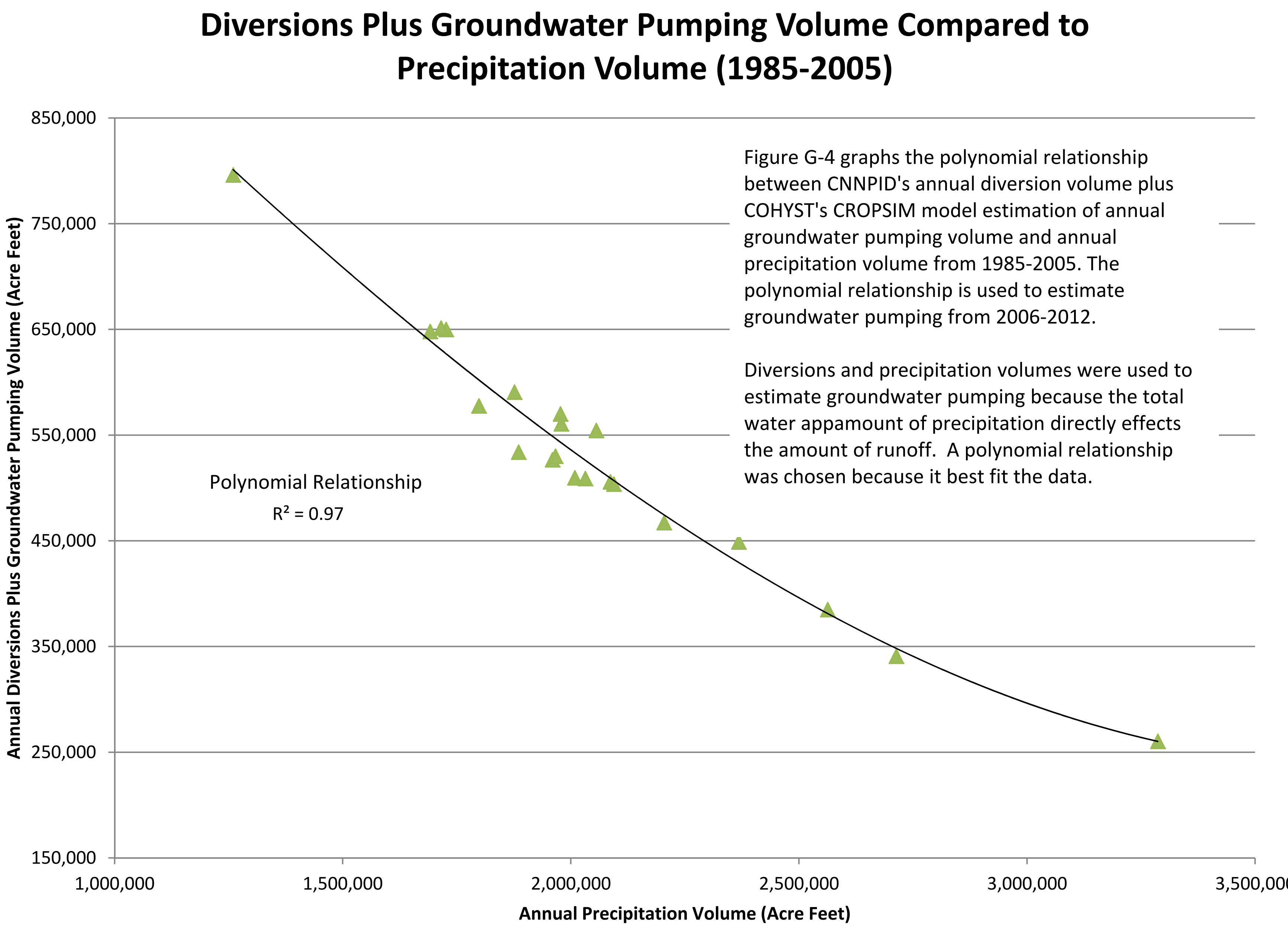

Figure G-4. Relationship between annual diversions plus groundwater pumping volume and annual precipitation volume

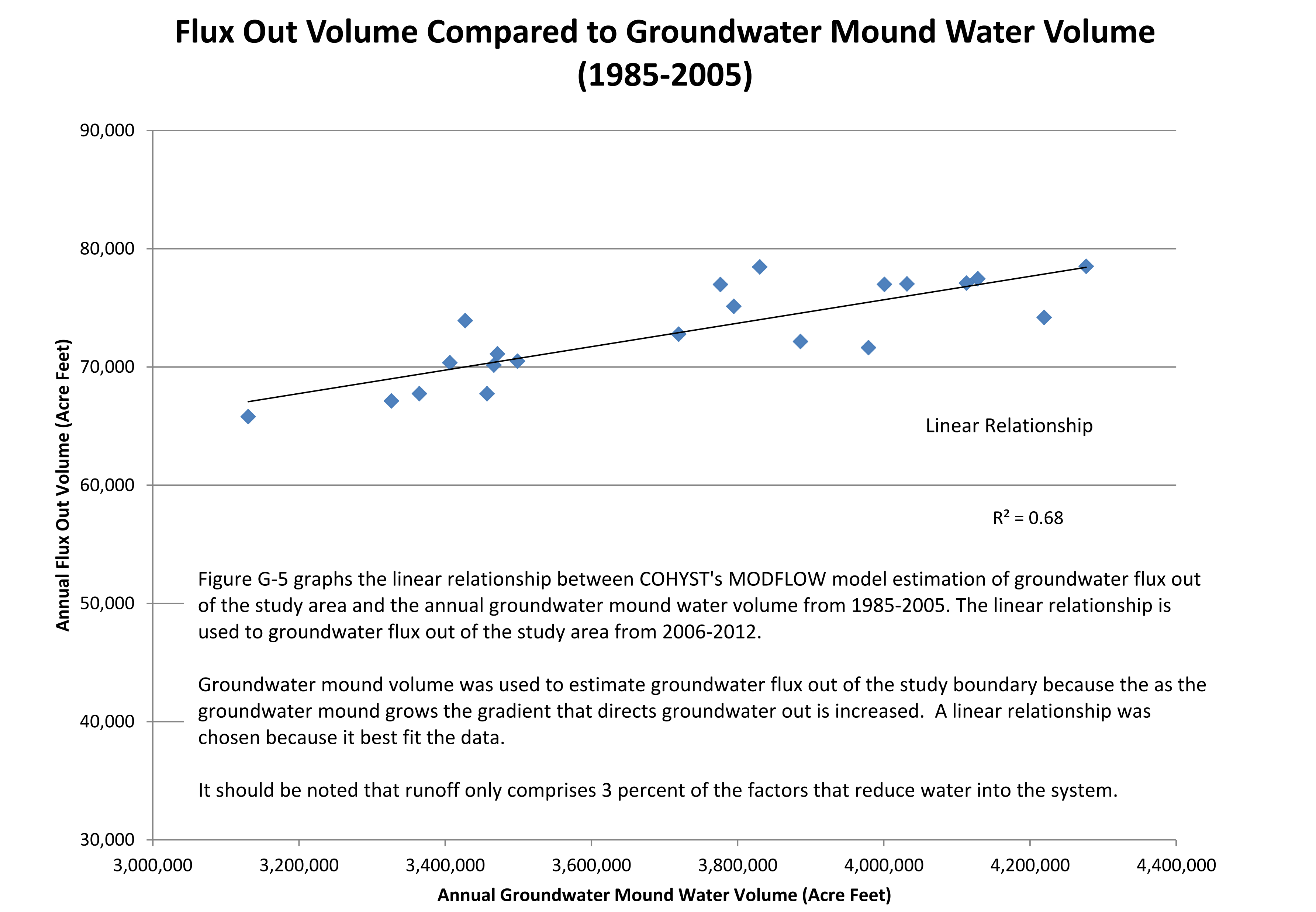

Figure G-5. Relationship between annual flux out volume and annual groundwater mound water volume

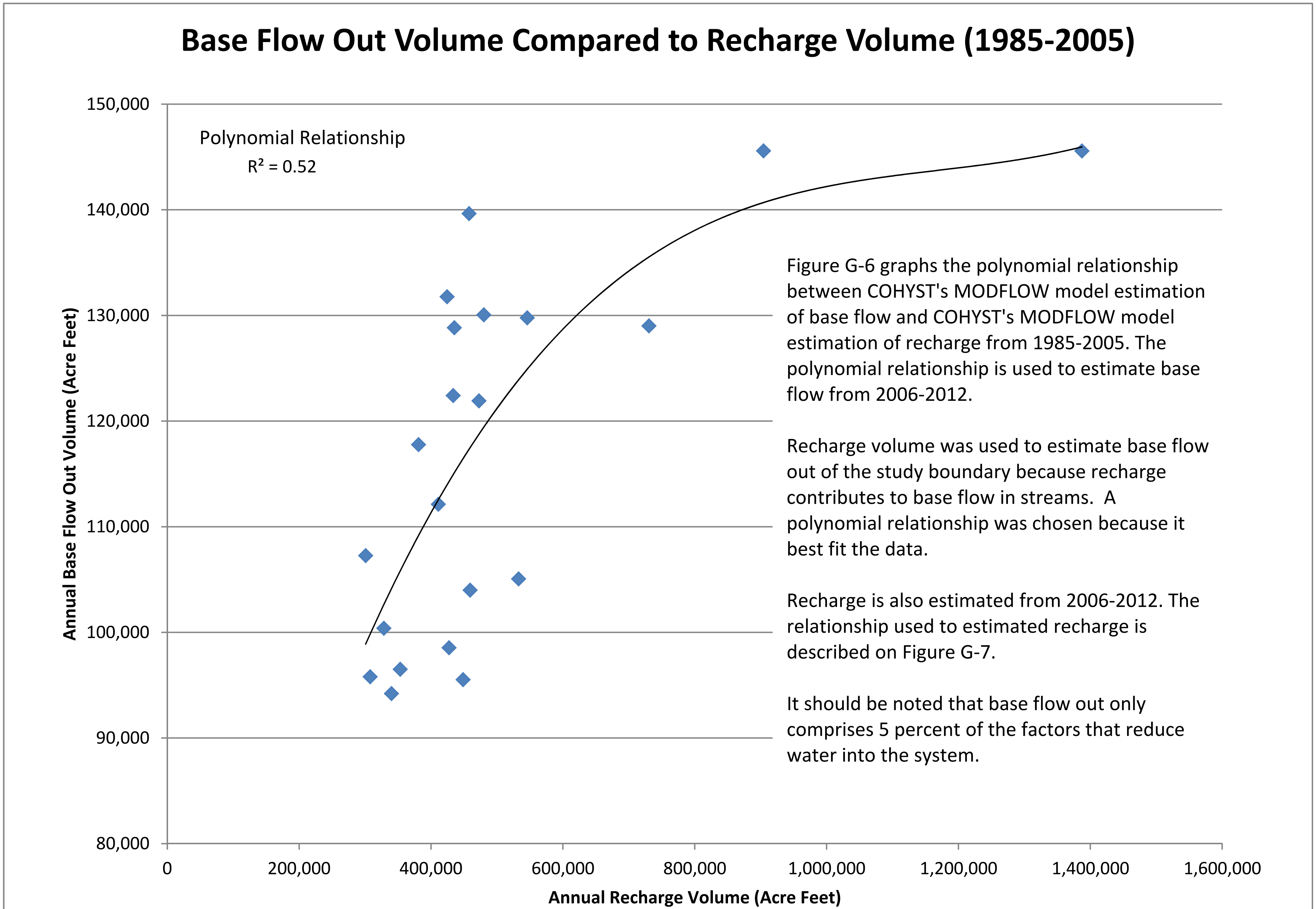

Figure G-6. Relationship between annual base flow out volume and annual recharge volume

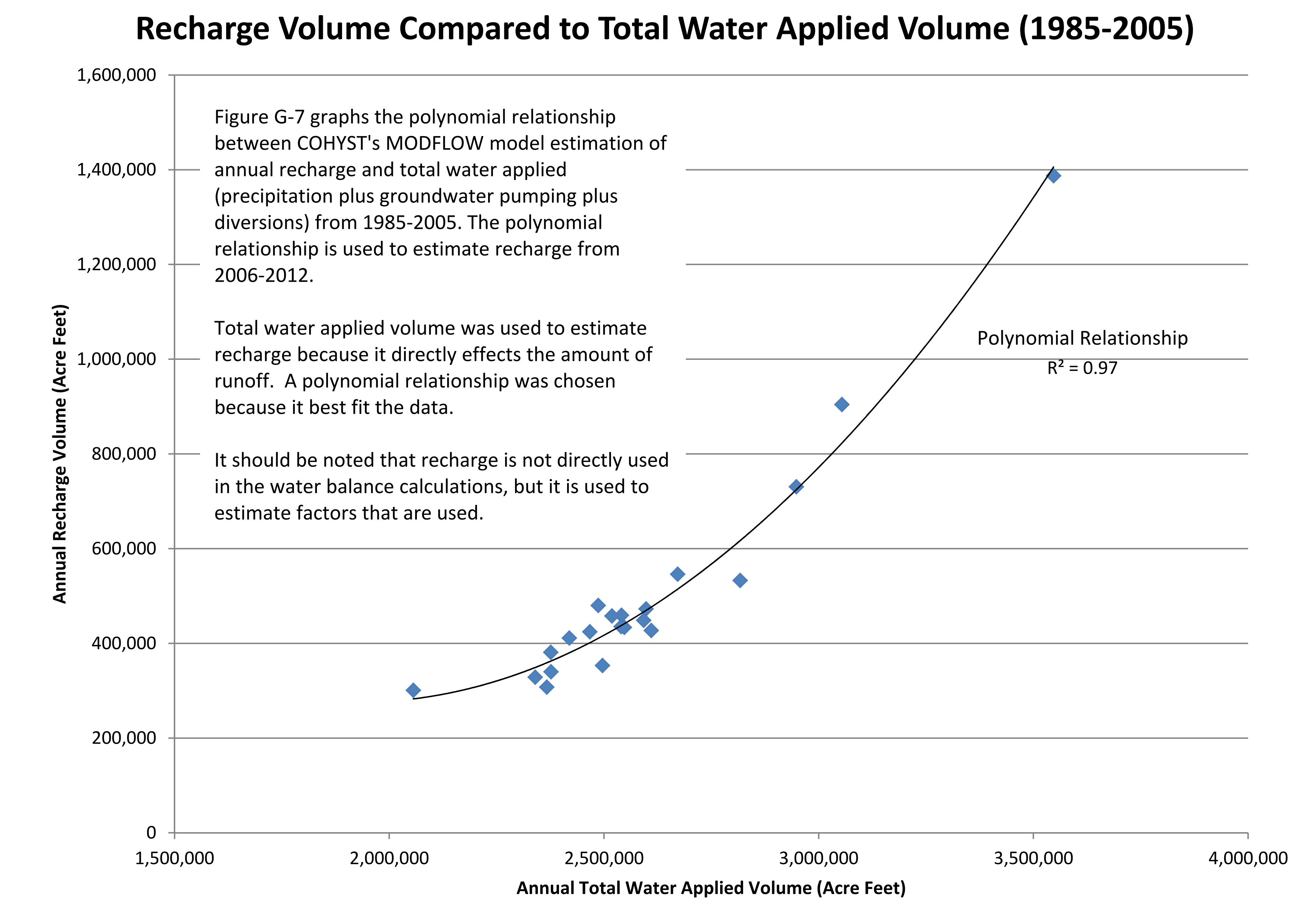

Figure G-7. Relationship between annual recharge volume and annual total water applied volume

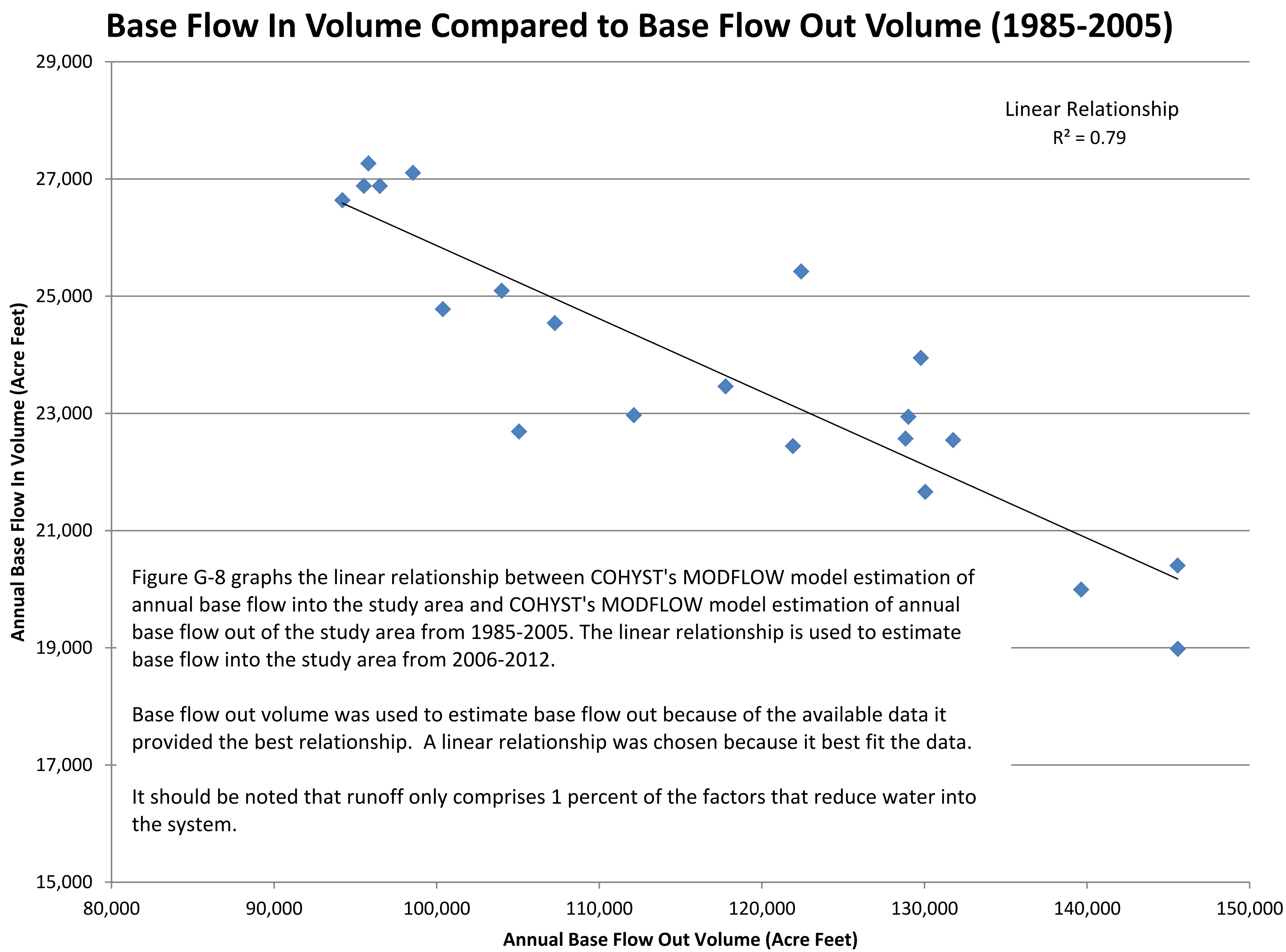

Figure G-8. Relationship between annual base flow in volume and annual base flow out volume

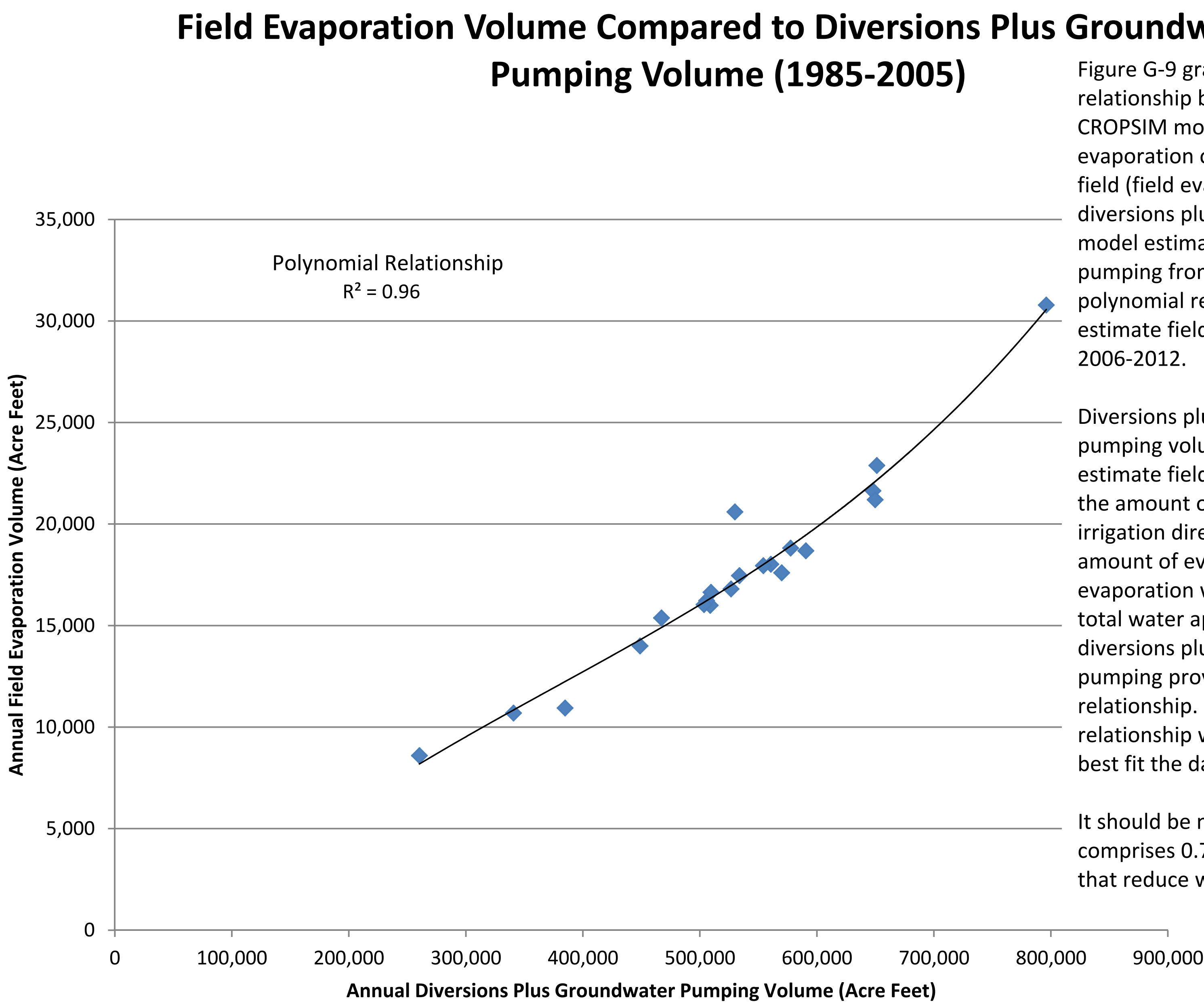

Figure G-9 graphs the polynomial relationship between COHYST's CROPSIM model estimation of evaporation of water applied at the field (field evaporation) and CNPPID diversions plus COHYST's CROPSIM model estimation of groundwater pumping from 1985-2005. The polynomial relationship is used to estimate field evaporation from 2006-2012.

Diversions plus groundwater pumping volume was used to estimate field evaporation because the amount of water used for irrigation directly effects the amount of evaporation. Field evaporation was also compared to total water applied, but the diversions plus groundwater pumping provided a much better relationship. A polynomial relationship was chosen because it best fit the data.

It should be noted that runoff only comprises 0.7 percent of the factors that reduce water into the system.

Figure G-9. Relationship between annual diversions plus groundwater pumping volume and annual precipitation volume

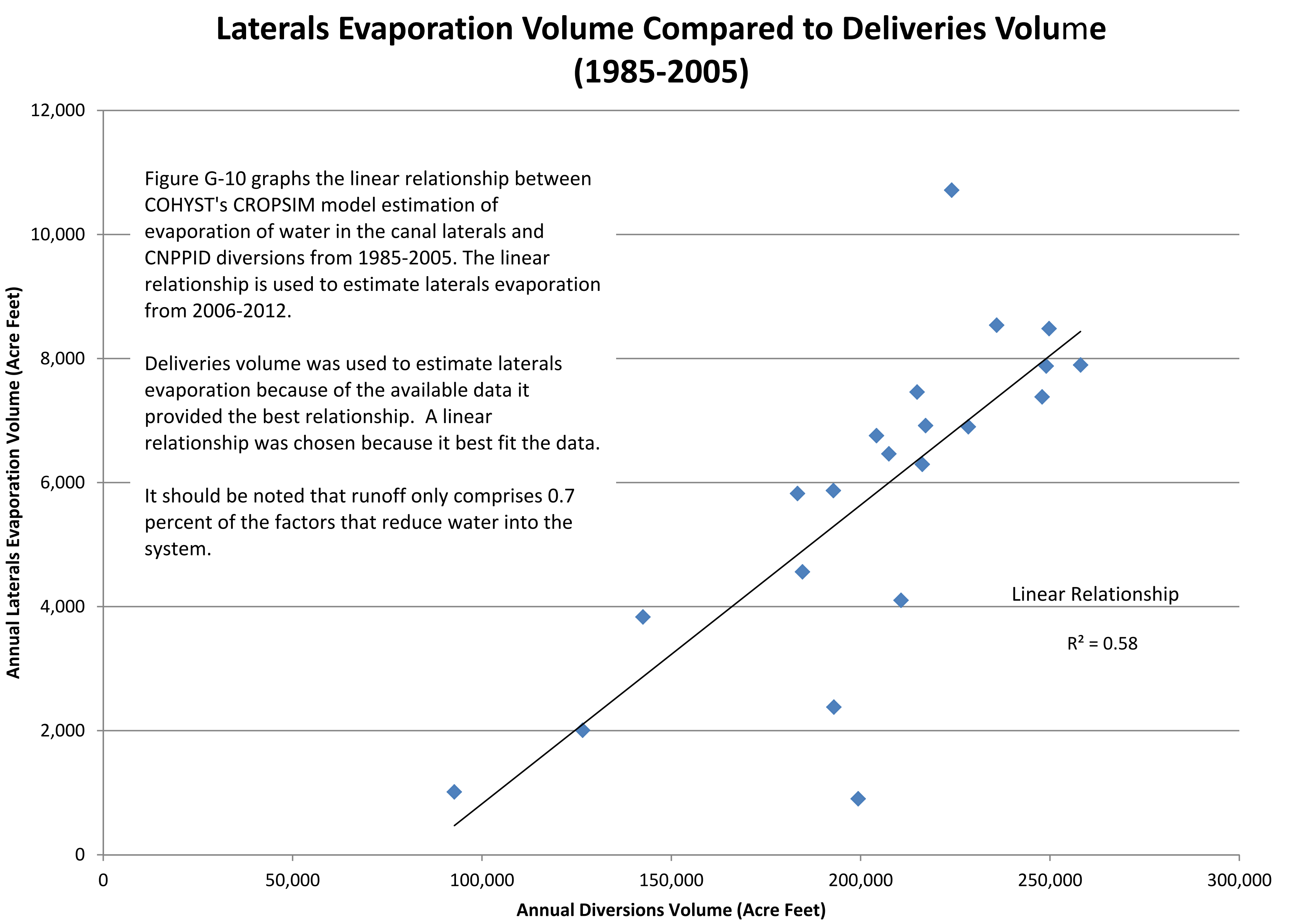

Figure G-10. Relationship between annual laterals evaporation volume and annual diversions volume

Appendix H

Groundwater Mound Water Volume with Varying Specific Yields

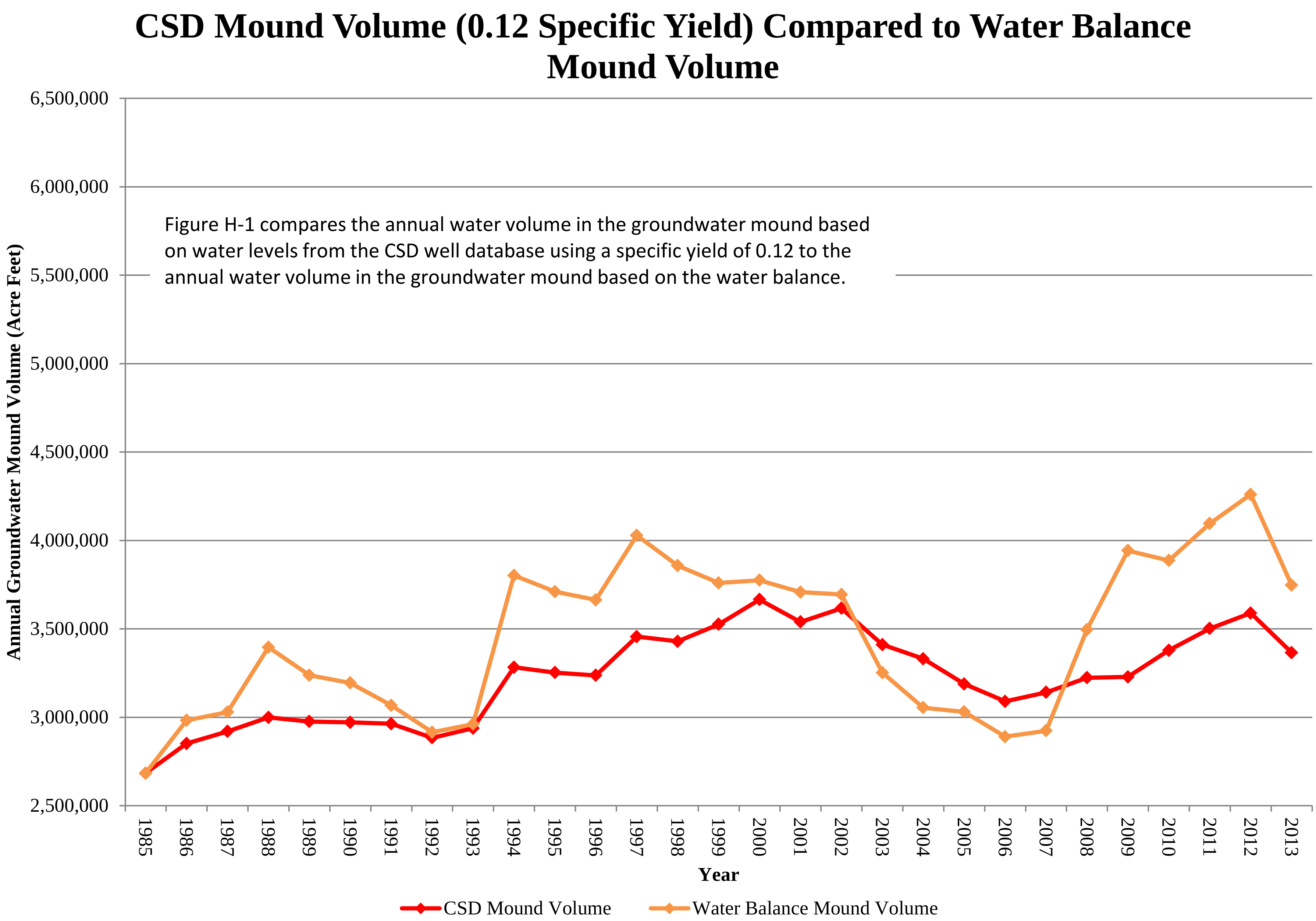

Figure H-1. Comparison of the calculated water balance mound volume and the CSD mound volume with 0.12 specific yield.

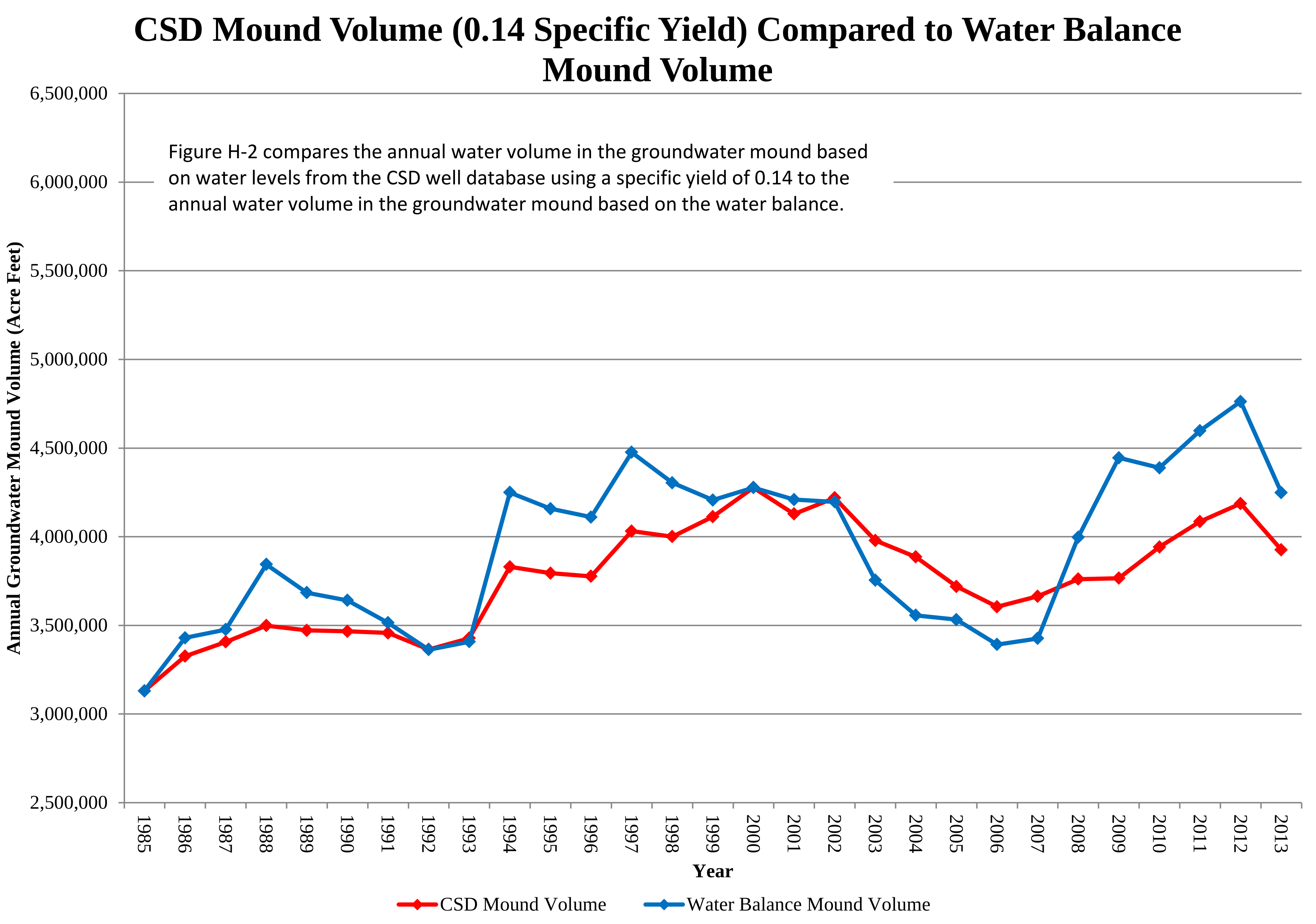

Figure H-2. Comparison of the calculated water balance mound volume and the CSD mound volume with 0.14 specific yield.

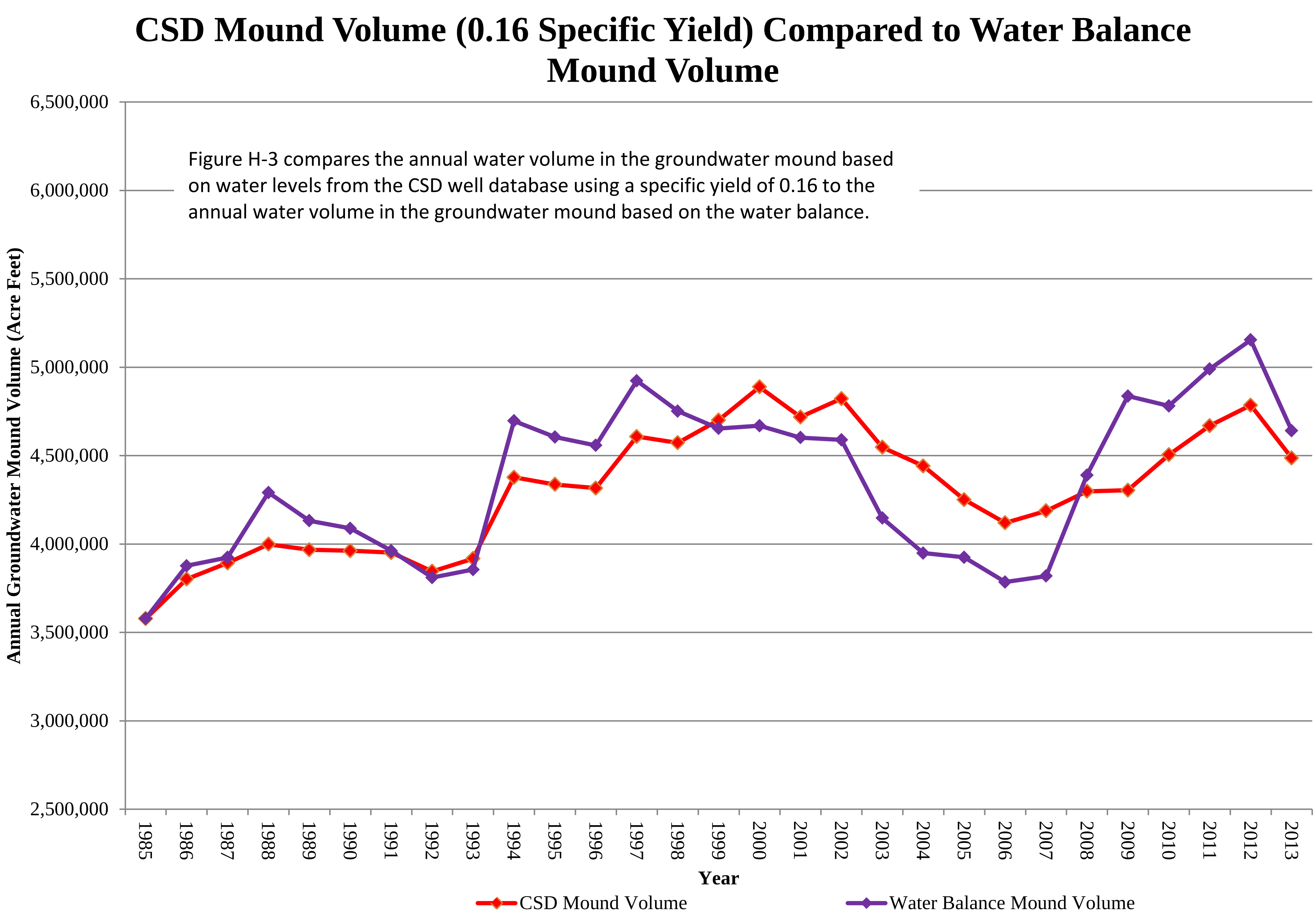

Figure H-3. Comparison of the calculated water balance mound volume and the CSD mound volume with 0.16 specific yield.

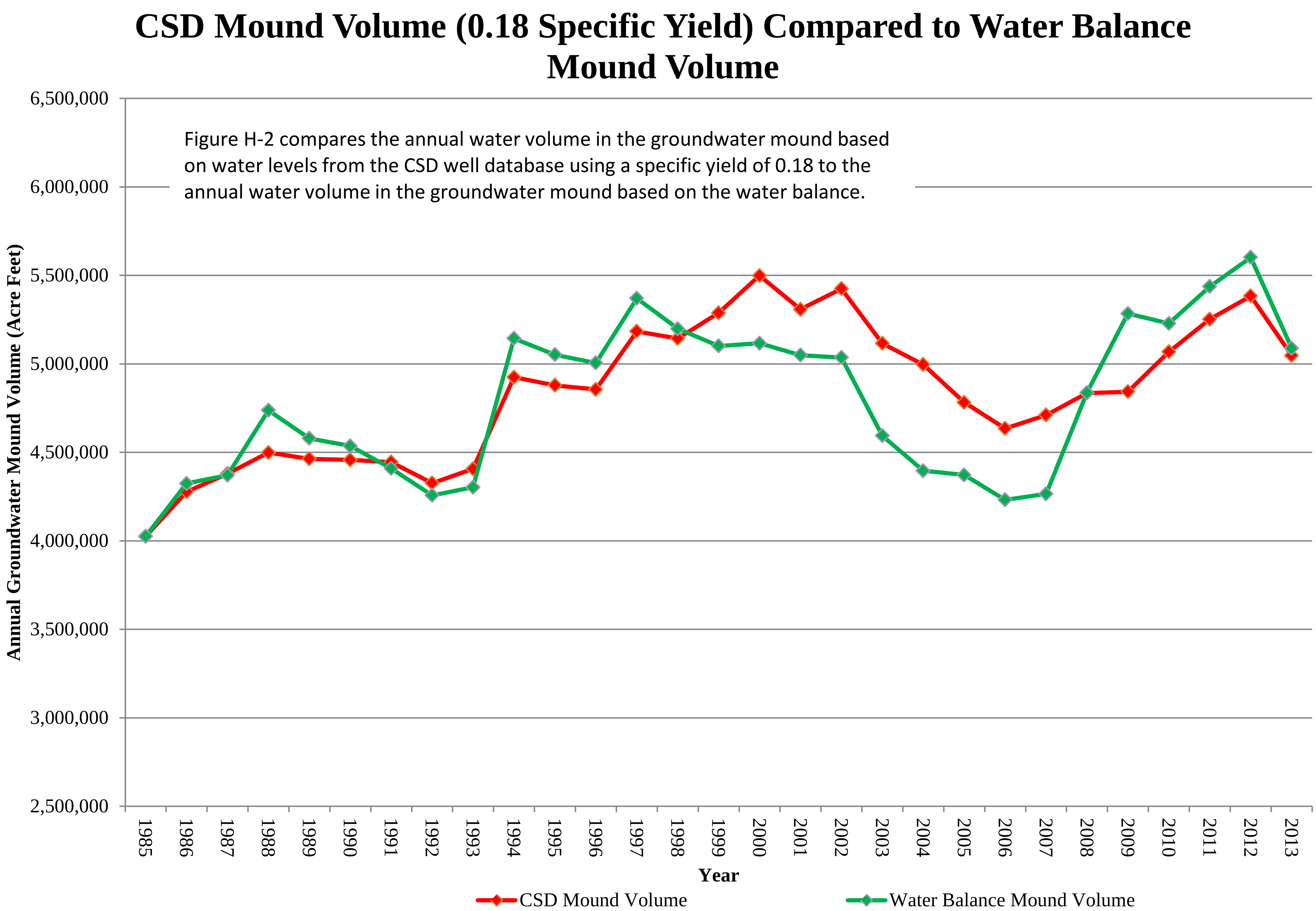

Figure H-4. Comparison of the calculated water balance mound volume and the CSD mound volume with 0.18 specific yield.

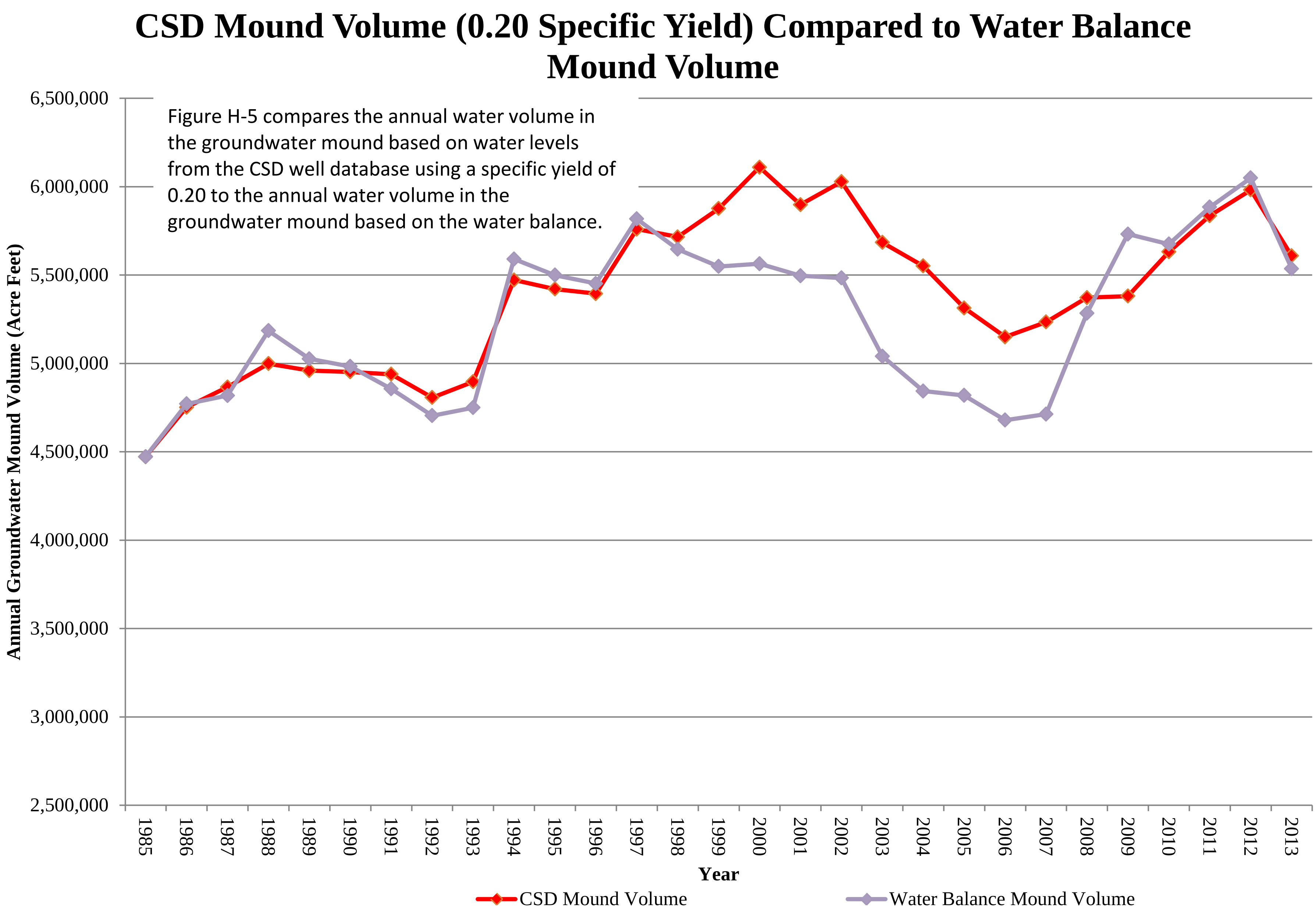

Figure H-5. Comparison of the calculated water balance mound volume and the CSD mound volume with 0.20 specific yield.

Appendix I

Water Balance Summary Tables

Table I-1. Groundwater Mound Water Volumes

Year	Precipitation (ac-ft)	Diversions (ac-ft)	Baseflow In (ac-ft)	Total Lake Seepage Upstream of Diversion Measurements	Total Canal Seepage Downstream of Diversion Measurements (ac-ft)	Flux In (ac-ft)	Field Losses (ac-ft)	ET (ac-ft)	Baseflow Out (ac-ft)	Runoff Out (ac-ft)	Flux Out (ac-ft)	Main Channel Canal Evaporation Downstream of Diversion Measurements (ac-ft)	Lateral Evaporation (ac-ft)	Yearly Balance (ac-ft)	Groundwater Mound Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - Water Balance (ac-ft)
1985	2,368,292	192,812	22,692	59,123	18,111	34,067	13,996	2,172,752	106,141	28,257	65,797	3,196	5,871	299,086	3.61E+10	3,130,484	3,130,484
1986	2,031,840	217,147	25,094	56,130	18,111	33,273	15,995	2,114,145	104,824	22,383	67,123	3,196	6,918	47,012	3.83E+10	3,326,308	3,429,570
1987	2,563,308	184,622	22,942	60,831	18,111	35,313	10,938	2,256,551	129,821	42,827	70,356	3,196	4,562	366,877	3.93E+10	3,406,361	3,476,582
1988	1,798,594	235,929	23,461	56,144	18,111	34,734	18,814	2,088,576	118,616	17,586	70,486	3,196	8,538	-158,840	4.03E+10	3,498,930	3,843,459
1989	1,885,610	214,917	22,970	60,886	18,111	34,286	17,462	2,049,373	112,907	18,747	71,110	3,196	7,460	-43,476	4.00E+10	3,471,412	3,684,619
1990	1,691,860	249,769	24,781	59,359	18,111	32,917	21,637	1,985,032	101,085	13,879	70,164	3,196	8,483	-126,680	3.99E+10	3,466,547	3,641,143
1991	1,726,867	258,081	26,640	56,717	18,111	32,461	21,195	2,060,123	94,861	15,599	67,731	3,196	7,896	-151,726	3.98E+10	3,457,168	3,514,463
1992	2,086,915	207,457	26,883	57,488	18,111	32,528	16,226	2,169,786	96,182	24,462	67,742	3,196	6,465	45,324	3.88E+10	3,364,589	3,362,737
1993	3,286,777	92,702	20,404	54,963	18,111	36,028	8,596	2,343,083	146,533	91,573	73,926	3,196	1,014	841,064	3.95E+10	3,427,375	3,408,060
1994	2,009,043	204,193	19,993	52,214	18,111	35,834	16,641	2,161,356	140,856	23,592	78,466	3,196	6,757	-91,476	4.41E+10	3,830,248	4,249,124
1995	1,977,442	247,936	25,422	56,086	18,111	34,480	17,601	2,157,700	123,598	21,918	75,131	3,196	7,381	-47,049	4.37E+10	3,794,684	4,157,649
1996	2,713,511	142,515	18,983	53,729	18,111	36,224	10,691	2,318,812	147,050	57,197	76,973	3,196	3,834	365,319	4.35E+10	3,776,446	4,110,600
1997	1,876,588	249,004	22,545	51,590	18,111	35,219	18,684	2,163,163	133,463	21,273	77,030	3,196	7,878	-171,631	4.65E+10	4,031,735	4,475,919
1998	1,959,866	216,262	21,661	49,514	18,111	35,517	16,806	2,138,303	131,699	25,132	76,986	3,196	6,295	-97,486	4.61E+10	4,000,794	4,304,288
1999	2,204,622	183,338	23,946	52,832	18,111	34,888	15,380	2,238,487	131,484	31,098	77,093	3,196	5,823	15,176	4.74E+10	4,113,130	4,206,803
2000	1,979,333	228,423	22,571	53,253	18,111	35,252	18,017	2,144,495	130,611	22,672	78,516	3,196	6,900	-67,466	4.93E+10	4,276,855	4,276,855
2001	2,094,420	192,924	22,442	52,253	18,111	33,500	16,032	2,176,392	123,720	27,355	77,460	3,196	2,380	-12,887	4.76E+10	4,128,596	4,209,389
2002	1,259,964	224,033	24,541	52,977	18,111	33,358	30,787	1,816,052	109,009	11,577	74,196	3,196	10,715	-442,548	4.86E+10	4,219,418	4,196,503
2003	1,715,687	210,671	27,268	51,386	18,111	32,152	22,881	2,038,907	97,368	14,732	71,639	3,060	4,102	-197,415	4.59E+10	3,979,037	3,753,954
2004	2,055,834	199,341	27,106	50,414	18,111	31,730	17,950	2,186,870	100,140	25,618	72,160	3,060	902	-24,164	4.48E+10	3,886,003	3,556,539
2005	1,966,463	126,586	26,882	50,414	18,111	31,129	20,598	2,143,468	98,159	19,598	72,776	3,060	2,008	-140,082	4.29E+10	3,719,408	3,532,376
2006	2,227,491	134,207	22,910	50,414	18,111	34,042	14,927	2,207,606	125,254	29,987	70,011	3,060	2,469	33,861	4.15E+10	3,604,821	3,392,293
2007	2,955,780	100,427	20,541	50,414	18,111	34,042	9,635	2,312,569	144,243	67,589	70,571	3,060	841	570,805	4.22E+10	3,664,260	3,426,154
2008	2,803,572	105,575	20,790	50,414	18,111	34,042	10,509	2,298,371	142,246	57,936	71,480	3,060	1,089	447,813	4.33E+10	3,760,638	3,996,959
2009	2,074,910	149,567	23,630	50,414	18,111	34,042	16,477	2,168,220	119,485	24,770	71,534	3,060	3,208	-56,080	4.34E+10	3,766,388	4,444,772
2010	2,475,667	130,995	21,811	50,414	18,111	34,042	12,790	2,256,428	134,062	40,399	73,186	3,060	2,314	208,801	4.54E+10	3,941,612	4,388,692
2011	2,398,226	147,449	22,135	50,414	18,111	34,042	13,414	2,243,052	131,469	36,890	74,539	3,060	3,106	164,846	4.71E+10	4,085,140	4,597,493
2012	1,104,913	193,465	26,445	50,414	18,111	34,042	35,683	1,713,020	96,934	11,302	75,499	3,060	5,323	-513,430	4.82E+10	4,186,938	4,762,339
2013	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.52E+10	3,925,867	4,248,909

Table I-2. Groundwater Mound Water Volumes with Recharge Time Adjustment

Year	Water Balance Volume (ac-ft)	Contribution to Groundwater Mound - 3 Year Recharge Time (ac-ft)	Adjusted Recharge Time Water Balance Groundwater Mound Water Volume (ac-ft)	Un-Adjusted Water Balance Groundwater Mound Water Volume (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)
1983	97,995	-	-	-	-
1984	99,825	-	-	-	-
1985	299,086	165,634	3,130,484	3,130,484	3,130,484
1986	47,012	148,639	3,296,118	3,429,570	3,326,308
1987	366,877	237,656	3,444,757	3,476,582	3,406,361
1988	-158,840	85,015	3,682,413	3,843,459	3,498,930
1989	-43,476	54,853	3,767,429	3,684,619	3,471,412
1990	-126,680	-109,664	3,822,282	3,641,143	3,466,547
1991	-151,726	-107,293	3,712,617	3,514,463	3,457,168
1992	45,324	-77,693	3,605,324	3,362,737	3,364,589
1993	841,064	244,885	3,527,631	3,408,060	3,427,375
1994	-91,476	264,968	3,772,516	4,249,124	3,830,248
1995	-47,049	234,178	4,037,484	4,157,649	3,794,684
1996	365,319	75,597	4,271,661	4,110,600	3,776,446
1997	-171,631	48,879	4,347,259	4,475,919	4,031,735
1998	-97,486	32,067	4,396,138	4,304,288	4,000,794
1999	15,176	-84,646	4,428,205	4,206,803	4,113,130
2000	-67,466	-49,925	4,343,559	4,276,855	4,276,855
2001	-12,887	-21,725	4,293,635	4,209,389	4,128,596
2002	-442,548	-174,299	4,271,910	4,196,503	4,219,418
2003	-197,415	-217,615	4,097,611	3,753,954	3,979,037
2004	-24,164	-221,373	3,879,996	3,556,539	3,886,003
2005	-140,082	-120,552	3,658,623	3,532,376	3,719,408
2006	33,861	-43,461	3,538,071	3,392,293	3,604,821
2007	570,805	154,860	3,494,609	3,426,154	3,664,260
2008	447,813	350,823	3,649,469	3,996,959	3,760,638
2009	-56,080	320,843	4,000,292	4,444,772	3,766,388
2010	208,801	200,176	4,321,135	4,388,692	3,941,612
2011	164,846	105,855	4,521,311	4,597,493	4,085,140
2012	-513,430	-46,594	4,627,165	4,762,339	4,186,938
2013	-	-	4,580,571	4,248,909	3,925,867

Table I-3. Groundwater Mound Water Volumes with Runoff Adjustment

Year	Water Balance Factors that Increase the Domain (ac-ft)	Water Balance Factors that Reduce the Domain Except Runoff (ac-ft)	Adjusted Runoff Volume (ac-ft)	Adjusted Runoff Water Balance (ac-ft)	Adjusted Runoff Water Balance Groundwater Mound Water Volume (ac-ft)	Un-Adjusted Water Balance Groundwater Mound Water Volume (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)
1985	2,695,097	2,367,754	28,257	299,086	3,130,484	3,130,484	3,130,484
1986	2,381,595	2,312,200	22,383	47,012	3,429,570	3,429,570	3,326,308
1987	2,885,127	2,475,423	42,827	366,877	3,476,582	3,476,582	3,406,361
1988	2,166,973	2,308,226	17,586	-158,840	3,843,459	3,843,459	3,498,930
1989	2,236,780	2,261,509	18,747	-43,476	3,684,619	3,684,619	3,471,412
1990	2,076,797	2,189,597	13,879	-126,680	3,641,143	3,641,143	3,466,547
1991	2,118,875	2,255,002	15,599	-151,726	3,514,463	3,514,463	3,457,168
1992	2,429,382	2,359,596	24,462	45,324	3,362,737	3,362,737	3,364,589
1993	3,508,985	2,576,348	349,539	583,097	3,408,060	3,408,060	3,427,375
1994	2,339,387	2,407,271	23,592	-91,476	3,991,158	4,249,124	3,830,248
1995	2,359,476	2,384,607	21,918	-47,049	3,899,682	4,157,649	3,794,684
1996	2,983,072	2,560,556	57,197	365,319	3,852,633	4,110,600	3,776,446
1997	2,253,056	2,403,414	21,273	-171,631	4,217,952	4,475,919	4,031,735
1998	2,300,931	2,373,284	25,132	-97,486	4,046,322	4,304,288	4,000,794
1999	2,517,737	2,471,463	31,098	15,176	3,948,836	4,206,803	4,113,130
2000	2,336,942	2,381,735	22,672	-67,466	3,964,012	4,276,855	4,276,855
2001	2,413,649	2,399,181	27,355	-12,887	3,896,546	4,209,389	4,128,596
2002	1,612,984	2,043,956	11,577	-442,548	3,883,659	4,196,503	4,219,418
2003	2,055,274	2,237,957	14,732	-197,415	3,441,111	3,753,954	3,979,037
2004	2,382,536	2,381,082	25,618	-24,164	3,243,696	3,556,539	3,886,003
2005	2,219,585	2,340,069	19,598	-140,082	3,219,532	3,532,376	3,719,408
2006	2,487,175	2,423,326	29,987	33,861	3,079,450	3,392,293	3,604,821
2007	3,179,314	2,540,920	184,041	454,353	3,113,311	3,426,154	3,664,260
2008	3,032,504	2,526,755	57,936	447,813	3,567,664	3,996,959	3,760,638
2009	2,350,675	2,381,985	24,770	-56,080	4,015,477	4,444,772	3,766,388
2010	2,731,040	2,481,840	40,399	208,801	3,959,397	4,388,692	3,941,612
2011	2,670,377	2,468,641	36,890	164,846	4,168,198	4,597,493	4,085,140
2012	1,427,390	1,929,518	11,302	-513,430	4,333,044	4,762,339	4,186,938
2013	-	-	-	-	3,819,614	4,248,909	3,925,867

Table I-4. Groundwater Mound Water Volumes with Varying Diversion Volumes

Year	Water Balance Factors that Reduce the Domain (ac-ft)	Water Balance Factors that Increase the Domain Except Diversions (ac-ft)	125% Diversions (ac-ft)	Water Balance - 125% Diversions (ac-ft)	Water Balance Groundwater Mound Water Volume - 125% Diversions (ac-ft)	100% Diversions (ac-ft)	Water Balance - 100% Diversions (ac-ft)	Water Balance Groundwater Mound Water Volume - 100% Diversions (ac-ft)	75% Diversions (ac-ft)	Water Balance -75% Diversions (ac-ft)	Water Balance Groundwater Mound Water Volume - 75% Diversions (ac-ft)	50% Diversions (ac-ft)	Water Balance -50% Diversions (ac-ft)	Water Balance Groundwater Mound Water Volume - 50% Diversions (ac-ft)	25% Diversions (ac-ft)	Water Balance -25% Diversions (ac-ft)	Water Balance Groundwater Mound Water Volume - 25% Diversions (ac-ft)	No Diversions (ac-ft)	Water Balance -No Diversions (ac-ft)	Water Balance Groundwater Mound Water Volume - No Diversions (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)
1985	2,396,011	2,502,284	241,016	347,289	3,130,484	192,812	299,086	3,130,484	144,609	250,883	3,130,484	96,406	202,680	3,130,484	48,203	154,476	3,130,484	0	106,273	3,130,484	3,130,484
1986	2,334,583	2,164,448	271,434	101,299	3,477,773	217,147	47,012	3,429,570	162,861	-7,275	3,381,367	108,574	-61,562	3,333,164	54,287	-115,849	3,284,961	0	-170,135	3,236,758	3,326,308
1987	2,518,250	2,700,505	230,777	413,032	3,579,072	184,622	366,877	3,476,582	138,466	320,721	3,374,092	92,311	274,566	3,271,602	46,155	228,410	3,169,112	0	182,255	3,066,622	3,406,361
1988	2,325,813	1,931,043	294,912	-99,858	3,992,104	235,929	-158,840	3,843,459	176,947	-217,822	3,694,814	117,965	-276,805	3,546,168	58,982	-335,787	3,397,523	0	-394,769	3,248,877	3,498,930
1989	2,280,256	2,021,863	268,646	10,253	3,892,247	214,917	-43,476	3,684,619	161,188	-97,206	3,476,991	107,459	-150,935	3,269,364	53,729	-204,664	3,061,736	0	-258,393	2,854,108	3,471,412
1990	2,203,476	1,827,028	312,211	-64,238	3,902,500	249,769	-126,680	3,641,143	187,327	-189,122	3,379,786	124,885	-251,564	3,118,429	62,442	-314,007	2,857,072	0	-376,449	2,595,715	3,466,547
1991	2,270,601	1,860,794	322,601	-87,206	3,838,262	258,081	-151,726	3,514,463	193,561	-216,246	3,190,663	129,041	-280,767	2,866,864	64,520	-345,287	2,543,065	0	-409,807	2,219,266	3,457,168
1992	2,384,058	2,221,925	259,321	97,188	3,751,056	207,457	45,324	3,362,737	155,593	-6,540	2,974,417	103,729	-58,405	2,586,098	51,864	-110,269	2,197,778	0	-162,133	1,809,459	3,364,589
1993	2,667,921	3,416,283	115,878	864,240	3,848,244	92,702	841,064	3,408,060	69,527	817,889	2,967,877	46,351	794,713	2,527,693	23,176	771,538	2,087,509	0	748,362	1,647,325	3,427,375
1994	2,430,863	2,135,194	255,241	-40,427	4,712,484	204,193	-91,476	4,249,124	153,145	-142,524	3,785,765	102,097	-193,572	3,322,406	51,048	-244,620	2,859,047	0	-295,669	2,395,687	3,830,248
1995	2,406,525	2,111,540	309,920	14,935	4,672,056	247,936	-47,049	4,157,649	185,952	-109,033	3,643,241	123,968	-171,017	3,128,834	61,984	-233,001	2,614,426	0	-294,985	2,100,019	3,794,684
1996	2,617,753	2,840,557	178,144	400,948	4,686,992	142,515	365,319	4,110,600	106,886	329,690	3,534,209	71,258	294,062	2,957,817	35,629	258,433	2,381,426	0	222,804	1,805,034	3,776,446
1997	2,424,687	2,004,052	311,255	-109,380	5,087,939	249,004	-171,631	4,475,919	186,753	-233,882	3,863,899	124,502	-296,133	3,251,879	62,251	-358,384	2,639,858	0	-420,635	2,027,838	4,031,735
1998	2,398,417	2,084,669	270,328	-43,420	4,978,560	216,262	-97,486	4,304,288	162,197	-151,551	3,630,017	108,131	-205,617	2,955,746	54,066	-259,682	2,281,475	0	-313,748	1,607,203	4,000,794
1999	2,502,561	2,334,399	229,173	61,011	4,935,139	183,338	15,176	4,206,803	137,504	-30,658	3,478,466	91,669	-76,493	2,750,129	45,835	-122,327	2,021,792	0	-168,162	1,293,456	4,113,130
2000	2,404,408	2,108,519	285,529	-10,360	4,996,150	228,423	-67,466	4,276,855	171,317	-124,572	3,447,808	114,212	-181,677	2,673,636	57,106	-238,783	1,899,465	0	-295,889	1,125,294	4,276,855
2001	2,426,536	2,220,725	241,155	35,344	4,985,790	192,924	-12,887	4,209,389	144,693	-61,118	3,323,236	96,462	-109,349	2,491,959	48,231	-157,580	1,660,682	0	-205,811	829,405	4,128,596
2002	2,055,532	1,388,951	280,041	-386,540	5,021,134	224,033	-442,548	4,196,503	168,025	-498,557	3,262,118	112,017	-554,565	2,382,610	56,008	-610,573	1,503,102	0	-666,581	623,594	4,219,418
2003	2,252,689	1,844,603	263,339	-144,747	4,634,594	210,671	-197,415	3,753,954	158,003	-250,083	2,763,562	105,336	-302,750	1,828,045	52,668	-355,418	892,529	0	-408,086	-42,987	3,979,037
2004	2,406,700	2,183,195	249,176	25,671	4,489,847	199,341	-24,164	3,556,539	149,506	-73,999	2,513,479	99,671	-123,834	1,525,295	49,835	-173,670	537,111	0	-223,505	-451,073	3,886,003
2005	2,359,667	2,092,999	158,233	-108,436	4,515,518	126,586	-140,082	3,532,376	94,940	-171,729	2,439,480	63,293	-203,375	1,401,461	31,647	-235,022	363,441	0	-266,668	-674,578	3,719,408
2006	2,453,314	2,352,968	167,759	67,413	4,407,083	134,207	33,861	3,392,293	100,655	309	2,267,751	67,104	-33,243	1,198,085	33,552	-66,794	128,420	0	-100,346	-941,246	3,604,821
2007	2,608,509	3,078,887	125,534	595,912	4,474,495	100,427	570,805	3,426,154	75,320	545,698	2,268,060	50,214	520,592	1,164,843	25,107	495,485	61,625	0	470,378	-1,041,592	3,664,260
2008	2,584,692	2,926,929	131,969	474,206	5,070,407	105,575	447,813	3,996,959	79,181	421,419	2,813,759	52,788	395,025	1,685,435	26,394	368,631	557,110	0	342,238	-571,214	3,760,638
2009	2,406,754	2,201,108	186,959	-18,688	5,544,614	149,567	-56,080	4,444,772	112,175	-93,472	3,235,178	74,784	-130,863	2,080,460	37,392	-168,255	925,742	0	-205,647	-228,976	3,766,388
2010	2,522,238	2,600,045	163,744	241,550	5,525,926	130,995	208,801	4,388,692	98,246	176,053	3,141,706	65,498	143,304	1,949,596	32,749	110,555	757,487	0	77,806	-434,623	3,941,612
2011	2,505,531	2,522,928	184,311	201,708	5,767,476	147,449	164,846	4,597,493	110,587	127,984	3,317,759	73,725	91,121	2,092,900	36,862	54,259	868,042	0	17,397	-356,817	4,085,140
2012	1,940,820	1,233,925	241,831	-465,064	5,969,184	193,465	-513,430	4,762,339	145,099	-561,797	3,445,742	96,733	-610,163	2,184,021	48,366	-658,529	922,301	0	-706,895	-339,420	4,186,938
2013	-	-	-	-	5,504,120	-	-	4,248,909	-	-	2,883,946	-	-	1,573,859	-	-	263,772	-	-	-1,046,316	3,925,867

Table I-5. Groundwater Mound Water Volumes with Varying Specific Yield

Year	Groundwater Mound Volume - CSD Well Data (ac-ft)	Specifc Yield = 0.12		Specifc Yield = 0.14		Specifc Yield = 0.16		Specifc Yield = 0.18		Specifc Yield = 0.20	
		Groundwater Mound Water Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - Water Balance (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - Water Balance (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - Water Balance (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - Water Balance (ac-ft)	Groundwater Mound Water Volume - CSD Well Data (ac-ft)	Groundwater Mound Water Volume - Water Balance (ac-ft)
1985	3.13E+06	2,683,272	2,683,272	3,130,484	3,130,484	3,577,696	3,577,696	4,024,909	4,024,909	4,472,121	4,472,121
1986	3.43E+06	2,851,121	2,982,358	3,326,308	3,429,570	3,801,495	3,876,782	4,276,682	4,323,994	4,751,868	4,771,206
1987	3.48E+06	2,919,738	3,029,370	3,406,361	3,476,582	3,892,984	3,923,794	4,379,607	4,371,006	4,866,230	4,818,218
1988	3.84E+06	2,999,083	3,396,247	3,498,930	3,843,459	3,998,778	4,290,671	4,498,625	4,737,883	4,998,472	5,185,095
1989	3.68E+06	2,975,496	3,237,407	3,471,412	3,684,619	3,967,328	4,131,831	4,463,244	4,579,043	4,959,160	5,026,255
1990	3.64E+06	2,971,326	3,193,930	3,466,547	3,641,143	3,961,768	4,088,355	4,456,989	4,535,567	4,952,211	4,982,779
1991	3.51E+06	2,963,287	3,067,251	3,457,168	3,514,463	3,951,049	3,961,675	4,444,930	4,408,887	4,938,812	4,856,099
1992	3.36E+06	2,883,933	2,915,524	3,364,589	3,362,737	3,845,244	3,809,949	4,325,900	4,257,161	4,806,555	4,704,373
1993	3.41E+06	2,937,750	2,960,848	3,427,375	3,408,060	3,917,000	3,855,272	4,406,625	4,302,484	4,896,249	4,749,696
1994	3.99E+06	3,283,070	3,801,912	3,830,248	4,249,124	4,377,426	4,696,336	4,924,605	5,143,549	5,471,783	5,590,761
1995	3.90E+06	3,252,586	3,710,437	3,794,684	4,157,649	4,336,781	4,604,861	4,878,879	5,052,073	5,420,977	5,499,285
1996	3.85E+06	3,236,953	3,663,388	3,776,446	4,110,600	4,315,938	4,557,812	4,855,430	5,005,024	5,394,922	5,452,236
1997	4.22E+06	3,455,773	4,028,707	4,031,735	4,475,919	4,607,697	4,923,131	5,183,659	5,370,343	5,759,621	5,817,555
1998	4.05E+06	3,429,252	3,857,076	4,000,794	4,304,288	4,572,336	4,751,500	5,143,878	5,198,713	5,715,420	5,645,925
1999	3.95E+06	3,525,540	3,759,591	4,113,130	4,206,803	4,700,720	4,654,015	5,288,310	5,101,227	5,875,900	5,548,439
2000	3.96E+06	3,665,876	3,774,767	4,276,855	4,276,855	4,887,835	4,669,191	5,498,814	5,116,403	6,109,793	5,563,615
2001	3.90E+06	3,538,797	3,707,301	4,128,596	4,209,389	4,718,396	4,601,725	5,308,195	5,048,937	5,897,995	5,496,149
2002	3.88E+06	3,616,644	3,694,414	4,219,418	4,196,503	4,822,192	4,588,838	5,424,966	5,036,050	6,027,740	5,483,262
2003	3.44E+06	3,410,603	3,251,866	3,979,037	3,753,954	4,547,471	4,146,290	5,115,905	4,593,502	5,684,339	5,040,714
2004	3.24E+06	3,330,860	3,054,451	3,886,003	3,556,539	4,441,146	3,948,875	4,996,290	4,396,087	5,551,433	4,843,299
2005	3.22E+06	3,188,064	3,030,287	3,719,408	3,532,376	4,250,752	3,924,711	4,782,096	4,371,923	5,313,440	4,819,135
2006	3.08E+06	3,089,847	2,890,205	3,604,821	3,392,293	4,119,795	3,784,629	4,634,770	4,231,841	5,149,744	4,679,053
2007	3.11E+06	3,140,794	2,924,066	3,664,260	3,426,154	4,187,725	3,818,490	4,711,191	4,265,702	5,234,657	4,712,914
2008	3.57E+06	3,223,404	3,494,871	3,760,638	3,996,959	4,297,872	4,389,295	4,835,106	4,836,507	5,372,340	5,283,719
2009	4.02E+06	3,228,333	3,942,684	3,766,388	4,444,772	4,304,444	4,837,108	4,842,499	5,284,320	5,380,555	5,731,532
2010	3.96E+06	3,378,524	3,886,604	3,941,612	4,388,692	4,504,699	4,781,028	5,067,787	5,228,240	5,630,874	5,675,452
2011	4.17E+06	3,501,549	4,095,405	4,085,140	4,597,493	4,668,732	4,989,829	5,252,323	5,437,041	5,835,914	5,884,253
2012	4.33E+06	3,588,804	4,260,251	4,186,938	4,762,339	4,785,072	5,154,675	5,383,206	5,601,887	5,981,340	6,049,099
2013	3.82E+06	3,365,029	3,746,821	3,925,867	4,248,909	4,486,705	4,641,245	5,047,543	5,088,457	5,608,381	5,535,669

Appendix J

Subarea Groundwater Mound Volumes

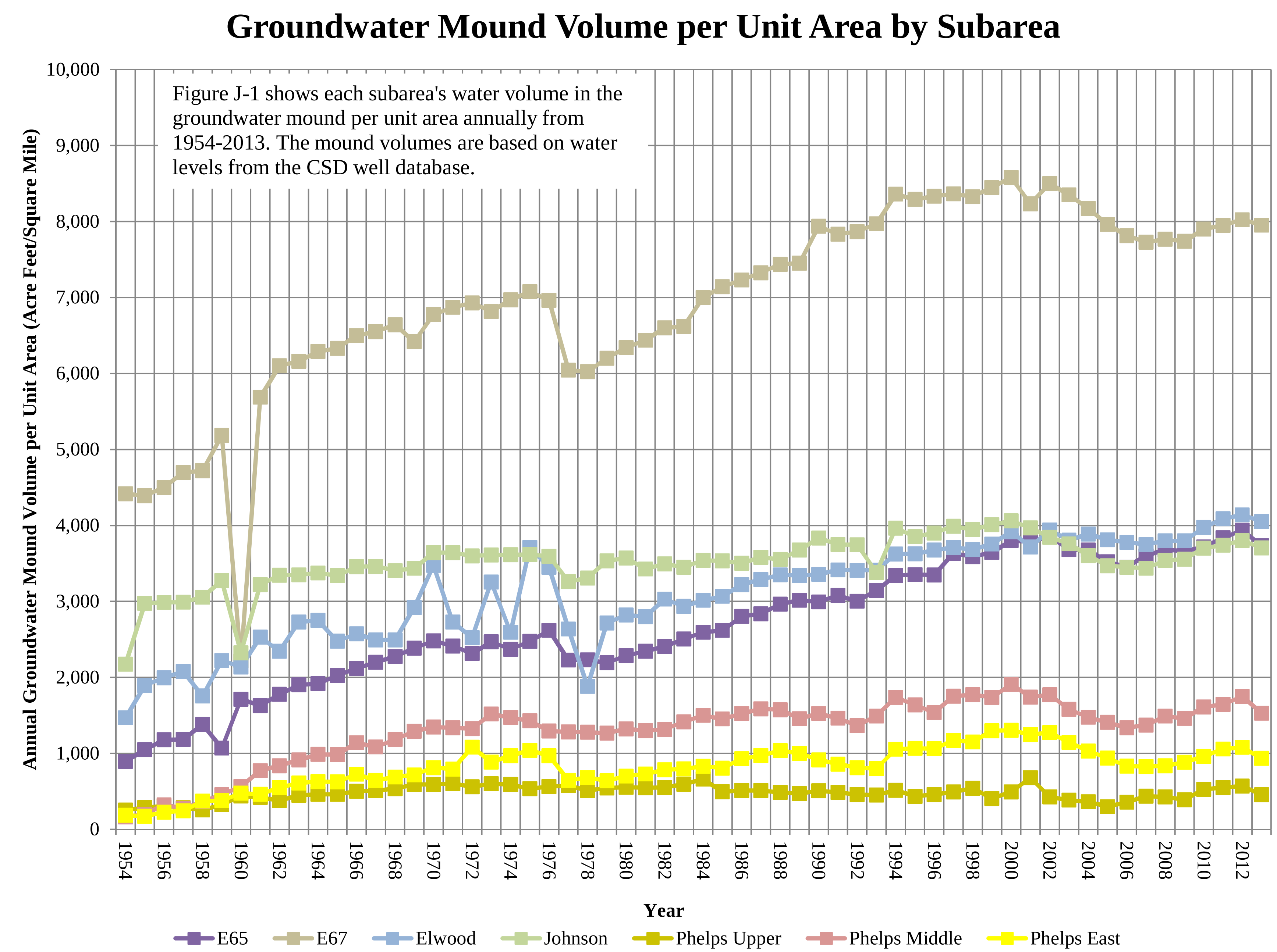

Figure J-1. Calculated volume of the groundwater mound per unit area in each subarea.

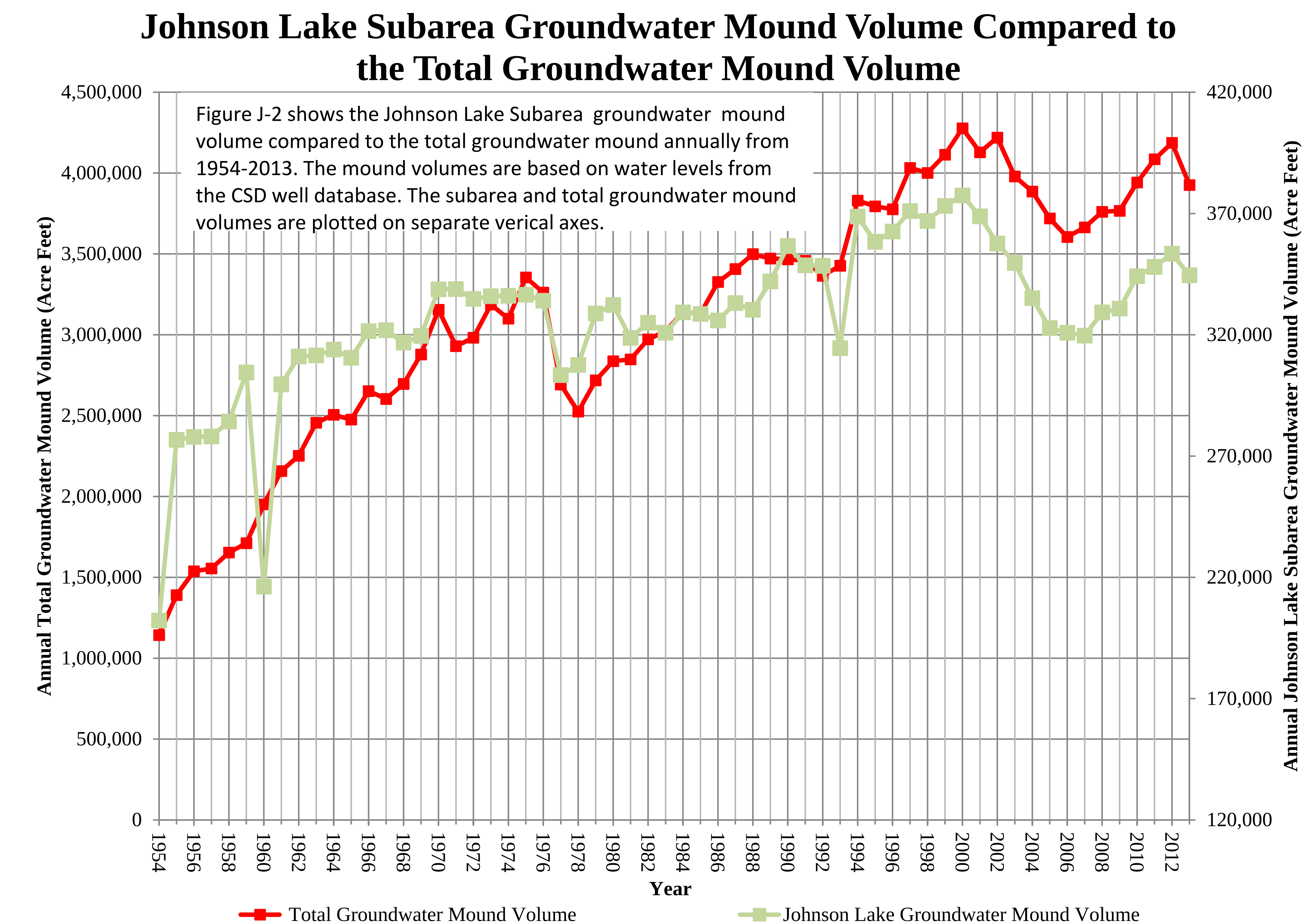

Figure J-2. The annual Johnson Lake Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.

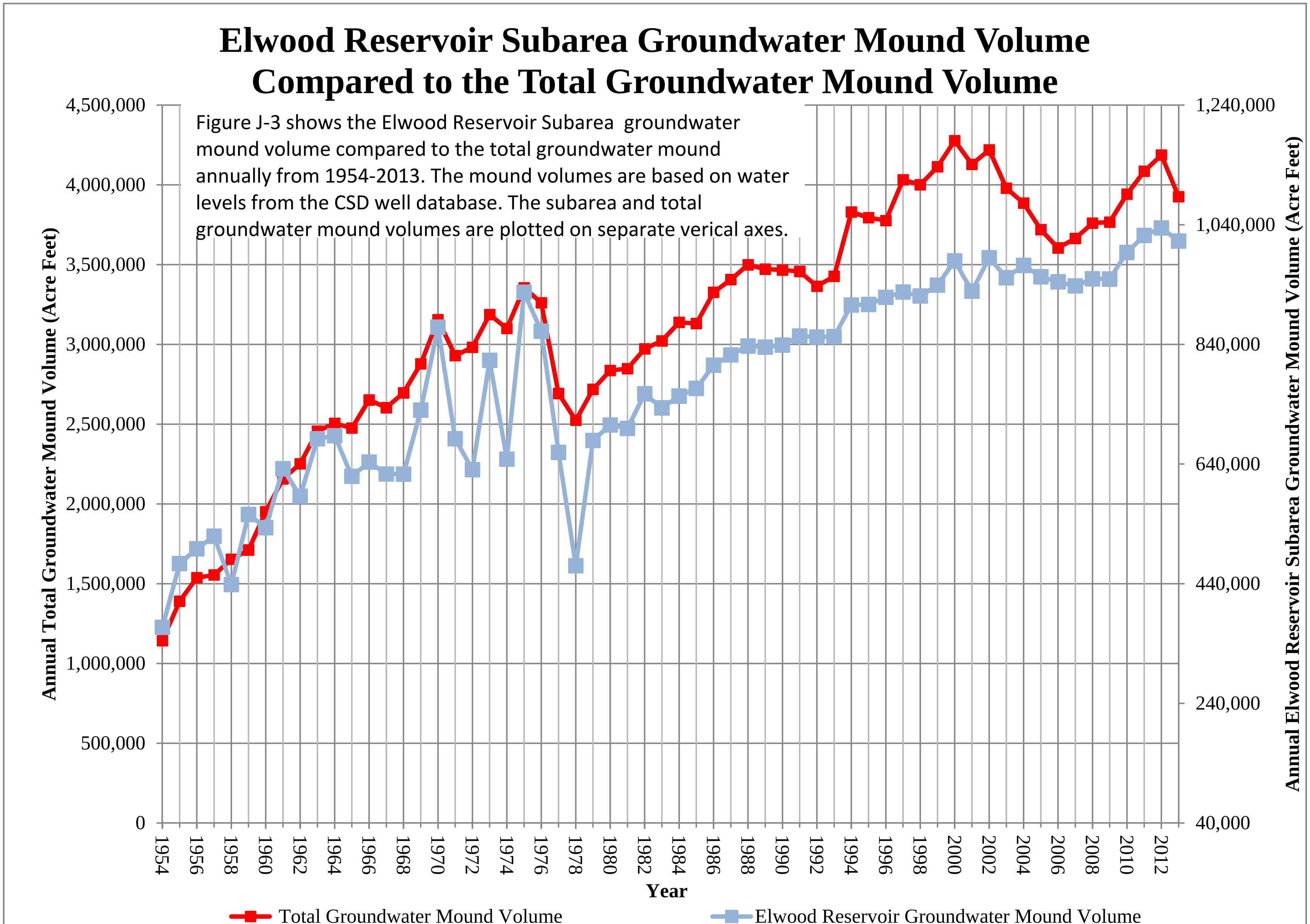

Figure J-3. The annual Elwood Reservoir Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.

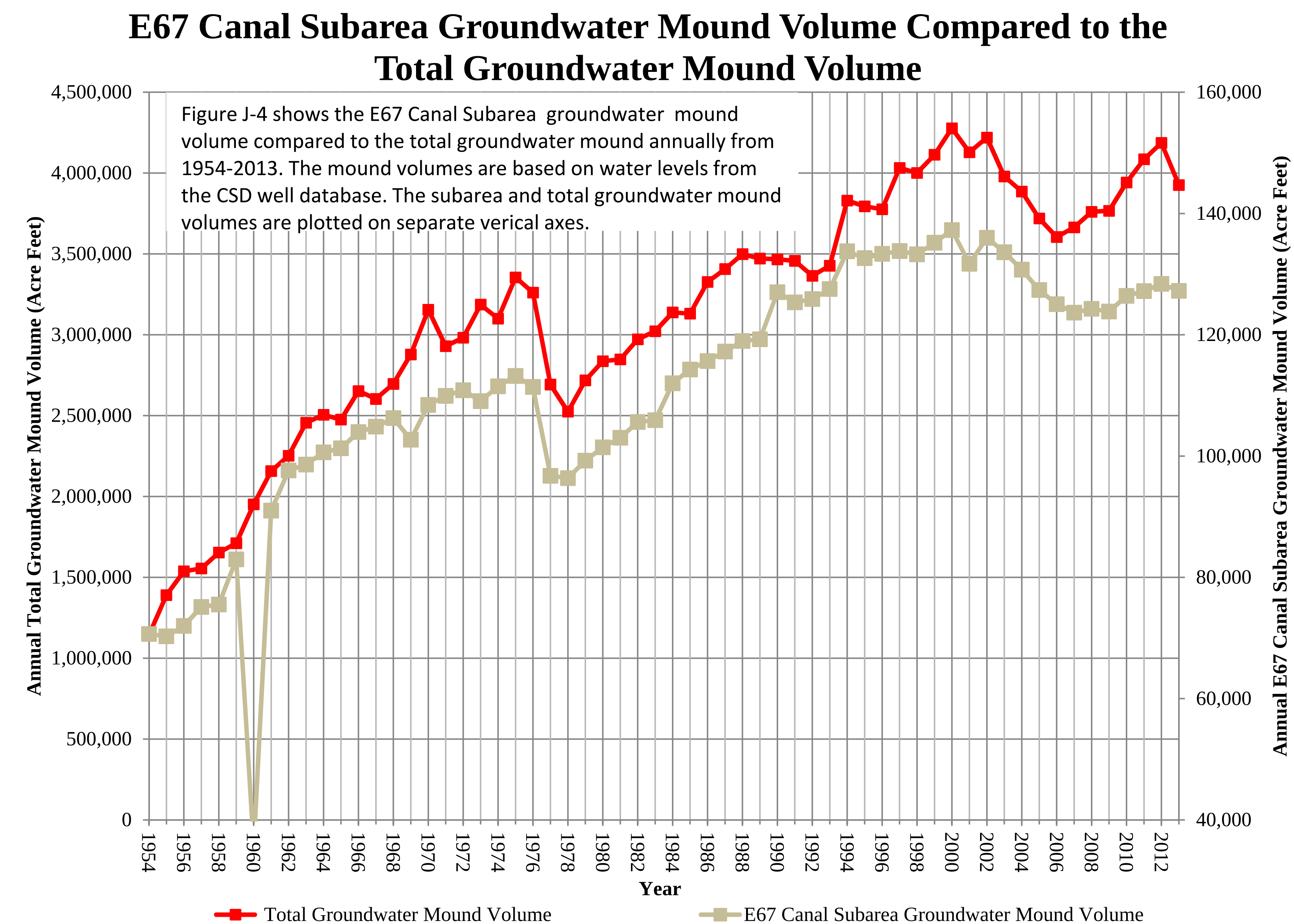

Figure J-4. The annual E67 Canal Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.

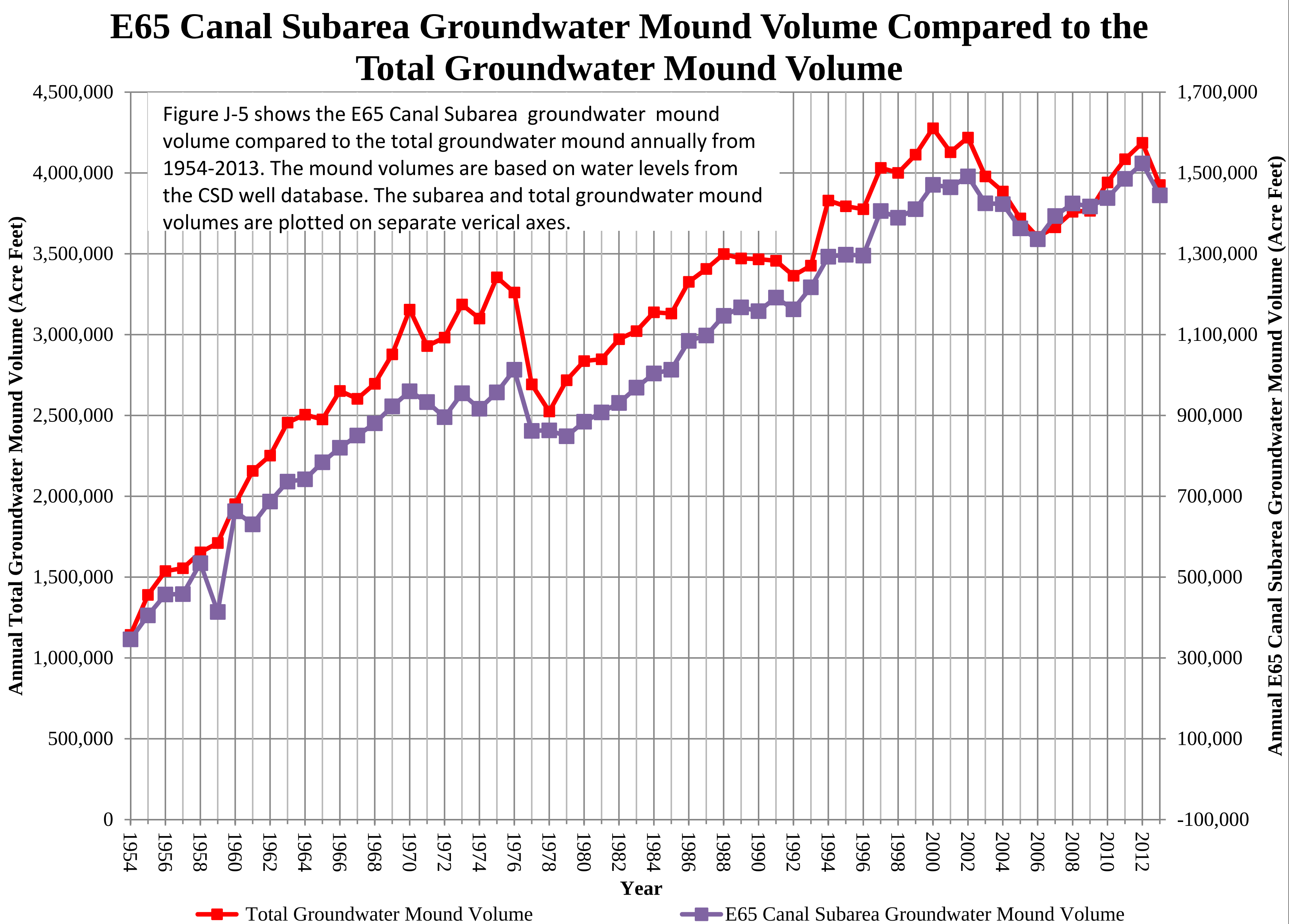

Figure J-5. The annual E65 Canal Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.

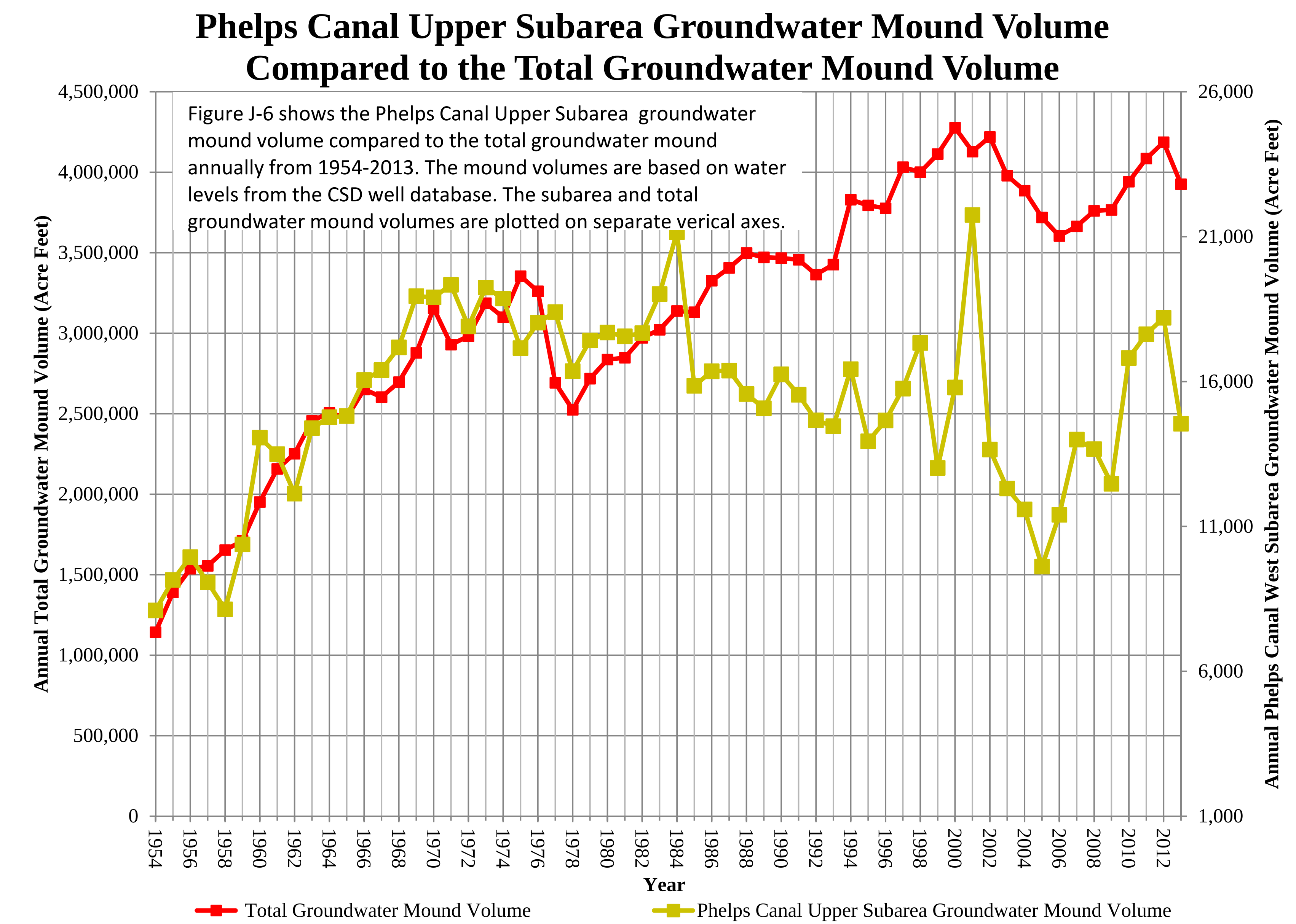

Figure J-6. The annual Phelps Canal West Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.

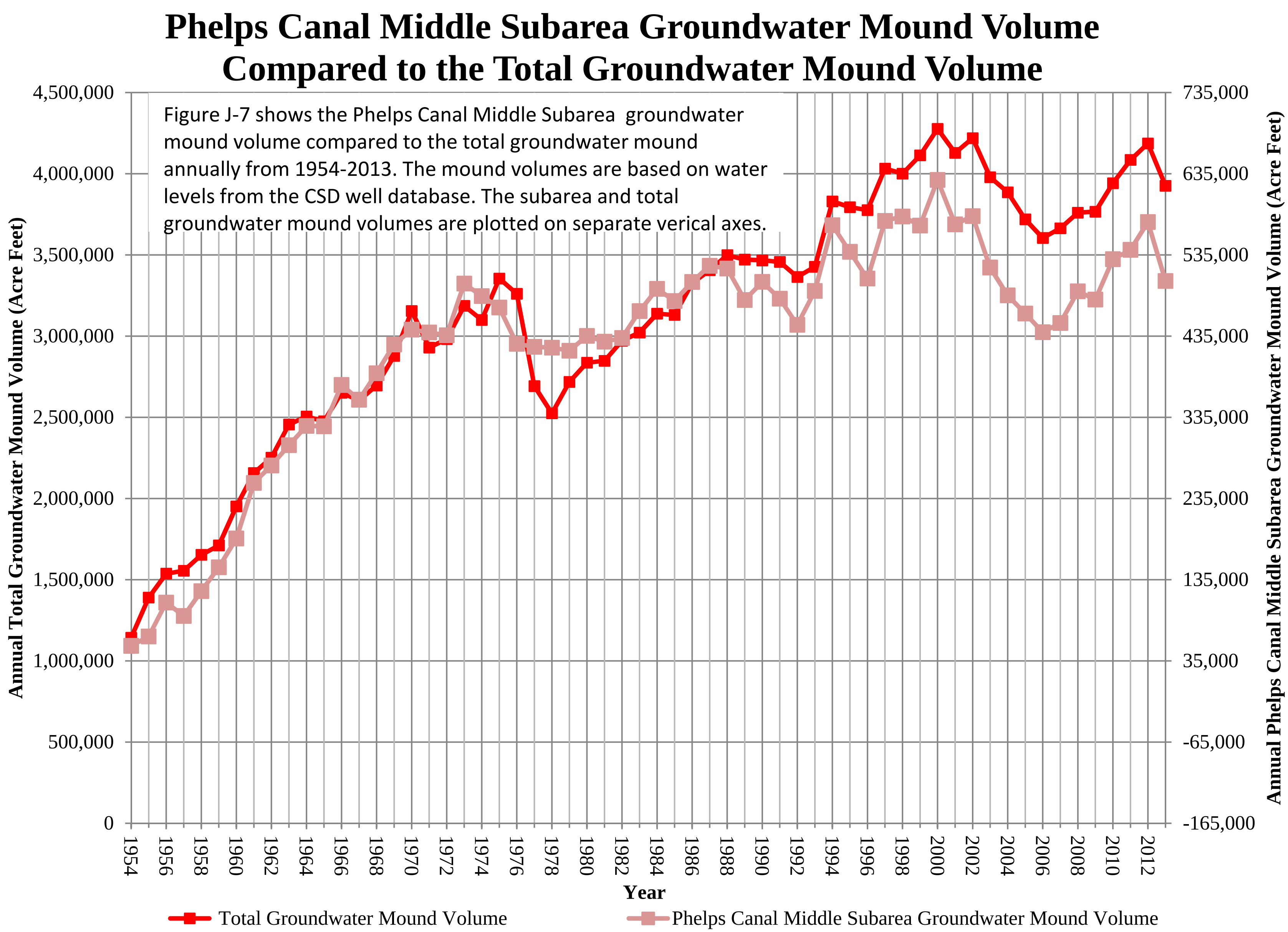

Figure J-7. The annual Phelps Canal Middle Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.

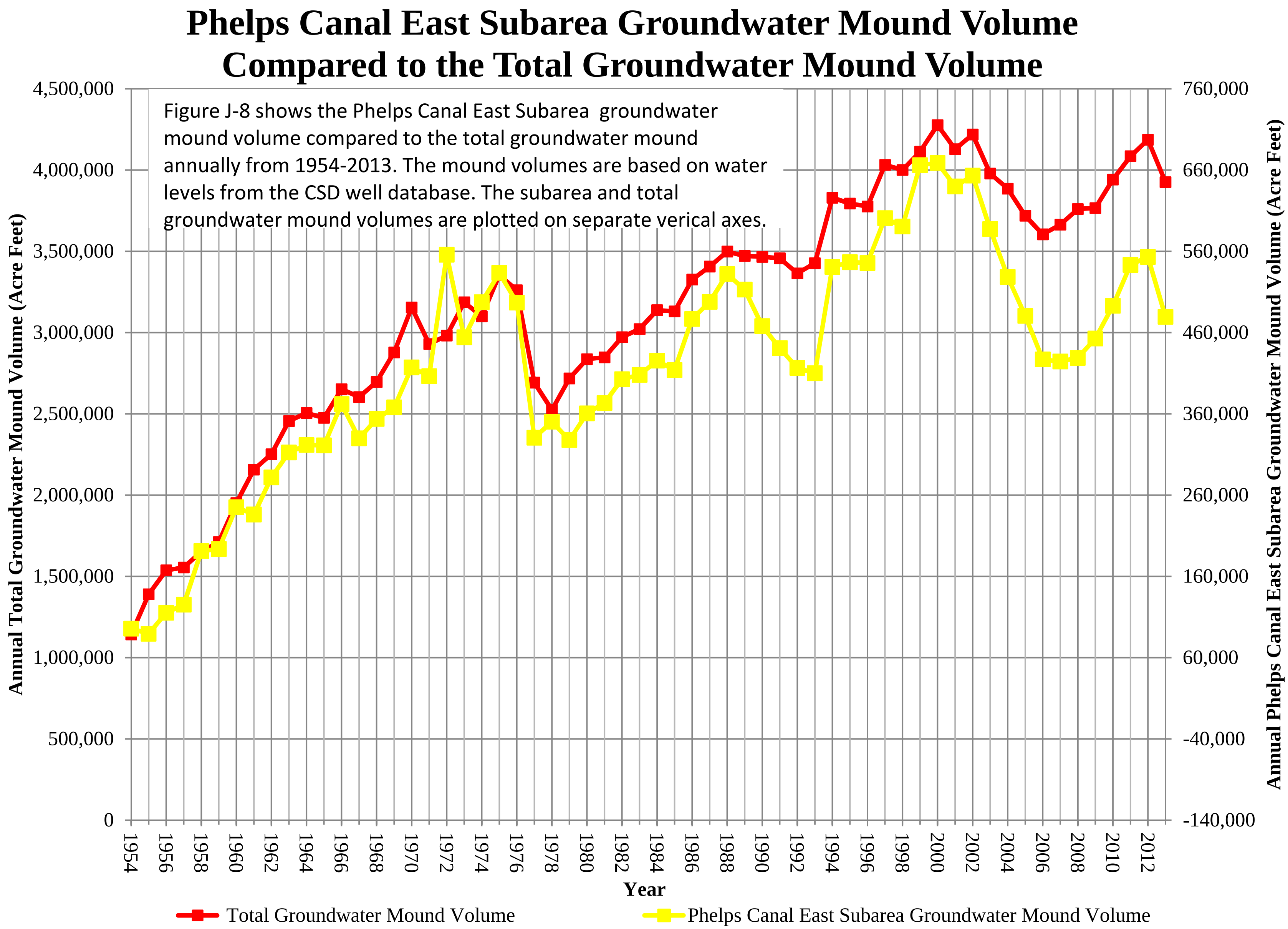

Figure J-8. The annual Phelps Canal East Subarea groundwater mound volumes compared to the annual groundwater mound volumes of the entire study area.