SYNERGEN WELL PERMIT HYDROLOGIC EVALUATION

Prepared for:

Upper Big Blue Natural Resources District

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ACRONYMS AND ABBREVIATIONS

BRB .... Blue River Basin (Model)
gpm .... gallons per minute
NeDNR .... Nebraska Department of Natural Resources
NUBBS .... Northern Upper Big Blue Subregional (Model)
NWIS .... National Water Information System
TFG .... The Flatwater Group
UBBNRD .... Upper Big Blue Natural Resources District
UNL-CSD .... University of Nebraska-Lincoln Conservation and Survey Division
USGS .... United States Geological Survey

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EXECUTIVE SUMMARY

Aurora Development Corporation is assisting a proposed large water user, Synergen, in the area with the process of conducting necessary environmental assessments and investigations and securing necessary permits. One such permit is a well permit, issued by the Upper Big Blue Natural Resources District, which requires a hydrologic evaluation of the potential impacts of the large water use. For this purpose, Olsson coordinated with the Upper Big Blue Natural Resources District to obtain files for the Blue River Basin regional groundwater model created by GSI Environmental and, from this, constructed the Northern Upper Big Blue Subregional model. This subregional model, covering 874 square miles in the vicinity of Aurora, Nebraska (Figure 1, Location Map), was constructed with Synergen's proposed large water use centrally located within the domain to ensure that the simulated radius of influence of the proposed well(s) would not be impacted by the model boundaries.

Olsson used a three-step strategy to develop a model capable of testing the impact of the proposed water use on existing wells in the area. The first step was to construct the subregional model using the regional model files supplied by GSI Environmental. The second part of model development involved creating a steady-state simulation, followed by simulation of a transient period from 1941 to 2018 to ensure the model's capability to replicate changing water level conditions in the local aquifer. With the calibrated transient model, the third phase of the process involved simulating the proposed well(s) pumping throughout the last 25 years of the transient period at the proposed pumping rate and documenting the simulated impact on existing wells in the area.

This report documents the characteristics of the site, the model development, and an assessment of the impact of the proposed new well(s). The proposed use was simulated at a continuous pumping rate of 2,300 gallons per minute for 25 years. Impacts of this simulation were evaluated for the 54 groundwater wells with complete records within a three-mile radius of the new use.

The impact analysis showed that Synergen's water use will have a minimal impact on existing wells in the area. Water level reductions at the proposed site were 10-14.5 feet, with reductions at the edge of the three-mile radius being no more than one to three feet. The reduction in static saturated interval at wells within the three-mile radius was overwhelmingly in the range of 2-3%. Therefore, the expected impacts to the groundwater supply and pumping capacity at existing wells should be minimal and should not impact their operations. Based on the results of this hydrologic analysis, there does not appear to be any reason why Synergen's water use should not be approved for construction and operation at a maximum pumping rate of 2,300 gallons per minute.

1. INTRODUCTION

As required by the Upper Big Blue Natural Resources District (UBBNRD), a hydrogeologic study must be included as part of any application for large water users that pump 500 acre-feet or more per year. Olsson created a subregional groundwater model of the local aquifer - the Northern Upper Big Blue Subregional (NUBBS) model - from the Blue River Basin (BRB) model provided by UBBNRD's consultant. The NUBBs model was used to evaluate potential impacts of a proposed new large water user near Aurora, Synergen, to provide support for Synergen's permit application. The NUBBS model area covers 874 square miles with the northern and southern model boundaries 11 and 18.5 miles from the location of the proposed use, respectively. The western and eastern model boundaries are located 10 and 23 miles, respectively, from the proposed use; the NUBBS model boundary, identified as 'model' boundary, can be seen in black and white in **Figure 1** (we note that the dark area in this figure is due to refinement of the NUBBS model grid in the area – this is more easily observed in **Figure 24**). The NUBBS model area was defined with the proposed well(s) centrally located within the model domain to ensure that the simulated radius of influence of the proposed use would not be impacted by the model boundaries and to include nearby wellhead protection areas in the area east/northeast of the site.

Olsson used a three-step strategy to develop a subregional model capable of testing the impact of the proposed water use on existing wells in the area. The first step involved construction of a site-specific model using hydrostratigraphic data supplied by UBBNRD. The second part of model development involved creating a steady-state simulation followed by simulation of a transient period from 1941 to 2018 to ensure the model's capability to replicate changing water level conditions in the aquifer. With the calibrated transient model, the third phase of the process involved simulating the proposed well pumping throughout the transient period at the proposed pumping rate and documenting the simulated impact on existing wells. Each step in this process is described in further detail in the following sections.

2. SITE CHARACTERIZATION AND CONCEPTUAL MODEL

We describe below the general site/subregional characteristics and a conceptual model of the area.

2.1 Topography and Land Use

Within the BRB model area of interest, there are four predominant topographic regions as mapped by the University of Nebraska-Lincoln Conservation and Survey Division (UNL-CSD): plains, dissected plains, rolling hills, and valleys (Korus et al., 2013). The subregional NUBBS model lies within the western/central portions of the BRB model area of interest, an area characterized by plains that are uplands with generally low relief that have been covered by windblown loess or eolian sand. Runoff is low in the area, owing to the generally flat slopes of land surface as observed in **Figure 2**.

Land use in the area of the NUBBS model, as observed in **Figure 3**, is predominantly agricultural, with the majority of that land being irrigated row crops (corn being the most common). Urban land use accounts for less than 1% of the NUBBS model area, with most of that being within the city of Aurora, east of the proposed large water use site.

2.2 Geology and Hydrostratigraphy

In this portion of the High Plains Aquifer, groundwater moves through the pore spaces between unconsolidated and consolidated grains of clay, silt, sand, siltstone, and sandstone. Underlying the proposed Synergen site and the NUBBS model area is primarily Quaternary deposits. This forms the primary aquifer and water supply unit in the region. These sediments are considered part of the High Plains Aquifer. Underlying the Tertiary sand and sandstone deposits are late Tertiary silts and siltstones (Cannia et al., 2006).

Brown and Caldwell/GSI Environmental created five model layers for the BRB regional model for geologic and hydrostratigraphic representation. The model layers were provided to Olsson electronically by Brown and Caldwell, at UBBNRD's request, for the regional model for the creation of the NUBBS model. These layers were designed using test hole data from UNL-CSD and were supplemented with drillers' logs of additional wells in the regional model domain (GSI Environmental, 2023). The age, geologic properties, and water supply information for model layers 1-5 are described in **Table 1**. Layer 1 primarily represents Upper Quaternary silt and clay loess, with some sand and gravel at certain locations. Layer 2 represents fine to medium Middle Quaternary-age sand and gravels. Layer 3 represents Lower Quaternary fine silt and clay, with some sand and gravels. Layer 4 represents the primary water-bearing unit of the High Plains Aquifer; this layer consists of Middle Quaternary medium to coarse sand and gravel. Layer 5 represents Tertiary-age silt and clay, underlain with weathered bedrock material derived from shale, siltstones, limestones, and sandstones. The thickness of model layers 1-5 can be observed in **Figures 4-8**. The thickness of Layer 4, the primary water-bearing layer for this subregional model, ranged from less than 10 feet thick in the southeastern portion of the model to almost 140 feet thick on the western edge of the modeled area.

Table 1. Stratigraphic description of geologic units used in the NUBBS model (GSI Environmental, 2023).

Layer	Geologic Period	Geologic Unit	Description	Water Supply
1	Quaternary	Upper Quaternary (Loess)	Silt and clay loess, with some sand and gravel at locations	Source of water to domestic and livestock wells
2		Middle Quaternary	Medium to fine grained sand and gravel that forms an unconfined to semi-confined aquifer layer	A major source of water throughout the BRB regional model area but is limited to alluvial and channel deposits
3		Lower Quaternary	Fine silt and clay layer, with some sand and gravel, that confines or partially confines Layer 4	Rarely used as a water source
4		Middle Quaternary	Medium to coarse sand and gravel that is simulated as a confined or leaky confined unit	The primary source of water throughout the BRB regional model area. Generally supplies sufficient water yield to all well types
5	Tertiary	Middle Tertiary silts, clays, and weathered bedrock	Silt and clay with some sand and gravel. This layer also contains, and is underlain with, weathered bedrock material derived from shale, chalk, limestone, siltstone, and sandstone.	Rarely used as a water source

The BRB regional model dataset also contains the values for the hydraulic conductivities and aquifer storage parameters for these hydrostratigraphic units. The hydraulic conductivities of model layers 1-5 are shown in **Figures 9-13**. The NUBBS model cells matched theses hydrogeologic parameters of the original BRB model cell in which they fell. These parameters are spatially identical between the NUBBS model and the BRB regional model. Within the NUBBS model, Layer 1 has arithmetic mean hydraulic conductivity value of 37.4 feet per day (ft/d); Layer 2 has an arithmetic mean value of 249.2 ft/d; and Layers 3, 4, and 5, have mean values of 24.8 ft/d, 297.3 ft/d, and 0.2 ft/d, respectively. This supports the reference in **Table 1** that Layers 2 and 4 are the two major water sources in the BRB regional model. As seen in **Figures 9 and 11,** the hydraulic conductivities for Layers 1 and 3 have a similar spatial distribution with the highest hydraulic conductivity values in the Platte River valley, and fairly low hydraulic conductivities spread throughout the rest of the NUBBS model domain. As shown in **Figure 13,** Layer 5 has a homogenous spatial distribution of extremely low hydraulic conductivity values, indicating the Tertiary-aged materials and the weathered bedrock material as described in **Table 1**.

The storage coefficients for Layers 1-5 can be seen in **Figures 14-18**. The storativity values of the unconfined hydrostratigraphic units in Layers 1 and 2 were higher than those of the confining or partially confined Layers 3, 4, and 5, with Layer 5 having the lowest arithmetic mean value of these three layers. Layers 1 and 2 had arithmetic mean values of 0.10 ft^{-1} and 0.20 ft^{-1}, and Layers 3 and 4 had arithmetic mean storage coefficient values of 0.01 ft^{-1} and 0.002 ft^{-1}, respectively.

There are 5,530 active registered wells within the NUBBS model boundary (NeDNR 2023). **Figure 19** illustrates the well type and percentage of each well type found within the subregional model boundary. The majority, 84.8%, of the active registered wells in the model boundary are irrigation wells, followed by 7.3% domestic wells, 3.0% monitoring wells, 0.4% commercial and industrial wells, and 4.5% wells that fall into all other categories. Test holes from UNL-CSD are indicated in **Figure 19** as well, as they were the primary source of geologic and hydrostratigraphic data in the creation of the BRB regional model.

Figure 20 shows all active, registered irrigation wells within the NUBBS model domain, categorized by the wells' registered pumping rate up to 2,400 gallons per minute (gpm). There are four locations where the pumping rates are generally lower: the first is to the north of the NUBBS model, near Marquette; the second is to the east of the model domain, near York; and the third and fourth are along the West Fork of the Big Blue River, one in the southwest of the model domain where the stream enters the model boundary, and the other near where the stream exits the model domain to the southeast. **Figure 21** indicates that within the model boundary, the deepest wells - 228 to 343 feet - are predominately located in the northern and eastern edge of the model and to the southwest of Aurora. The shallowest wells - less than 61 feet - are located along the major surface water features including the Platte River and the West Fork of the Big Blue River and directly to the east of York. **Figure 7**, which shows the thickness of Layer 4 (the primary water-bearing hydrostratigraphic unit in the NUBBS model), indicates an increasing thickness and therefore a substantial aquifer to the west of Aurora. The thickness of Layer 4 surrounding Aurora is close to or greater than 100 feet, and the two areas where the West Fork of the Big Blue River enters and exits the model domain have thickness less than 20 feet in some areas.

2.3 Hydrology

2.3.1 Surface Water

The Blue River basin comprises the land surface that drains to the Big Blue River and Little Blue River. The total area of the Big Blue River surface-water basin is approximately 6,150 square miles (approximately 4,590 square miles within Nebraska). For the area of interest of the NUBBS model constructed for this analysis, the majority of the land surface falls within the Big Blue River basin, largely within Hamilton County. The NUBBS model is bounded on the northwest by the Platte River.

2.3.1.1 Surface Water Streams

Figure 2 shows the stream courses of the Big Blue River and its major tributaries in the subregional model domain. The major tributaries of the Big Blue River in the area are Lincoln Creek and Beaver Creek. These streams are additionally fed by smaller tributaries and surface runoff. These streams also interact with groundwater, generally gaining water from groundwater discharge to the streams; however, some stream reaches may contribute water to underlying groundwater where the stream stage is above the groundwater table. Stream reaches that receive water from groundwater discharge are commonly referred to as “gaining reaches” or “gaining streams,” and stream reaches that contribute water to the underlying groundwater are commonly referred to as “losing reaches” or “losing streams.”

2.3.1.2 Baseflow Estimation

Baseflow is defined as the groundwater that discharges to streams through their beds and banks and often provides a “base level” of total streamflow in the absence of overland runoff, direct precipitation, wastewater discharges, or other sources of surface water. Baseflow discharges to streams are not constant and fluctuate up and down as groundwater levels fluctuate up and down, respectively. Total streamflow can be measured directly while baseflow can only be estimated, owing to the diffuse nature of the discharge of groundwater through the lengths of streambeds.

Total streamflow is continuously measured in Nebraska at specific stream gage locations on streams, and these stream gages are operated by both the United States Geological Survey (USGS) and Nebraska Department of Natural Resources (NeDNR). None of these stream gages are located within the NUBBS model domain, but the draft BRB model report provides location and station ID information for each gaging station in the regional model domain (GSI Environmental 2023).

Baseflows are most commonly estimated from measured total streamflow time-series records using a variety of mathematical techniques. The baseflow estimation method selected for the regional model was Base Flow Index (BFI) that was developed by researchers at U.S. Bureau of Reclamation and coded into a Fortran-based computer program (Wahl and Wahl, 1995). The BFI calculation implements a deterministic procedure originally developed by the British Institute of Hydrology, and the method combines a local minimums approach with a recession slope test (Institute of Hydrology, 1980).

For the NUBBS model, Olsson used the SFR package provided by GSI Environmental, with the relevant cells representing the West Fork of the Big Blue River being those used for the subregional analysis described here. **Table 2,** below, is adapted from the BRB model report to show the relevant stream gage for the West Fork of the Big Blue River; note, the stream gage listed is not within the NUBBS model domain.

Table 2. Stream Gages in BRB Regional Model Domain.

USGS/NeDNR ID Number	Descriptive Location	Approximate Daily Streamflow Period of Record	Approximate Contributing Drainage Area (sq mi)[1]
06880800	West Fork Big Blue River near Dorchester, Nebraska	October 1958 - present (missing April 2013 - March 2014)	1,192

Notes:

1. Approximate contributing drainage areas from USGS National Water Information System (NWIS). Available at: https://waterdata.usgs.gov/nwis/inventory/

2.3.2 Groundwater Flow System

The movement of groundwater across the NUBBS model area is predominantly west to east as seen in **Figure 22**, displaying the starting heads from Layer 4, the layer designated as the principal aquifer in the BRB regional model, during the steady-state simulation period. There is some slight variation seen along the West Fork of the Big Blue River as it passes through the southern portion of the model domain. The water table gradient across the area is less than the land surface slope and is estimated to be 0.00153 from west to east.

Recharge to the flow system occurs primarily through deep percolation of precipitation and excess irrigation return flow beyond the root zone of crops and native plant species. Recharge estimates from numerous field and modeling studies in the Hamilton County area of Nebraska range from about 1.5 to nearly 9 inches per year as shown in **Table 3**. Szilagyi and colleagues (2005) estimated the mean annual total recharge rate range in northwestern Hamilton County to be 1.46 to 2.36 inches, based on a statewide water balance model. This rate equates to 6-9% of annual precipitation in the area. An earlier study by Dugan and Zelt (2000) reported that mean annual recharge in the Hamilton County area was between 3 and 5 inches per year, equating to about 15-20% of annual precipitation in the area. Additionally, in a study of hydrogeologic conditions impacting spatial trends of nitrate concentrations in municipal supply wells at York, Nebraska (approximately 26 miles to the east of the proposed Synergen site and three miles to the east of the model boundary), Clark and colleagues (2007) estimated groundwater recharge at 20% of annual precipitation, with maximum estimates on irrigated land as high as 8.9 inches annually depending on application method, with an average estimate at 5.0 inches annually.

Although these rates vary by study, the mean recharge estimate computes to 3.6 inches per year, equating to about 17.7% of annual precipitation; it is important to note that land use has a significant influence on recharge rates and that irrigated lands within the project area are likely to have an average closer to the estimates of Clark and colleagues (2007). The recharge estimates in **Table 3** are presented as support to the recharge estimates used by the calibrated BRB regional model as described in **Section 3.6**.

Table 3. Literature Review of Estimated Recharge Rates.

Research Author	Low Estimate (in)	High Estimate (in)	Average Estimate (in)	Percent Precipitation (%)
Szilagyi et al., 2005	1.46	2.36	1.91	6-9
Dugan and Zelt, 2000	3.0	5.0	4.0	15-20
Clark et al., 2007	---	8.9	5.0	20-36
Average Recharge based on Literature Review			***3.6***	***17.7***

As shown in **Figure 23,** the calculated transmissivity of the aquifer in the NUBBS model varies from about 9,000 gallons per day per foot (gpd/ft) to over 700,000 gpd/ft. The highest transmissivity values are just to the east the proposed Synergen site. Low transmissivity values are found in the eastern portion of the modeled area as well as the southwest corner of the area. This is consistent with the fact that no irrigation wells are found in the southwest corner of the modeled area and support the conclusion of aquifer thinning in that area.

Groundwater level changes mapped by UNL-CSD (2022) indicate that since predevelopment, defined as pre-1960 by UNL-CSD (2022) to spring 2022, groundwater levels have increased up to 10 feet in the eastern part of Hamilton County and have decreased up to 10 feet in the southern part of the county, with pockets of decrease along the Platte River. However, the majority of water levels across Hamilton County remain unchanged, fluctuating between rising five feet and falling five feet (UNL-CSD, 2022). Locally, observation well data supplied by the USGS in the project area can verify water table fluctuations with no significant upwards nor downwards trends (see **Appendix A**). For example, a USGS observation well - #405040098144701 - had water level elevation readings just above 1,820 feet above mean sea level in 1950 and has most recently been measured at 1,820 feet above sea level in 2020. Most of the USGS observation wells within the NUBBS model domain experienced a drop in water levels beginning in the late 1970s, with water levels rebounding from 25 to 30 feet in the late 1990s, followed by a recent drop in water levels that brought current water levels closer to or - in some cases - slightly below the initial water level elevations taken in the 1950s and 1960s. This phenomenon can be observed in all of the figures in **Appendix A**, although it is more drastic at certain locations.

3. REFINED GROUNDWATER MODEL DEVELOPMENT

A refined subregional groundwater model was constructed to encompass Aurora and a three-mile radius around the proposed location of the proposed Synergen site. The model continues to extend out past the three-mile radius to the model boundary outlined in Section 1.

3.1 Model Code and Applications

The regional BRB model and the refined subregional NUBBS model both use the MODFLOW 6 program (Langevin et al., 2017). This version of the industry-standard MODFLOW modeling software from USGS provides substantial flexibility in model discretization, improved simulation of complex water table scenarios, improved control and separation of stressors, and an improved numerical solver that provides results faster and with fewer mass-balance errors than the standard finite-difference method (GSI Environmental, 2023; Langevin et al., 2017). Model files from the BRB model were used as the underlying information in the creation of all NUBBS model files. The general descriptions of the MODFLOW 6 files used in the creation of the NUBBS model are summarized in **Table 4**.

Table 4. The MODFLOW 6 Files that Compose the Refined NUBBS Groundwater Model.

MODFLOW File	Description
DISU	Unstructured Discretization File: this file is used to specify the model grid geometry, such as elevations of the vertical layers. Each grid cell is given a node number, and the ways each node is supposed to interact with other nodes is described. This file also specifies the time discretization of the model.
EVT	Evapotranspiration Package: this package specifies how the model should simulate the head-dependent flux of evapotranspiration from the water table (e.g., riparian corridors). The evapotranspiration (ET) surface, extinction depth, and monthly ET rate are defined in this file.
GHB	General-Head Boundary Package: this package specifies the transient head values for the boundary cells of the model for each stress period.
IMS	Iterative Model Solution File: this file provides linear and nonlinear solution schemes to solve matrix equations by defining the complexity of the model.
MAW	Multi-Aquifer Well Package: this file is used to simulate a specified flux into or out of individual cells (e.g., groundwater pumping) and can simulate pumping from more than one layer in the model.
NPF	Node Property Flow Package: this file is used to specify properties controlling flow between cells, such as hydraulic conductivity and specific yield.
OC	Output Control Option: this file specifies which head, drawdown, or budget data should be printed or saved.
RCH	Recharge Package: this file specifies the transient recharge flux in each cell.
SFR	Streamflow-Routing Package: the streams in the model are defined in this file. The stream routing, inflows, stream stage, streambed hydraulic conductance, and top and bottom elevation of the streambed are included in this file.
WEL	Well Package: this file is used to simulate a specified flux into or out of individual cells (e.g., groundwater pumping).

3.2 Model Discretization

The NUBBS model encompasses 874 square miles (559,358 acres), covering nearly all of Hamilton County and extending into Merrick, Polk, York, Fillmore, Clay, Adams, and Hall Counties. The NUBBS model extends 33.5 miles in the north-south direction and 38 miles east-west. The NUBBS model discretization follows the UBBNRD modeling guidelines of no cell in a subregional model exceeding the size of the BRB regional model. The largest cells in the NUBBS model are 2,640 feet on each side, equating to 1/2-mile on each side and 160 acres in area. This cell size is equal to the smallest cell size in the BRB regional model used in the area of interest. The area of interest in the NUBBS model is a three-mile buffer surrounding Synergen's proposed location. Within this area of interest, cell sizes are refined to 330 feet by 330 feet, equaling 1/16-mile on each side with an area of 2.5 acres. From there, the NUBBS grid cell discretization is expanded using quadtree nearest neighbor transition from a 2.5-acre cell inside the three-mile radius of the proposed large water user location to a 160-acre cell at the edge of the modeled area (see **Figure 24**). This quadtree refinement was created using Groundwater Vistas and allows the focus of the model to remain on the area of interest while including the boundary areas in the model without requiring the same refined inputs, i.e. the focus of the model inputs and results are centered around the proposed location of the large water use and not the boundaries of the model 20 miles away from the proposed location. Similarly to the BRB regional model, the NUBBS model grid is aligned with the NeDNR statewide GIS dataset for constructing groundwater flow model grids, originating at Nebraska State Plane Coordinates x = 2,086,920.0 feet, y = 282,480 feet.

Vertical discretization of the NUBBS model matches that of the BRB regional model. The five-layer model was constructed primarily from test hole data available through UNL-CSD and was supplemented with drillers' logs of additional wells, and is designed to represent the geologic and hydrostratigraphic units of the model domain (GSI Environmental 2023). **Table 5** describes the geologic and hydrostratigraphic characteristics of each layer (GSI Environmental 2023).

Table 5. Description of Vertical Discretization in the NUBBS Model.

Layer	Hydrostratigraphic Sub-unit
1	Upper Quaternary age silt and clay loess, with some sand and gravel at locations.
2	Medium to fine Middle Quaternary age sand and gravel that forms an unconfined to semi-confined aquifer layer and provides some pumping for irrigation purposes.
3	Lower Quaternary age fine silt and clay layer, with some sand and gravel, that confines or partially confines Layer 4.

Layer	Hydrostratigraphic Sub-unit
4	Middle Quaternary age medium to coarse sand and gravel that is simulated as a confined or leaky confined unit. This model layer provides the primary source for pumping for irrigation purposes.
5	Tertiary age silt and clay with some Middle Tertiary age sand and gravel. This layer also contains, and is underlain with, weathered bedrock material derived from shale, chalk, limestone, siltstone, and sandstone.

Within the NUBBS model, Layers 1 through 4 represent various deposits from the Quaternary period (e.g. loess, glacial till, and unconsolidated sands and gravels) and Layer 5 represents weathered bedrock from the Tertiary period as designed in the BRB regional model. The vertical thickness of the BRB regional model layers used in the NUBBS model were developed based on lithologic logs from UNL-CSD test holes and NeDNR registered irrigation wells and extrapolated to a three-dimensional surface using Leapfrog Works and the National Elevation Dataset at the 1-arc-second (30-meter) resolution and averaged within the BRB model cells (GSI Environmental 2023; USGS 2019). Model cells which contain layers that are “pinched out” from land surface incisions were assigned a minimum thickness of one foot (GSI Environmental 2023). The horizontal spatial discretization of the NUBBS model did not alter the vertical spatial discretization of the BRB regional model; the layer thicknesses of the underlying BRB regional model cell were used to define the NUBBS model cell layer thicknesses.

The NUBBS model followed the same temporal discretization as the BRB regional model. This includes a single steady-state stress period to represent the hydrologic conditions for the year 1940. The initial conditions of the NUBBS model matched those of the BRB regional model. Following the steady-state stress period, the next 936 transient stress periods are discretized into monthly stress periods that simulate the months of January 1941 through December 2018. This time period is appropriate for the purpose of evaluating the impact of the proposed well as it covers a broad range of dry, average, and wet conditions. This ensures that the model calibration produces a tool that accurately assesses the impact of the proposed well(s). Without changing the temporal discretization of the BRB regional model, the impacts of the proposed well(s) were represented in the NUBBS model beginning in 1993 and continuing for 25 years through 2018.

3.3 Boundary Conditions

Groundwater models often use surface water features - such as rivers, streams, and lakes - that are hydrologically connected to an aquifer or geologic structures or materials that inhibit groundwater flow as boundary conditions. This is considered best practice as the stage elevations of major surface water features are less affected by stresses of pumping and recharge (Anderson et al. 2015). The BRB regional model used physical hydrologic features to establish the boundary conditions surrounding the model (GSI Environmental 2023). Due to the positioning of the NUBBS model in relation to the BRB regional model, boundary conditions were altered so that they would not negatively influence the subregional model results.

A portion of the West Fork of the Big Blue River is present within the NUBBS model domain. This feature is represented with the MODFLOW Streamflow Routing (SFR) package in both the BRB and NUBBS models. This package establishes a boundary condition along the West Fork of the Big Blue River as it enters the NUBBS model area from the west and is routed through and exits the model to the east. The SFR package was updated with new starting and ending nodes that correlate with the edges of the NUBBS model, but no further manipulation of the SFR package was needed as there was no difference in model cell size between the subregional and regional models along this boundary condition. The Platte River runs along the northwestern edge of the NUBBS model and is represented in the BRB regional model using the River (RIV) package in MODFLOW. In the creation of the NUBBS model, cells in which the BRB regional model extended well past the Platte River were excluded. The grid refinement of the NUBBS model allowed the Platte River to be more precisely represented spatially and was therefore recreated along the northwestern border of the NUBBS model. Not all of the cells that more accurately follow the Platte River were originally designated as part of the RIV package along the Platte River in the BRB regional model; to minimize influence on the subregional model’s boundary conditions, these nodes were represented using the MODFOW General Head Boundary (GHB) package (Langevin et al. 2017). GHB nodes constitute the majority of the subregional model’s boundary conditions, using the head elevations of the BRB regional model nodes at the same locations. The SFR nodes following the West Fork of the Big Blue River and the GHB nodes along the perimeter are the only two boundary conditions present in the NUBBS model (see **Figure 25**). The GHB nodes, including those along the Platte River used the Heads (HDS) output file from the BRB regional model to NUBBS ensure model inputs remained consistent with the BRB regional model.

For the steady-state simulation, the NUBBS model used the initial head elevations from the BRB regional model. For the transient simulation, the NUBBS general-head elevations were specified for each stress period using the overlying BRB head values. GHB nodes that had final head elevations less than the cell bottom, or “went dry” by the final stress period of the BRB regional model, were removed from the GHB package. This resulted in the removal of some GHB cells in the upper layers of the model as to not artificially introduce more into the subregional model, rather than rewetting the cells after the head elevations had fallen below the cell bottom.

3.4 Aquifer Properties

The hydraulic conductivity and aquifer storage properties of the aquifer materials are foundational in groundwater models' flow regime and water level changes. Two important aquifer parameters are specified in this model, hydraulic conductivity and storage coefficient, as used from the BRB regional model.

Hydraulic conductivity refers to the ability of a geologic material to transmit water. The hydraulic conductivity represented in the BRB regional model was established in the calibration process of model construction. The hydraulic conductivity of the NUBBS model was created using the calibrated conductivity values of the BRB regional model. Hydraulic conductivity varies in each layer as the geologic strata vary vertically, as explained above. The hydraulic conductivity values for each layer can be seen in **Figures 9-13**.

The specific storage of an aquifer is related to the compressibility of the aquifer materials and can be represented within the Storage (STO) Package (Langevin et al. 2017; Woessner and Poeter 2020). The specific storage and specific yield within the model varies among the geologic materials represented by the five model layers as outlined in the BRB regional model (GSI Environmental 2023). In MODFLOW 6, the "STORAGECOEFFICIENT" option allows the user to specify storage coefficients rather than specific storage and specific yield explicitly. The BRB regional model made use of the "STORAGECOEFFICIENT" option in MODFLOW 6 which specifies the storage coefficient of each cell, this was determined by using values assigned to specific storage and specific yield to each geologic unit as defined in the BRB model documentation (GSI Environmental 2023). The NUBBS model uses the storage coefficient of the underlying BRB regional model cells; the storage coefficient values are presented by layer in **Figures 14-18**.

3.5 Calibration Targets

As mentioned above, the NUBBS model made use of rigorously calibrated inputs from the BRB regional model. USGS observation well data were used to calibrate the BRB regional model (GSI Environmental 2023). There are 12 calibration targets from the BRB regional model that are found within the NUBBS model domain; these are shown in **Figure 26**. These same targets were examined within the NUBBS model to ensure similar water level accuracy when compared to the BRB regional model; these hydrographs can be seen in **Appendix A**.

3.6 Recharge and Pumping Inputs

The recharge inputs for the BRB regional model and the NUBBS model were designed using the MODFLOW 6 Recharge (RCH) Package. This package models the deep percolation of water through the vadose zone as a specified-flow boundary condition adding inflow to the aquifer system (GSI Environmental 2023). The BRB and NUBBS models use a MODFLOW option that applies recharge inputs are applied to the uppermost saturated layer. The temporal and spatial distributions of recharge estimates were developed by The Flatwater Group (TFG 2023) for input into the groundwater model. The RCH package input for each model cell is an areal recharge flux rate, given in feet per day (ft/d), which MODLFOW 6 then applies across the model cell surface to calculate a volumetric flow rate. The RCH package for the NUBBS model uses the areal recharge flux rate values of the overlying BRB regional model cells, as the values are independent of cell size.

Groundwater pumping for the BRB regional model was represented using the MODFLOW 6 Well (WEL) package. This package is a specified-flow boundary condition that models the removal of water from the aquifer system by assigning a volumetric pumping rate to a model cell. This rate is input using units of cubic feet per day (ft^3/d). The BRB regional model assigned all pumping within the model to Layer 4, which represents the more productive aquifer materials of the High Plains Aquifer and coarse-grained glacial aquifer systems (GSI Environmental 2023). Because groundwater pumping inputs to MODFLOW 6 are volumetric pumping flow rates, the values of the BRB regional model WEL package must be distributed across multiple subregional model cells where there is further cell refinement. The exact location of the well or wells in the BRB regional model are not defined. At cells where the NUBBS model has increased grid refinement compared to the BRB regional model, the volumetric pumping flow rate of the BRB regional model cell is distributed evenly across the overlying subregional model cells using a WEL or MAW file, depending on cell proximity to the proposed Synergen location. This distribution prevents any addition or loss of groundwater pumping and applies the same volumetric flow rate to the same area. Distributing the pumping across the same spatial extent limits error that could be introduced by reassigning the entire volumetric pumping of a 1/2-mile by 1/2-mile cell to a 1/16-mile by 1/16-mile cell.

UBBNRD guidelines for large water user hydrogeologic studies require all existing and proposed groundwater wells to be modeled as multi-node wells or similar. MODFLOW 6 does not permit the use of a Multi-Node Well (MNW) package as do previous versions of MODFLOW; instead, it uses the Multi-Aquifer Well (MAW) package (Langevin et al. 2017). In accordance with UBBNRD guidelines for large water user hydrogeologic studies, the MAW package was used to recreate the volumetric pumping flow rates for all existing and proposed wells within five miles of the proposed Synergen site. Groundwater pumping outside of the five-mile buffer to the proposed site was modeled using a WEL package. Similar to the WEL package, the MAW package requires the groundwater pumping to be assigned to a specific cell (Langevin et al. 2017). All groundwater pumping in the NUBBS model was assigned to Layer 4, as the vertical discretization of the NUBBS and BRB models are identical. A major difference between the MAW and WEL packages is the specification of starting head elevations for the cells containing a MAW boundary condition. The starting head elevations used for the MAW cells came directly from the Starting Heads Elevation (HDS) package, which were identified from the underlying BRB regional model cells. Lastly, the MAW package uses one of four methods to calculate the saturated conductance for the MAW; the NUBBS model used the Thiem equation to calculate saturated conductance.

3.7 Model Calibration Assessment

The BRB regional model's initial calibration was done with manual adjustments to input parameters to provide initial estimates of parameter values. The BRB regional model was then calibrated using the Parameter Estimation (PEST) software to use information from manually measured heads and streamflow elevations from stream gaging stations to iteratively calibrate the MODFLOW groundwater model input parameters to match the historical water level elevations most accurately without exceeding reasonable hydrologic parameter values. PEST was used to calibrate the recharge in the steady-state stress period of the BRB regional model beginning in 1940. Because there is little information available about the hydrogeologic conditions in 1940, PEST was permitted to adjust recharge rates applied to the BRB model's steady-state stress period with little constraint, with the intent of improving overall initial groundwater level conditions of the model rather than estimating true recharge rates (GSI Environmental 2023). The recharge adjustment and recharge rate of the steady-state stress period should be viewed as a net aquifer stress which would encompass both the recharge and the pumping conditions leading up to the time period simulated in the transient model. PEST was used to calibrate horizontal and vertical hydraulic conductivity, streambed leakance, and recharge rates for the transient BRB regional model simulation. The final head elevations of Layer 4 from the NUBBS transient model run without the addition of the pumping from Synergen are displayed in **Figure 27**. Layer 4 is the only layer presented in these outputs because it contains all of the groundwater pumping in this subregional model. The changes in head elevations from the beginning to end of the baseline, without the extraction of groundwater from Synergen, NUBBS model run for Layer 4 are shown in **Figure 28**.

The NUBBS model is not a newly developed model; rather, it is a finer-resolution section of a regional model. This approach does not necessitate the re-calibration of the subregional model to the same extent as the BRB regional model. The differences between the baseline NUBBS model run and the BRB regional model should theoretically be minimal, as the same inputs are used with an improved spatial resolution. **Illustration 1** displays the average computed water levels from the BRB and NUBBS models to the average observed water levels across the entire model simulation, along with a trendline for both datasets. As the illustration shows, there is generally a good match between observed and computed water levels for both models.

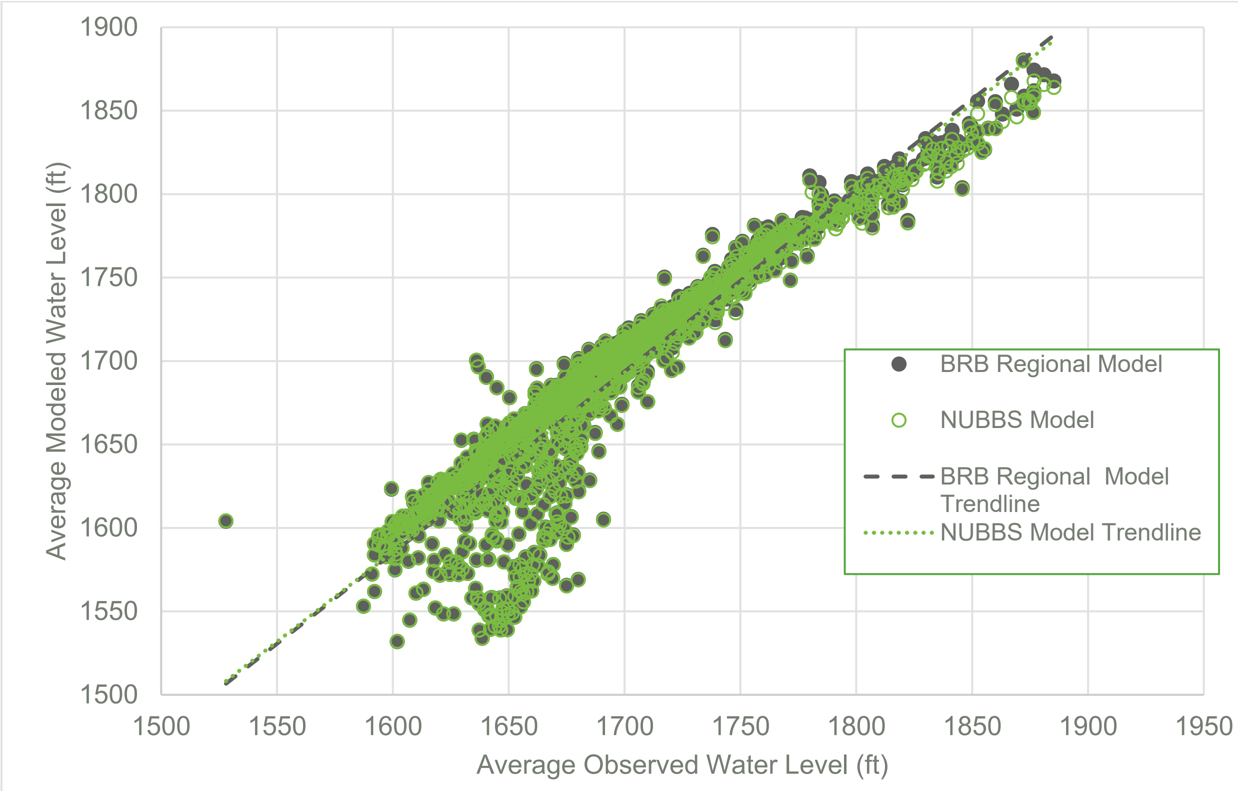

Illustration 1. Average Modeled and Observed Water Levels from the BRB and NUBBS Models.

Table 6 presents the calibration statistics of the illustrated water level data. Both **Table 6** and **Illustration 1** demonstrate a minimal difference between the residuals of the BRB regional model and the NUBBS model. The NUBBS model residual mean of -3.31 feet - indicating a small bias in the water level residuals - coupled with the scaled absolute residual mean of 9.41 feet, are not only representative of the BRB regional model statistics but an overall improvement on matching observed water levels across the NUBBS model area.

Table 6. Comparison of Calibration Statistics.

Parameter	BRB Regional Model Calibration Value	NUBBS Model Calibration Value
Residual Mean	-3.39	-3.31
Absolute Residual Mean	9.48	9.41
Residual Standard Deviation	10.68	10.63
Sum of Squares	211,975.26	209,215.83
Root Mean Square (RMS) Error	11.21	11.13
Minimum Residual	-64.17	-64.21
Maximum Residual	51.04	50.99
Range in Observations	115.20	115.20
Scaled Residual Standard Deviation	0.09	0.09
Scaled Absolute Residual Mean	-0.03	-0.03
Scaled RMS Error	0.10	0.10

Further, the probability distributions of the target residuals and the absolute target residuals from both the BRB and NUBBS models over the entire model simulation are plotted in **Illustrations 2 and 3**, respectively. These two illustrations show that the majority of the residual values for both the BRB and NUBBS models fall within 20 feet of the observed water level. For example, **Illustration 2** shows that only approximately 15% of the residuals exceed 20 feet. Alternatively, **Illustration 3** shows that 82% of the absolute residual values do not exceed 20 feet.

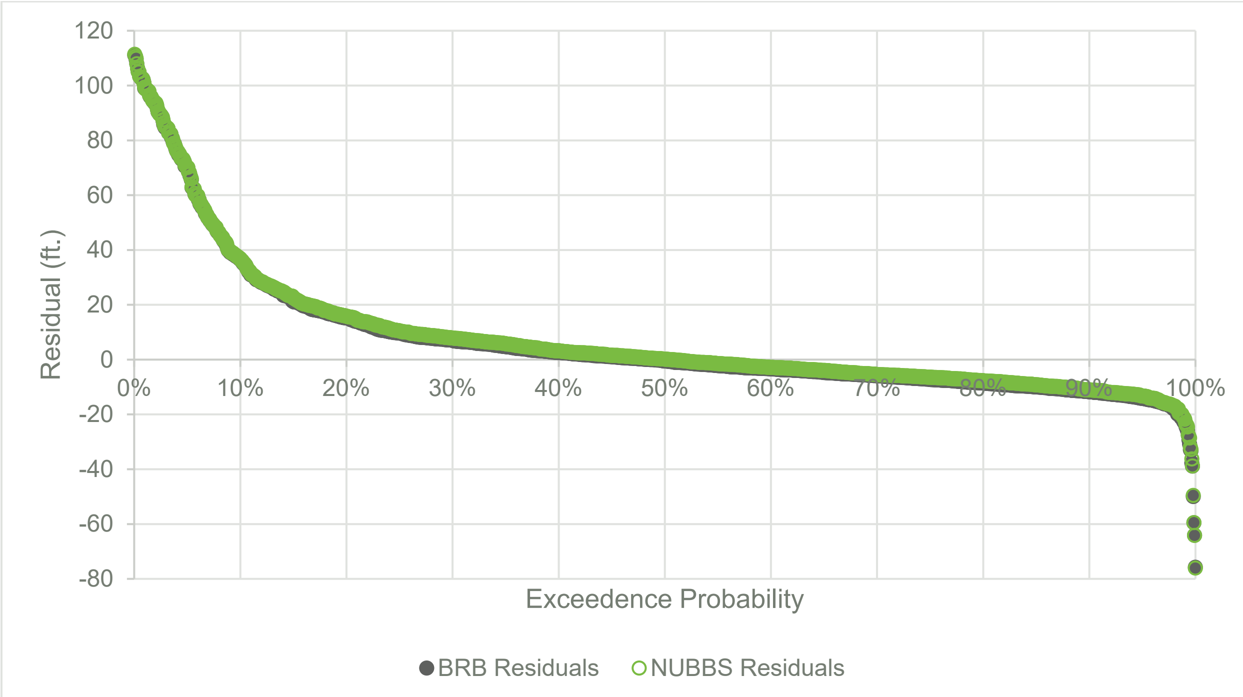

Illustration 2. Probability distribution of the target residuals from the entire model simulations.

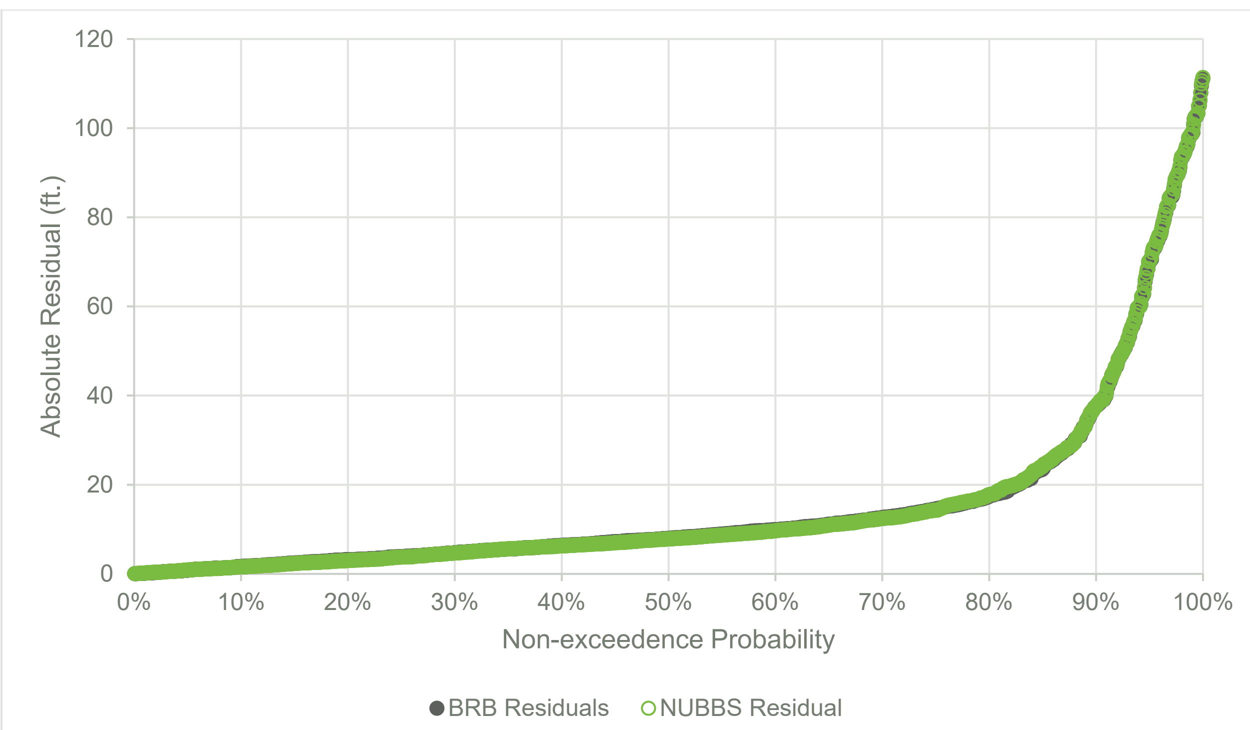

Illustration 3. Probability of the target absolute residuals from entire model simulations.

Table 7 shows the average volumetric model budget for the entire 78 year period of the NUBBS baseline model simulation, without the addition of Synergen. Zone 1 represents the area within a three-mile radius of the proposed Synergen location and Zone 2 represents the remaining model domain. These values are in acre-feet per year. As seen, the discrepancy in the mass balance for the model is one acre-foot per year, or less than 0.00001%. The differences in zone budgets between the BRB regional model and the NUBBS model by parameter are plotted in **Appendix B**.

Table 7. Average Volumetric Model Budget for Baseline NUBBS Model (Units: Acre-feet per Year).

	Zone 1		Zone 2	
	In	Out	In	Out
Storage	6,851	5,620	183,805	159,892
GHB	-	-	79,827	37,653
Recharge	5,311	-	135,823	-
SFR	-	-	2,860	14,142
Well	1	8,562	1	188,600
Between Zones	18,845	16,821	16,821	18,845
Total	31,007	31,003	419,137	419,132

As evident through the illustrations, tables, and appendices, the differences between the BRB regional model and the NUBBS model are minimal. Thus, it can be concluded that the NUBBS model is as effectively calibrated as the BRB regional model to represent the groundwater flow in the modeled area.

3.8 Well Assessment

This section discusses the evaluation and the results for the impact analysis of Synergen's proposed large water use. The planned water usage at the facility will be 2,300 gpm and will be continuous throughout the year.

The location of Synergen's proposed water use was dispersed across the four model nodes nearest the precise location. These include nodes 350325, 350236, 355668, and 355669. The NUBBS model was run as a baseline condition with no additional pumping at these nodes. A second NUBBS model run inserted pumping of 2,300 gpm continuously spread evenly across the four nodes beginning 25 years before the end of the model simulation. The pumping values dispersed across the four nodes representing the large water user equate to just under 10.2 acre-feet per day. The two NUBBS model runs can be compared to assess Synergen's impact on surrounding groundwater users.

The UBBNRD Guidelines for Large Water User Hydrologic Studies require an assessment of expected impacts to groundwater supplies and pumping capacities for all existing wells within a three-mile radius, henceforth termed the Evaluation Area, of any proposed large water use. **Table 8** presents the same average volumetric water budget across the 78 year period of the NUBBS model as shown in **Table 7**, but for the model simulation that includes Synergen's proposed use. The primary differences between the two budgets are the increased pumping in Zone 1 due to the addition of the proposed well and the corresponding changes to the storage and inter-zonal flows.

Table 8. Average Volumetric Model Budget for NUBBS Model with Proposed Large Water User (Units: Acre-feet per Year).

	Zone 1		Zone 2	
	In	Out	In	Out
Storage	6,916	5,434	184,034	159,340
GHB	-	-	79,978	37,628
Recharge	5,311	-	135,823	-
SFR	-	-	2,856	14,135
Well	1	9,771	1	188,601
Between Zones	19,276	16,293	16,293	19,276
Total	31,503	31,499	418,985	418,980

According to NeDNR records, there are 178 active registered wells in the Evaluation Area, all of which are mapped in **Figure 29**; monitoring, groundwater heat exchanger, and other wells that do not impact the water budget were excluded from this selection. The City of Aurora has seven wells for public water supply, all of which are outside of the Evaluation Area and are thus not included in this analysis.

Table 9 contains data from the NeDNR groundwater well registration database for the 178 active registered wells. Wells in **Table 9** that are missing information regarding the depth of the well or depth of the pump in the well are included in **Table 10**, although some statistics are incomputable. **Table 10** contains the results of the groundwater modeling analysis for the wells within the Evaluation Area; 54 wells have complete datasets.

Table 9. Data on Active Registered Wells in Evaluation Area.

Well Registration Number	Well Use	Depth of Well (ft)	Static Water Level (ft)	Pumping Water Level (ft)	Depth of Pump (ft)	Static Saturated Interval (ft)
G-064988	Irrigation	182	91	125	N/A	91
G-104192	Domestic	196	82	83	125	114
G-040141	Irrigation	191	69	80	N/A	122

Well Registration Number	Well Use	Depth of Well (ft)	Static Water Level (ft)	Pumping Water Level (ft)	Depth of Pump (ft)	Static Saturated Interval (ft)
G-112448	Domestic	183	71.5	74	120	111.5
G-114332	Domestic	173	69	100	100	104
G-065024	Irrigation	208	90	125	N/A	118
G-047423	Irrigation	195	56	120	120	139
G-026253	Irrigation	188	93	112	N/A	95
G-110459	Domestic	165	50	60	100	115
G-038155	Irrigation	208	82	104	N/A	126
G-117652	Domestic	185	87	90	120	98
G-016204	Irrigation	191	90	107	N/A	101
G-093858	Domestic	185	80	85	120	105
G-149693	Domestic	202	94	96	125	108
G-150341	Domestic	185	90	93	125	95
G-015440	Irrigation	196	82	97	N/A	114
G-098385	Irrigation	220	82	125	140	138
G-036506	Irrigation	206	85	105	N/A	121
G-018479	Irrigation	175	90	105	N/A	85
G-006372	Irrigation	177	75	110	120	102
G-149695	Domestic	180	67	67	125	113
G-042259	Irrigation	210	N/A	N/A	N/A	N/A
G-014650	Irrigation	221	91	125	N/A	130
G-022013	Irrigation	201	70	77	N/A	131
G-064989	Irrigation	221	91	125	N/A	130
G-032469	Irrigation	233	N/A	100	N/A	N/A
G-054570	Irrigation	227	82	99	N/A	145
G-047375	Irrigation	223	90	103	N/A	133
G-015441	Irrigation	203	80	97	N/A	123
G-192356	Irrigation	200	84	108	140	116
G-008350	Irrigation	199	87	103	N/A	112
G-022813	Irrigation	202	91	111	N/A	111
G-012557	Irrigation	185	84	106	N/A	101
G-001764	Irrigation	N/A	86	120	120	N/A
G-029176	Irrigation	220	78	92	N/A	142
G-192024	Irrigation	201	70	77	110	131
G-033347	Irrigation	220	80	96	N/A	140
G-025874	Irrigation	201	88	94	N/A	113
G-053956	Irrigation	201	90	108	N/A	111
G-042435	Irrigation	235	100	106	N/A	135
G-008349	Irrigation	253	107	160	160	146

Well Registration Number	Well Use	Depth of Well (ft)	Static Water Level (ft)	Pumping Water Level (ft)	Depth of Pump (ft)	Static Saturated Interval (ft)
A-004536	Irrigation	N/A	N/A	N/A	N/A	N/A
G-058382	Irrigation	221	80	120	N/A	141
G-063814	Irrigation	254	96	110	N/A	158
A-006256	Irrigation	186	77	93	N/A	109
G-018547	Irrigation	190	90	100	N/A	100
G-026384	Irrigation	234	78	120	140	156
G-008865	Irrigation	172	85	100	N/A	87
G-017105	Irrigation	229.3	74	130	150	155.3
G-015369	Irrigation	160	85	92	N/A	75
G-073326	Irrigation	200	78	120	140	122
G-029021	Irrigation	220	77	125	145	143
G-028949	Irrigation	204	87	106	N/A	117
G-011193	Irrigation	192	89	103	N/A	103
G-141230	Domestic	195	80	90	120	115
G-062507	Irrigation	208	65	120	N/A	143
G-027631	Irrigation	211	105	111	N/A	106
G-070390	Commercial/Industrial	200	110	140	160	90
G-038387	Commercial/Industrial	186	80	95	N/A	106
G-038388	Commercial/Industrial	180	80	95	N/A	100
G-003231	Irrigation	194	86	112	N/A	108
G-011973	Irrigation	185	92	105	N/A	93
G-167150	Commercial/Industrial	182	93	N/A	N/A	89
G-006391	Irrigation	189	85	98	N/A	104
G-064429	Irrigation	195	103	130	160	92
G-072899	Irrigation	220	81	100	N/A	139
G-012556	Irrigation	174	72	91	N/A	102
G-081348	Irrigation	221	78	89	120	143
G-003157	Irrigation	175	74	85	N/A	101
G-003474	Irrigation	184	72	79	N/A	112
G-050751	Irrigation	208	90	120	N/A	118
G-058428	Irrigation	234	90	120	N/A	144
G-038984	Irrigation	240	94	129	N/A	146
G-017101	Irrigation	196	94	113	N/A	102
A-006546	Irrigation	200	97	103	N/A	103
G-115177	Irrigation	240	90	130	130	150
G-128154	Commercial/Industrial	200	103.6	109	140	96.4
G-073457	Commercial/Industrial	160	100	105	N/A	60
G-070139	Commercial/Industrial	180	110	110	N/A	70

Well Registration Number	Well Use	Depth of Well (ft)	Static Water Level (ft)	Pumping Water Level (ft)	Depth of Pump (ft)	Static Saturated Interval (ft)
G-088914	Irrigation	240	95	130	140	145
G-162223	Irrigation	220	100	108	140	120
G-071133	Commercial/Industrial	234	96	105	N/A	138
G-036536	Commercial/Industrial	280	96	105	N/A	184
G-034135	Irrigation	248	105	128	145	143
G-012105	Irrigation	181	86	95	N/A	95
G-048919	Irrigation	240	92	130	150	148
G-088556	Domestic	163	75	80	120	88
G-107782	Irrigation	200	80	100	140	120
A-005243	Irrigation	N/A	N/A	N/A	N/A	N/A
G-042183	Irrigation	240	86	105	N/A	154
G-017489	Irrigation	160	87	107	N/A	73
G-054422	Irrigation	198	90	120	N/A	108
G-009587	Irrigation	160	84	99	N/A	76
G-142955	Domestic	200	85	90	160	115
A-006147	Commercial/Industrial	240	91	108	170	149
G-147063	Commercial/Industrial	240	88	111	170	152
G-006375	Commercial/Industrial	157	75	84	N/A	82
G-044363	Irrigation	281	90	120	N/A	191
G-010337	Irrigation	205	87	100	130	118
G-003114	Irrigation	176	87	99	N/A	89
G-016396	Irrigation	192	91	107	N/A	101
G-036414	Irrigation	241	95	112	N/A	146
G-037340	Irrigation	250	76	115	N/A	174
G-051441	Irrigation	221	95	120	N/A	126
G-012106	Irrigation	181	86	95	N/A	95
G-047479	Irrigation	200	100	115	N/A	100
G-107781	Irrigation	180	80	100	N/A	100
G-043353	Irrigation	273	90	104	N/A	183
G-040497	Irrigation	227	85	105	N/A	142
G-022468	Irrigation	172	86	102	N/A	86
G-001519	Irrigation	N/A	N/A	N/A	N/A	N/A
G-008928	Irrigation	286	90	150	150	196
G-026401	Irrigation	214	82	97	N/A	132
G-056318	Irrigation	234	90	131	N/A	144
G-144325	Irrigation	221	91	116	N/A	130
G-086166	Domestic	140	80	130	20	60
G-029504	Irrigation	201	85	105	N/A	116

Well Registration Number	Well Use	Depth of Well (ft)	Static Water Level (ft)	Pumping Water Level (ft)	Depth of Pump (ft)	Static Saturated Interval (ft)
G-009936	Irrigation	175	72	86	N/A	103
G-064637	Irrigation	200	106	118	N/A	94
G-040042	Irrigation	188	91	110	N/A	97
G-022367	Irrigation	218	86	104	N/A	132
A-005061	Irrigation	N/A	N/A	N/A	N/A	N/A
G-055570	Irrigation	240	89	118	N/A	151
G-004430	Irrigation	172	74	86	N/A	98
G-059192	Irrigation	260	81	95	N/A	179
G-101207	Irrigation	220	73	97	130	147
G-065202	Irrigation	208	87	130	N/A	121
A-006530	Irrigation	N/A	N/A	N/A	N/A	N/A
G-027435	Irrigation	186	81	98	N/A	105
G-045337	Irrigation	221	78	110	N/A	143
G-048473	Irrigation	240	83	94	N/A	157
G-036325	Irrigation	236	83	94	N/A	153
G-005059	Irrigation	162	81	94	N/A	81
G-006619	Irrigation	185	80	105	N/A	105
G-006625	Irrigation	211	76	98	130	135
G-025239	Irrigation	231	90	95	N/A	141
G-027267	Irrigation	220	87	102	N/A	133
G-056176	Irrigation	171	82	95	140	89
G-043983	Irrigation	250	100	140	160	150
G-100003	Domestic	165	75	90	120	90
G-003286	Irrigation	175	78	92	N/A	97
G-166927	Irrigation	196	80	105	150	116
G-062477	Irrigation	247	75	120	N/A	172
G-038379	Irrigation	221	90	115	N/A	131
G-045338	Irrigation	182	80	115	N/A	102
G-097192	Irrigation	230	77	102	140	153
G-073657	Irrigation	222	78	90	N/A	144
G-004326	Irrigation	174	78	92	N/A	96
G-036857	Irrigation	260	82	95	N/A	178
G-085141	Irrigation	200	85	120	N/A	115
A-004612	Irrigation	250	83	120	140	167
G-113702	Domestic	152	73.5	74	125	78.5
G-024974	Irrigation	192	87	87	N/A	105
G-003287	Irrigation	172	79	94	N/A	93
G-054934	Irrigation	247	65	120	N/A	182

Well Registration Number	Well Use	Depth of Well (ft)	Static Water Level (ft)	Pumping Water Level (ft)	Depth of Pump (ft)	Static Saturated Interval (ft)
A-004611	Irrigation	240	90	114	N/A	150
G-193316	Domestic	190	85	95	120	105
G-001593	Irrigation	240	88	105	N/A	152
G-049411	Irrigation	223	83	98	N/A	140
G-012324	Irrigation	194	86	99	N/A	108
G-067890	Irrigation	N/A	N/A	N/A	N/A	N/A
G-016835	Irrigation	170	87	102	N/A	83
G-014484	Irrigation	212	78	87	N/A	134
G-048474	Irrigation	248	91	100	N/A	157
G-085142	Irrigation	200	85	120	140	115
G-001645	Irrigation	N/A	N/A	N/A	N/A	N/A
G-053021	Irrigation	179.4	90	120	140	89.4
G-033412	Irrigation	217	72	87	N/A	145
G-004393	Irrigation	168	84	N/A	N/A	84
G-022011	Irrigation	182	82	97	N/A	100
G-042334	Irrigation	221	90	115	N/A	131
G-006407	Irrigation	230	91	113	N/A	139
G-029687	Irrigation	242	83	130	150	159
G-000157	Irrigation	N/A	85	130	130	N/A
G-000277	Irrigation	N/A	N/A	N/A	N/A	N/A
G-024620	Irrigation	188	78	102	N/A	110
G-012105	Irrigation	181	86	95	0	95

Table 10. Effect of Proposed Well(s) on Evaluation Area Wells.

Well Registration Number	Modeled Static Water Level Without Synergen (ft)	Modeled Static Water Level with Synergen (ft)	Modeled Maximum Drawdown (ft)	Reduction in Static Saturated Interval with Synergen (%)[1]
G-064988	1753.6	1751.6	2.0	2%
G-104192	1750.7	1748.7	1.9	2%
G-040141	1744.6	1742.3	2.3	2%
G-112448	1740.4	1738.1	2.3	2%
G-114332	1763.4	1761.7	1.7	2%
G-065024	1751.8	1749.5	2.3	2%
G-047423	1747.8	1745.2	2.6	2%
G-026253	1744.9	1742.2	2.7	3%

Well Registration Number	Modeled Static Water Level Without Synergen (ft)	Modeled Static Water Level with Synergen (ft)	Modeled Maximum Drawdown (ft)	Reduction in Static Saturated Interval with Synergen (%)[1]
G-110459	1738.7	1736.0	2.7	2%
G-038155	1737.6	1734.9	2.6	2%
G-117652	1736.1	1733.3	2.8	3%
G-016204	1732.9	1730.4	2.5	2%
G-093858	1731.2	1728.7	2.5	2%
G-149693	1732.0	1729.5	2.5	2%
G-150341	1731.7	1729.2	2.5	3%
G-015440	1732.1	1729.4	2.7	2%
G-098385	1730.9	1728.2	2.7	2%
G-036506	1727.1	1724.6	2.4	2%
G-018479	1724.6	1722.1	2.5	3%
G-006372	1763.0	1761.2	1.8	2%
G-149695	1761.5	1759.7	1.8	2%
G-042259	1759.1	1757.0	2.1	N/A
G-014650	1754.3	1751.9	2.4	2%
G-022013	1757.6	1755.4	2.2	2%
G-064989	1752.6	1749.9	2.7	2%
G-032469	1747.2	1744.1	3.1	N/A
G-054570	1737.8	1734.7	3.1	2%
G-047375	1741.1	1738.0	3.1	2%
G-015441	1735.1	1732.1	3.1	3%
G-192356	1737.2	1733.8	3.4	3%
G-008350	1733.0	1729.8	3.3	3%
G-022813	1726.5	1723.8	2.7	2%
G-012557	1722.5	1720.0	2.5	2%
G-001764	1766.3	1764.6	1.7	N/A
G-029176	1762.4	1760.5	1.9	1%
G-192024	1765.5	1763.8	1.8	1%
G-033347	1763.9	1761.9	1.9	1%
G-025874	1754.0	1751.3	2.7	2%
G-053956	1756.0	1753.4	2.6	2%
G-042435	1752.5	1749.4	3.0	2%
G-008349	1742.8	1739.1	3.7	3%
A-004536	1746.3	1742.5	3.8	N/A
G-058382	1737.8	1733.7	4.0	3%

Well Registration Number	Modeled Static Water Level Without Synergen (ft)	Modeled Static Water Level with Synergen (ft)	Modeled Maximum Drawdown (ft)	Reduction in Static Saturated Interval with Synergen (%)[1]
G-063814	1741.0	1736.7	4.3	3%
A-006256	1729.2	1726.1	3.2	3%
G-018547	1731.8	1728.1	3.8	4%
G-026384	1727.8	1724.5	3.3	2%
G-008865	1722.2	1719.5	2.7	3%
G-017105	1724.0	1721.1	2.9	2%
G-015369	1767.5	1765.8	1.7	2%
G-073326	1763.5	1761.4	2.0	2%
G-029021	1761.5	1759.4	2.1	1%
G-028949	1759.1	1756.7	2.5	2%
G-011193	1756.7	1754.0	2.7	3%
G-141230	1748.5	1744.6	3.9	3%
G-062507	1751.5	1748.0	3.6	2%
G-027631	1743.0	1738.3	4.7	4%
G-070390	1742.1	1736.6	5.5	6%
G-038387	1741.1	1735.5	5.6	5%
G-038388	1740.5	1734.7	5.9	6%
G-003231	1737.4	1732.8	4.5	4%
G-011973	1738.1	1732.7	5.4	6%
G-167150	1740.2	1734.3	5.9	7%
G-006391	1730.4	1726.4	4.0	4%
G-064429	1727.1	1723.6	3.6	4%
G-072899	1721.7	1718.8	2.9	2%
G-012556	1723.4	1720.3	3.1	3%
G-081348	1768.2	1766.5	1.7	1%
G-003157	1764.7	1762.8	1.9	2%
G-003474	1762.0	1759.8	2.2	2%
G-050751	1757.8	1755.1	2.6	2%
G-058428	1759.3	1756.9	2.5	2%
G-038984	1756.3	1753.4	2.9	2%
G-017101	1749.6	1745.6	4.0	4%
A-006546	1746.9	1742.2	4.7	5%
G-115177	1750.9	1747.1	3.8	3%
G-128154	1743.4	1737.9	5.5	6%
G-073457	1742.7	1737.0	5.7	10%

Well Registration Number	Modeled Static Water Level Without Synergen (ft)	Modeled Static Water Level with Synergen (ft)	Modeled Maximum Drawdown (ft)	Reduction in Static Saturated Interval with Synergen (%)[1]
G-070139	1742.1	1736.2	5.9	8%
G-088914	1745.2	1739.6	5.6	4%
G-162223	1739.0	1732.7	6.3	5%
G-071133	1737.2	1730.9	6.3	5%
G-036536	1736.9	1730.7	6.2	3%
G-034135	1740.0	1732.6	7.4	5%
G-012105	1737.4	1730.3	7.1	7%
G-048919	1739.7	1728.1	11.6	8%
G-088556	1731.7	1727.1	4.5	5%
G-107782	1735.4	1729.3	6.1	5%
A-005243	1729.8	1725.6	4.2	N/A
G-042183	1730.7	1726.3	4.5	3%
G-017489	1725.0	1721.6	3.4	5%
G-054422	1726.9	1723.2	3.7	3%
G-009587	1719.5	1716.8	2.7	4%
G-142955	1719.9	1717.2	2.8	2%
A-006147	1717.1	1714.5	2.5	2%
G-147063	1718.6	1715.9	2.7	2%
G-006375	1718.1	1715.5	2.6	3%
G-044363	1764.8	1762.8	1.9	1%
G-010337	1764.1	1762.2	2.0	2%
G-003114	1761.7	1759.5	2.2	2%
G-016396	1756.2	1753.4	2.8	3%
G-036414	1755.7	1752.7	2.9	2%
G-037340	1747.4	1742.9	4.5	3%
G-051441	1749.9	1746.2	3.7	3%
G-012106	1737.3	1731.2	6.1	6%
G-047479	1739.6	1733.7	5.9	6%
G-107781	1735.0	1729.9	5.2	5%
G-043353	1727.7	1723.9	3.8	2%
G-040497	1730.4	1726.1	4.2	3%
G-022468	1726.8	1723.1	3.7	4%
G-001519	1725.8	1722.3	3.5	N/A
G-008928	1719.6	1716.8	2.8	1%
G-026401	1718.7	1716.0	2.7	2%

Well Registration Number	Modeled Static Water Level Without Synergen (ft)	Modeled Static Water Level with Synergen (ft)	Modeled Maximum Drawdown (ft)	Reduction in Static Saturated Interval with Synergen (%)[1]
G-056318	1764.2	1762.3	1.9	1%
G-144325	1762.2	1760.2	2.1	2%
G-086166	1760.1	1757.9	2.2	4%
G-029504	1758.2	1755.8	2.5	2%
G-009936	1758.6	1756.3	2.3	2%
G-064637	1753.3	1750.3	3.0	3%
G-040042	1748.2	1744.5	3.7	4%
G-022367	1744.4	1740.0	4.3	3%
A-005061	1736.8	1732.4	4.4	N/A
G-055570	1739.0	1734.7	4.3	3%
G-004430	1732.4	1728.2	4.3	4%
G-059192	1734.6	1730.4	4.1	2%
G-101207	1730.0	1726.2	3.9	3%
G-065202	1727.4	1723.9	3.5	3%
A-006530	1720.6	1717.8	2.8	N/A
G-027435	1721.9	1718.9	2.9	3%
G-045337	1722.7	1719.8	2.9	2%
G-048473	1720.9	1718.2	2.8	2%
G-036325	1717.1	1714.6	2.5	2%
G-005059	1718.6	1716.0	2.6	3%
G-006619	1762.5	1760.7	1.8	2%
G-006625	1749.0	1745.8	3.2	2%
G-025239	1746.0	1742.6	3.4	2%
G-027267	1739.8	1736.3	3.5	3%
G-056176	1743.3	1740.0	3.3	4%
G-043983	1736.1	1732.2	3.9	3%
G-100003	1736.6	1732.8	3.8	4%
G-003286	1734.5	1730.6	3.8	4%
G-166927	1729.6	1726.4	3.2	3%
G-062477	1723.5	1720.6	2.8	2%
G-038379	1719.3	1716.8	2.5	2%
G-045338	1761.0	1759.1	1.9	2%
G-097192	1745.5	1742.5	3.0	2%
G-073657	1747.1	1744.4	2.7	2%
G-004326	1743.6	1740.8	2.8	3%

Well Registration Number	Modeled Static Water Level Without Synergen (ft)	Modeled Static Water Level with Synergen (ft)	Modeled Maximum Drawdown (ft)	Reduction in Static Saturated Interval with Synergen (%)[1]
G-036857	1744.5	1741.8	2.7	2%
G-085141	1734.9	1731.8	3.1	3%
A-004612	1738.0	1735.0	3.1	2%
G-113702	1736.1	1733.1	3.0	4%
G-024974	1727.9	1724.9	3.0	3%
G-003287	1728.3	1725.3	3.0	3%
G-054934	1726.8	1724.0	2.8	2%
A-004611	1725.3	1722.4	2.8	2%
G-193316	1726.1	1723.3	2.8	3%
G-001593	1723.1	1720.5	2.6	2%
G-049411	1721.6	1719.0	2.6	2%
G-012324	1751.8	1749.6	2.2	2%
G-067890	1750.2	1748.1	2.1	N/A
G-016835	1747.1	1744.7	2.4	3%
G-014484	1744.1	1741.6	2.5	2%
G-048474	1730.5	1727.7	2.8	2%
G-085142	1733.4	1730.7	2.7	2%
G-001645	1731.2	1728.7	2.5	N/A
G-053021	1726.6	1724.0	2.6	3%
G-033412	1727.9	1725.4	2.5	2%
G-004393	1724.8	1722.3	2.5	3%
G-022011	1725.7	1723.2	2.5	3%
G-042334	1745.9	1743.8	2.1	2%
G-006407	1745.0	1742.9	2.2	2%
G-029687	1738.5	1736.1	2.5	2%
G-000157	1741.1	1738.8	2.3	N/A
G-000277	1736.6	1734.3	2.3	N/A
G-024620	1733.0	1730.6	2.4	2%
G-012105	N/A	N/A	N/A	N/A

Notes:

1. The percent reduction in static saturated interval is calculated from modeled maximum drawdown and observed (reported in NeDNR's database) static saturated interval.

Illustrations 4 and 5 respectively display the rate and cumulative volumetric water budget of the NUBBS model with the inclusion of Synergen beginning operation 25 years from the end of the model simulation. These figures show the seasonal fluctuation in pumping is still present with agriculturally dominated water usage, generally the flux in pumping that is removed from storage is replaced by recharge for the first 285 stress periods; from that point on, pumping outpaces recharge. Recharge does not replace pumping long before the proposed large water use becomes active in the NUBBS model. **Illustrations 6 and 7** display the difference in rate and cumulative NUBBS computed water budget between the run with and without the addition of Synergen by rate and a cumulative difference, respectively. These figures show that initially, the extraction from the proposed large water use comes from storage, and over the 25-year period where the large water use was simulated, there was approximately 13,500 acre-feet coming from the general head boundary conditions. This implies general drawdown to the water table of 13,500 acre-feet across the entire modeled area over the course of 25 years. The drawdown in Layer 4 from the modeled pumping of Synergen is shown in **Figure 29**. It is important to reiterate that Synergen's use was active for the last 25 years of the model simulation. The resulting difference in water budget is about an addition of 3,720 acre-feet per year of pumping, equating to just over 93,000 acre-feet over a 25-year period if the well was run at 2,300 gpm continuously for 25 years.

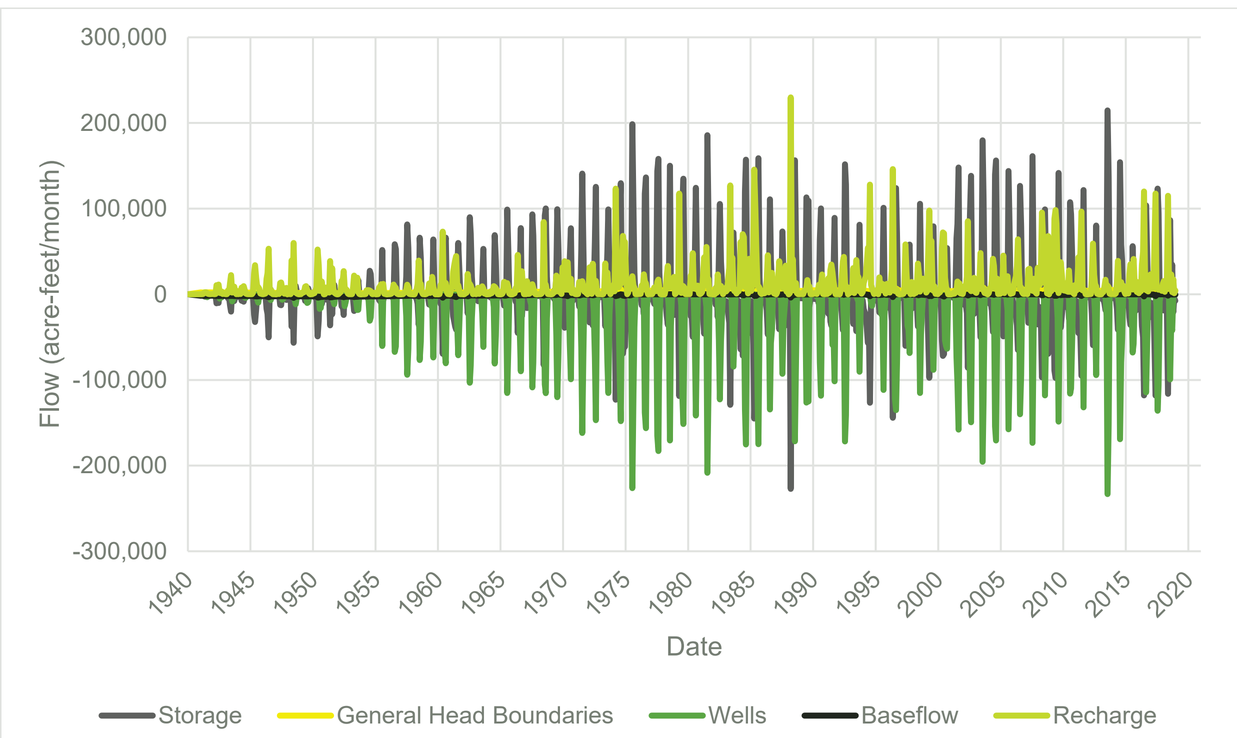

Illustration 4. NUBBS Model Volumetric Water Budget Rates with Synergen.

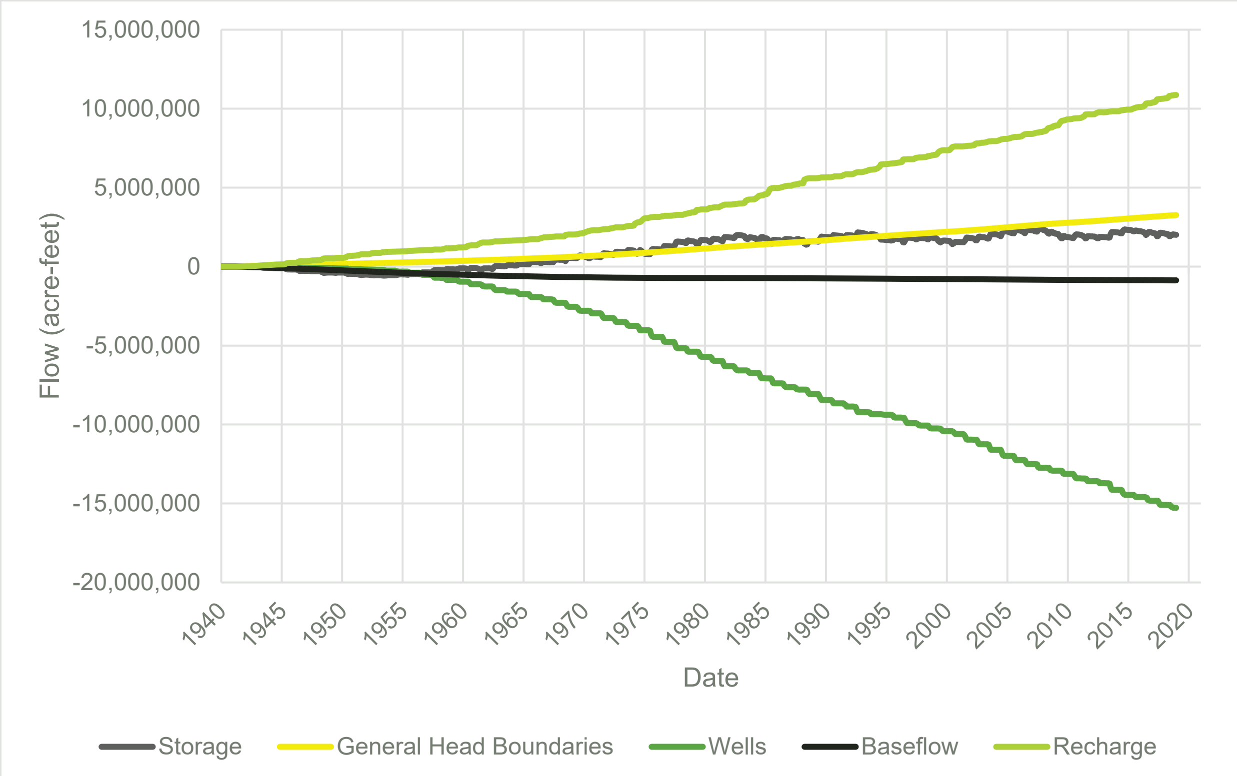

Illustration 5. NUBBS Model Cumulative Volumetric Water Budget with Synergen.

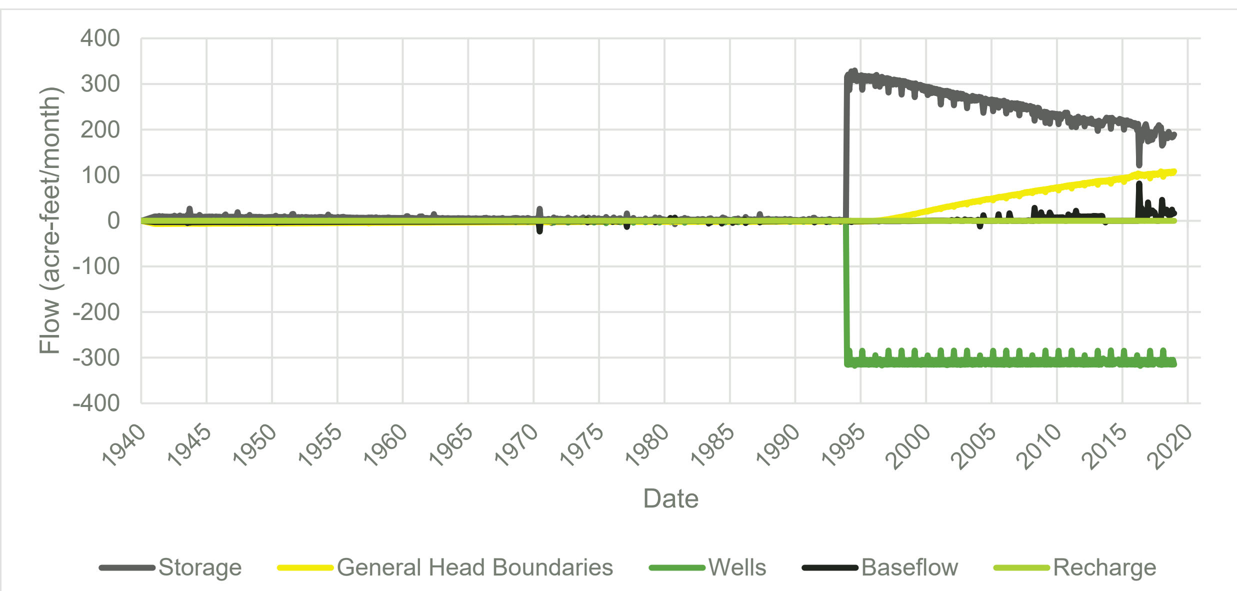

Illustration 6. Difference in NUBBS Model Volumetric Water Budget Rates with Synergen.

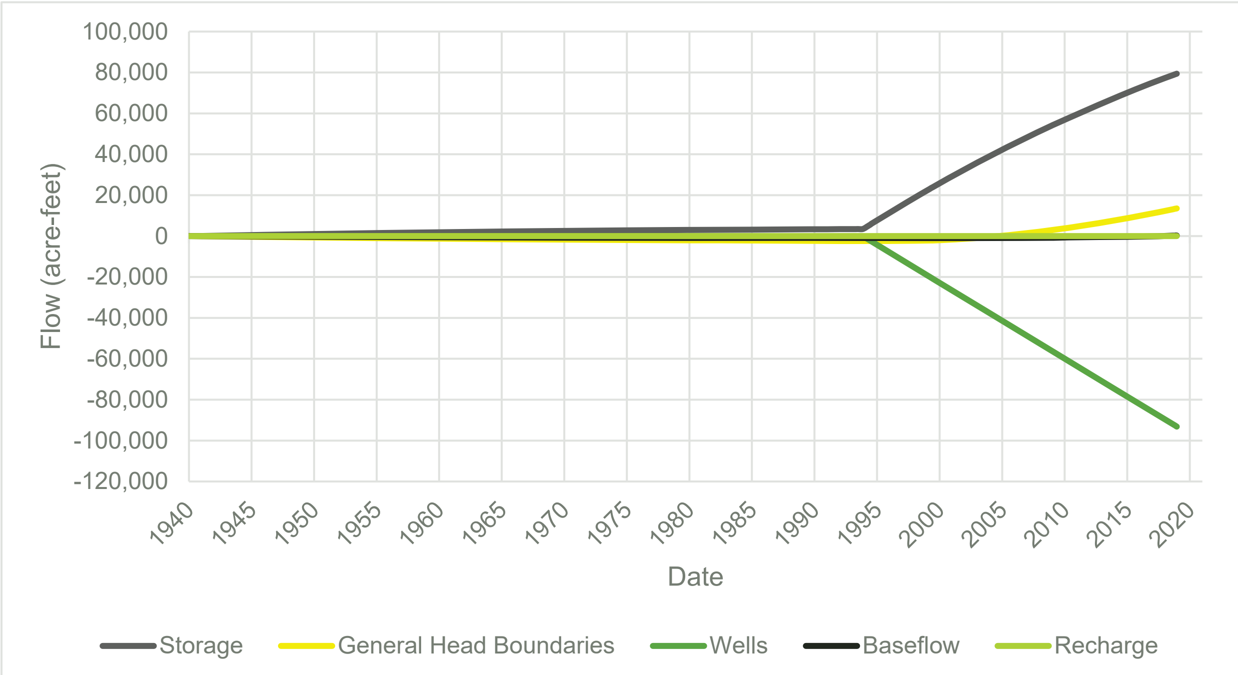

Illustration 7. NUBBS Model Cumulative Volumetric Water Budget with Synergen.

Table 11 displays the cumulative water budget at the final stress period in the NUBBS model run. This table is presented to show that the water budget comes close to balancing at the conclusion of the NUBBS model run with Synergen's proposed large water use.

Table 11. Cumulative Water Budget for Final Stress Period of NUBBS Model Run with Synergen.

	Cumulative (acre-feet)	
Terms	**In**	**Out**
Storage	2,015,408	-
GHB	3,260,937	-
Recharge	10,867,439	-
SFR	-	-868,502
Well	-	-15,274,575
Total	16,143,785	-16,143,078

4. MODEL INVESTIGATION SUMMARY AND CONCLUSIONS

This hydrologic evaluation of the aquifer system underlying the Aurora area used the BRB regional groundwater model to create a subregional model (the NUBBS model) to investigate the impacts of a proposed large water user, Synergen, west of Aurora. The aquifer parameters obtained from GSI Environmental appear to provide a good representation of the actual hydrostratigraphic layers that exist in the area. The impact analysis showed that Synergen's proposed new water use will have a minimal impact on existing wells in the area. Water level reductions within the immediate vicinity of the proposed well were in the range of 10 to 14.5 feet, while water level reductions at the edge of a three-mile radius were on the order of one to three feet. The reduction in static saturated interval for wells within the three-mile radius was overwhelmingly in the range of 2-3%. Therefore, the expected impacts to the groundwater supply and pumping capacity at existing wells should be minimal and should not affect their operations. There does not appear to be any reason why the proposed large water use should not be approved for construction and operation at a maximum pumping rate of 2,300 gpm.

It is important to reiterate that the NUBBS model is a product of the BRB regional model, this implies that the limitations that accompany regional groundwater modeling are innately present in a subregional model created from the regional conceptual and numeric model. Namely, limitations generally can be reduced to the loss of local-scale hydrogeologic details and processes with the spatial refinement of a model built to represent hydrogeology at a regional scale. Therefore, despite the NUBBS model being able to display the effects of the proposed large water use at a refined scale, the many of the inputs used in the NUBBS model come from the BRB regional model, which are underlain with the limitations of a regional groundwater model.

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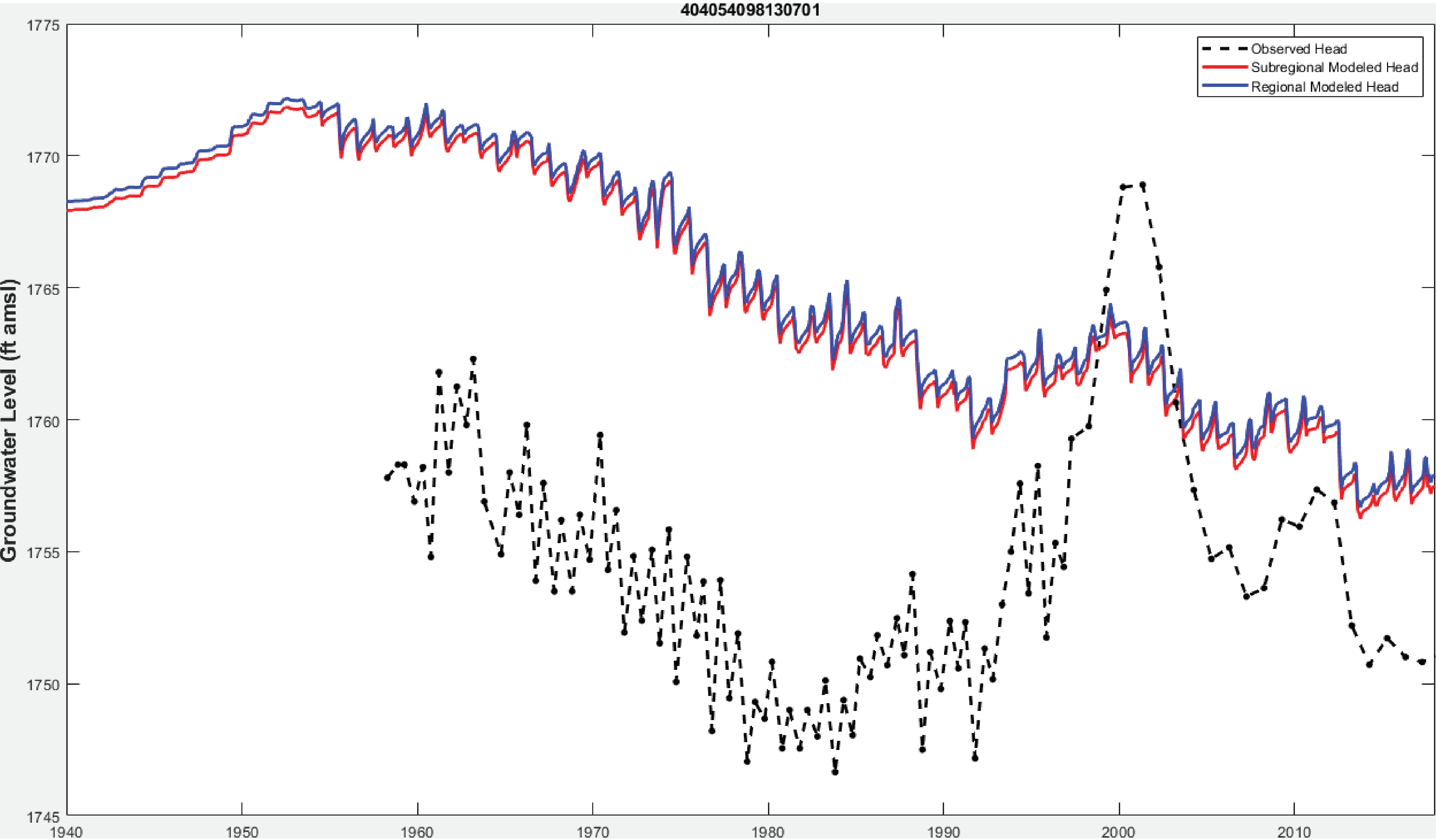
APPENDIX A
CALIBRATION HYDROGRAPHS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Subregional Modeled Head
Regional Modeled Head
Groundwater Level (ft amsl)
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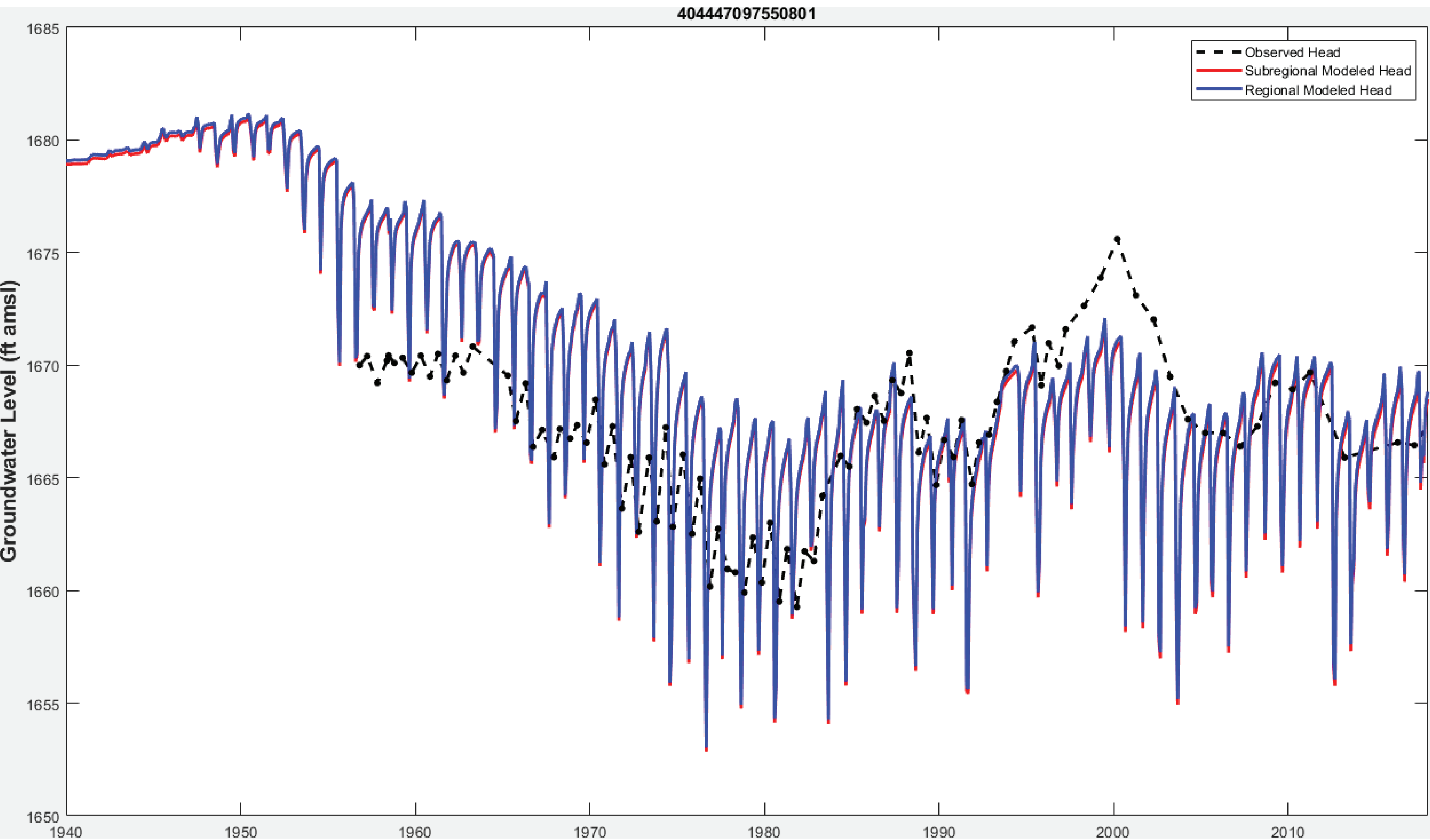
1770
1765
1760
1755
1750
1745
1940
1950
1960
1970
1980
1990
2000
2010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Regional Modeled Head
Groundwater Level (ft amsl)
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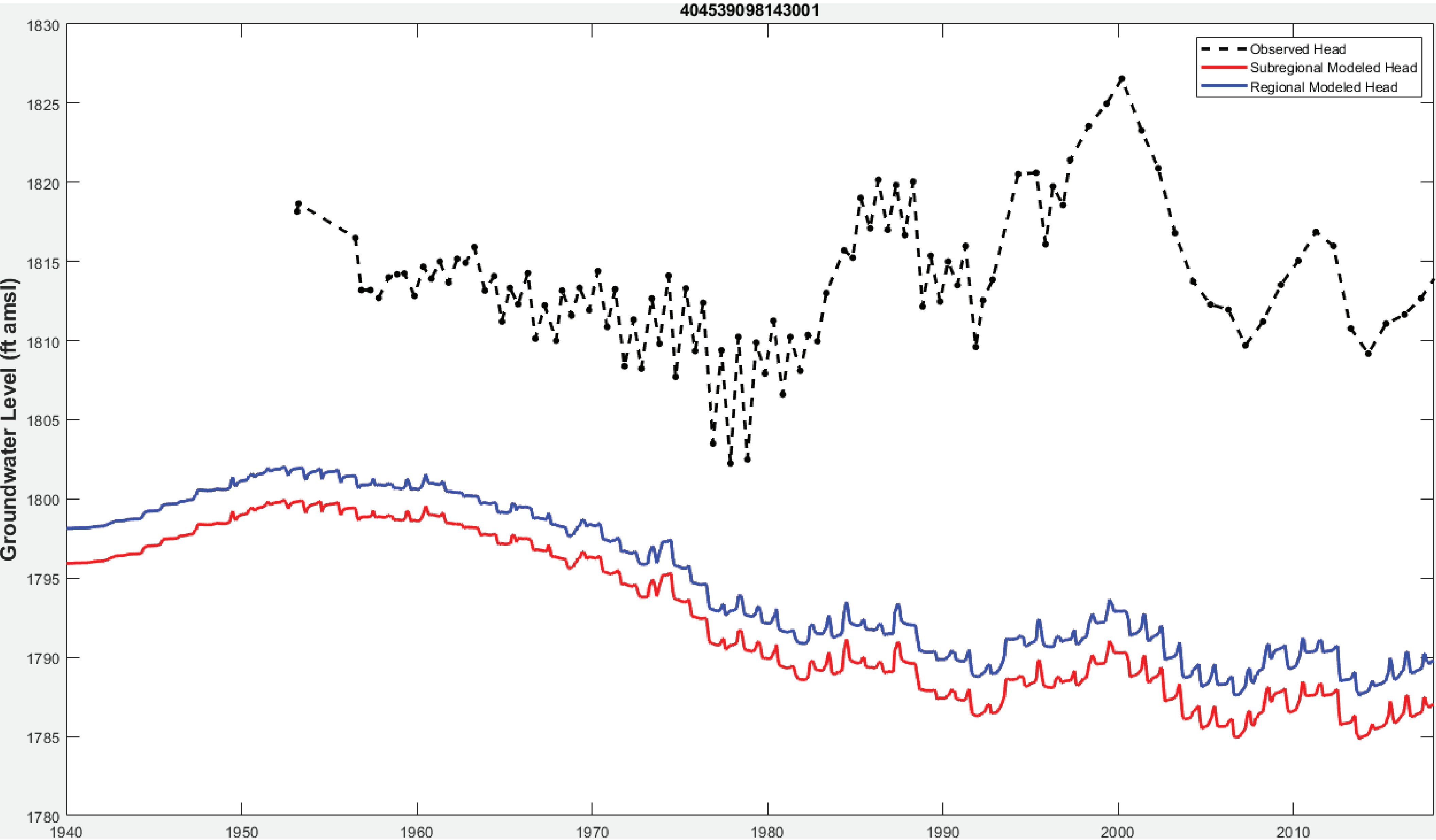
1680
1675
1670
1665
1660
1655
1650
1940
1950
1960
1970
1980
1990
2000
2010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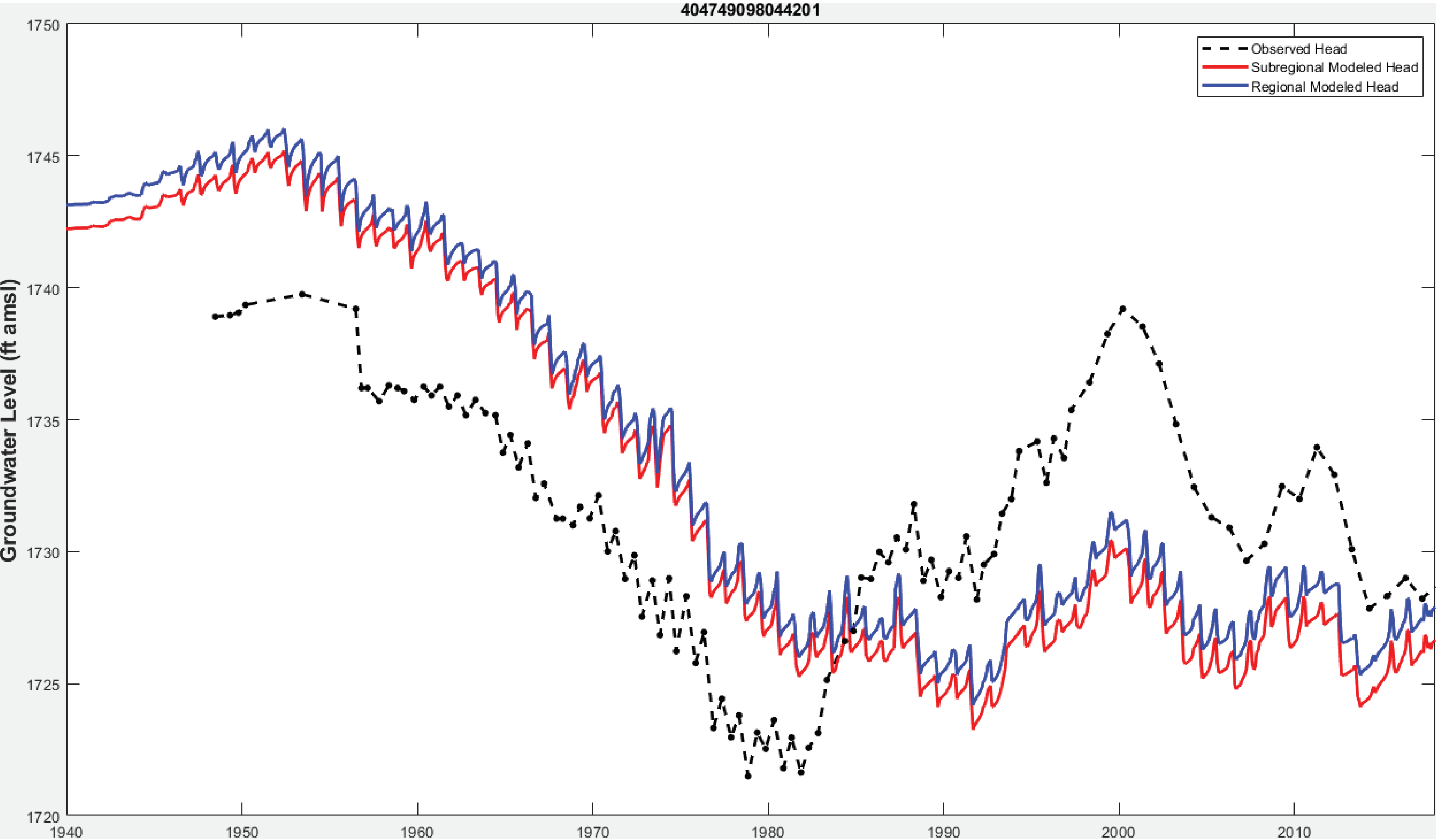
1825
1820
1815
1810
1805
1800
1795
1790
1785
1780
1940
1950
1960
1970
1980
1990
2000
2010
Observed Head
Subregional Modeled Head
Regional Modeled Head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Regional Modeled Head
Groundwater Level (ft amsl)
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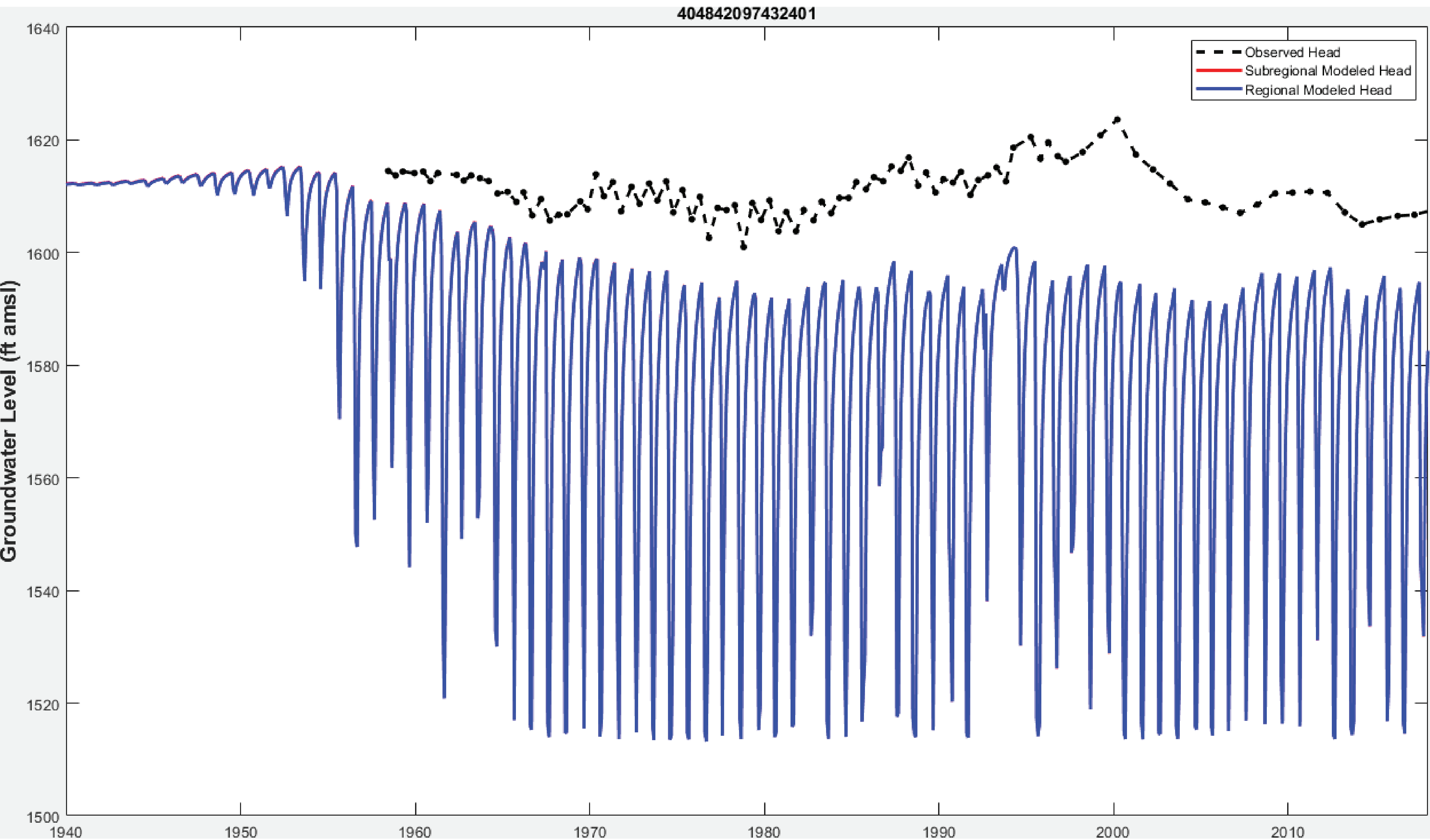
1745
1740
1735
1730
1725
1720
1940
1950
1960
1970
1980
1990
2000
2010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Regional Modeled Head
Groundwater Level (ft amsl)
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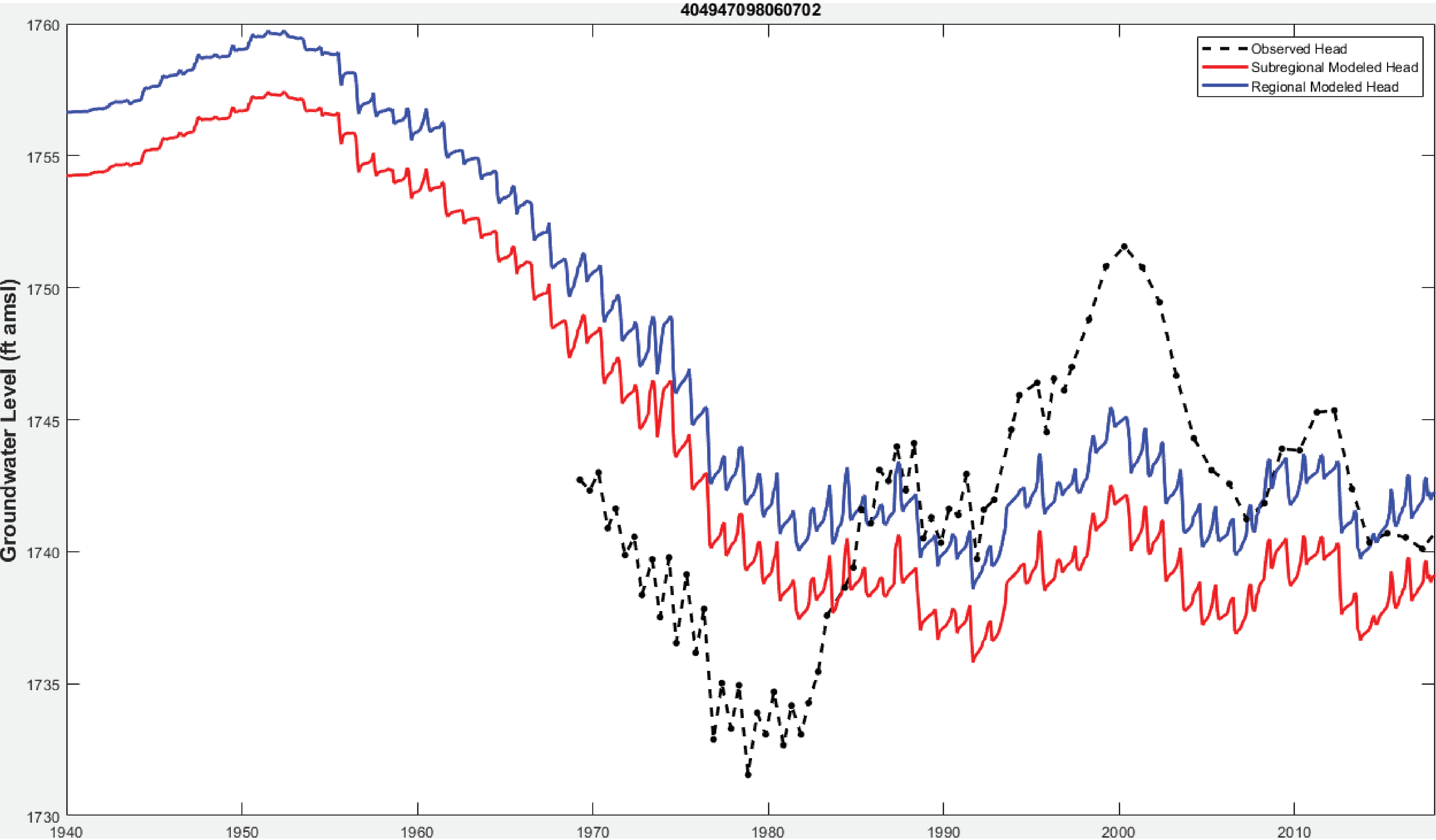
1620
1600
1580
1560
1540
1520
1500
1940
1950
1960
1970
1980
1990
2000
2010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Subregional Modeled Head
Regional Modeled Head
Groundwater Level (ft amsl)
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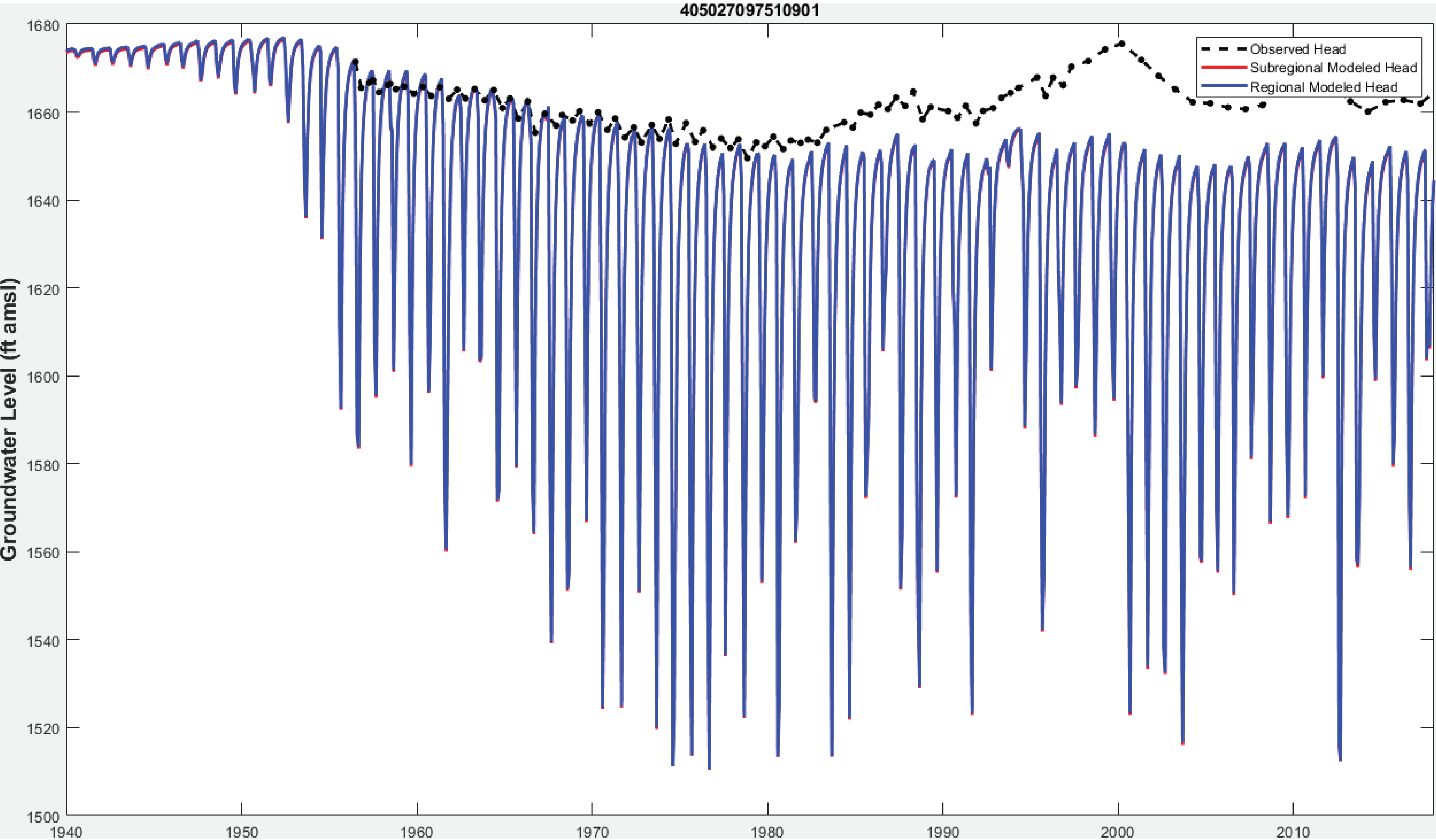
1750
1745
1740
1735
1730
1940
1950
1960
1970
1980
1990
2000
2010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Observed Head
Subregional Modeled Head
Regional Modeled Head
Groundwater Level (ft amsl)
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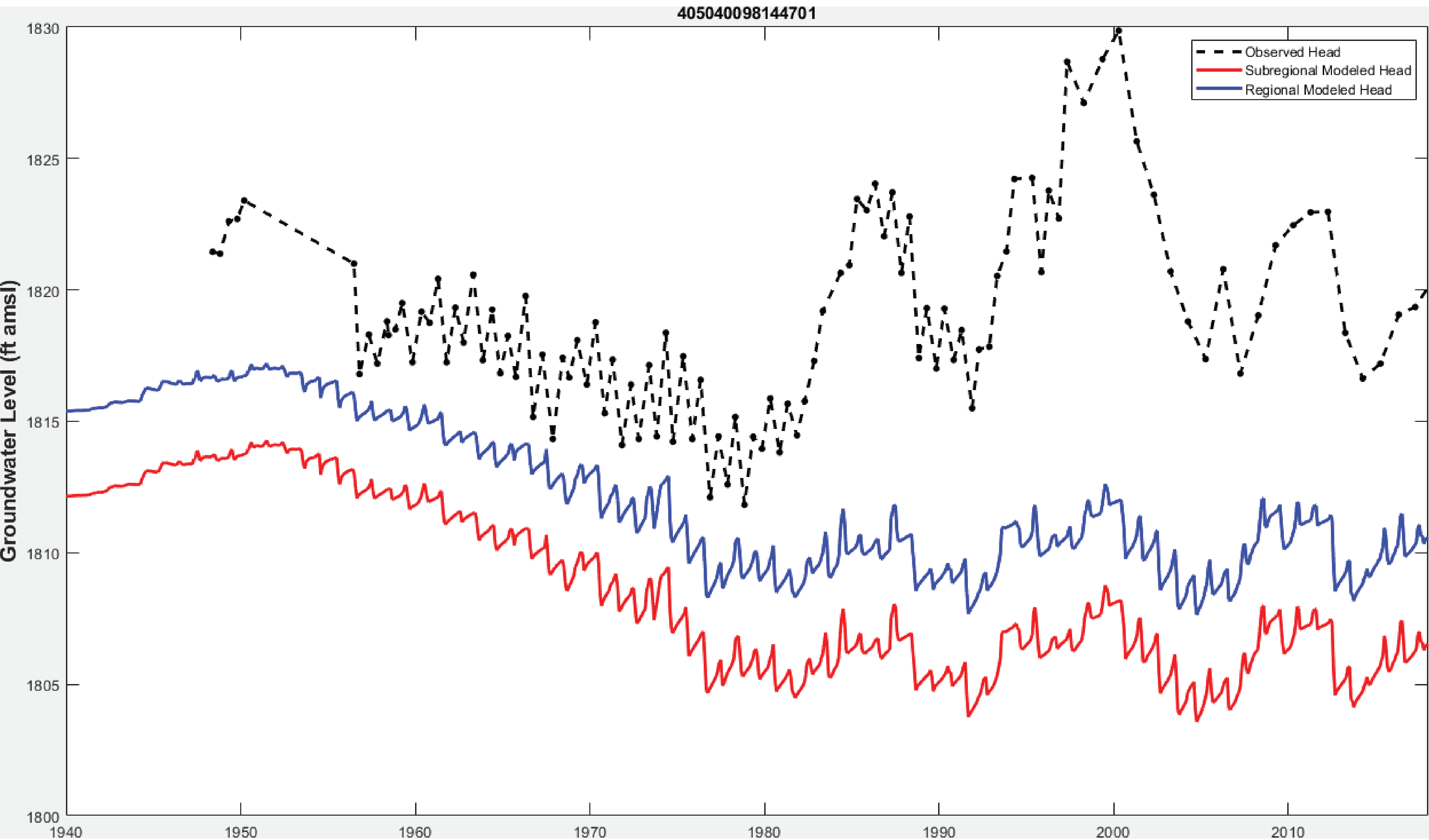
1640
1620
1600
1580
1560
1540
1520
1500
1940
1950
1960
1970
1980
1990
2000
2010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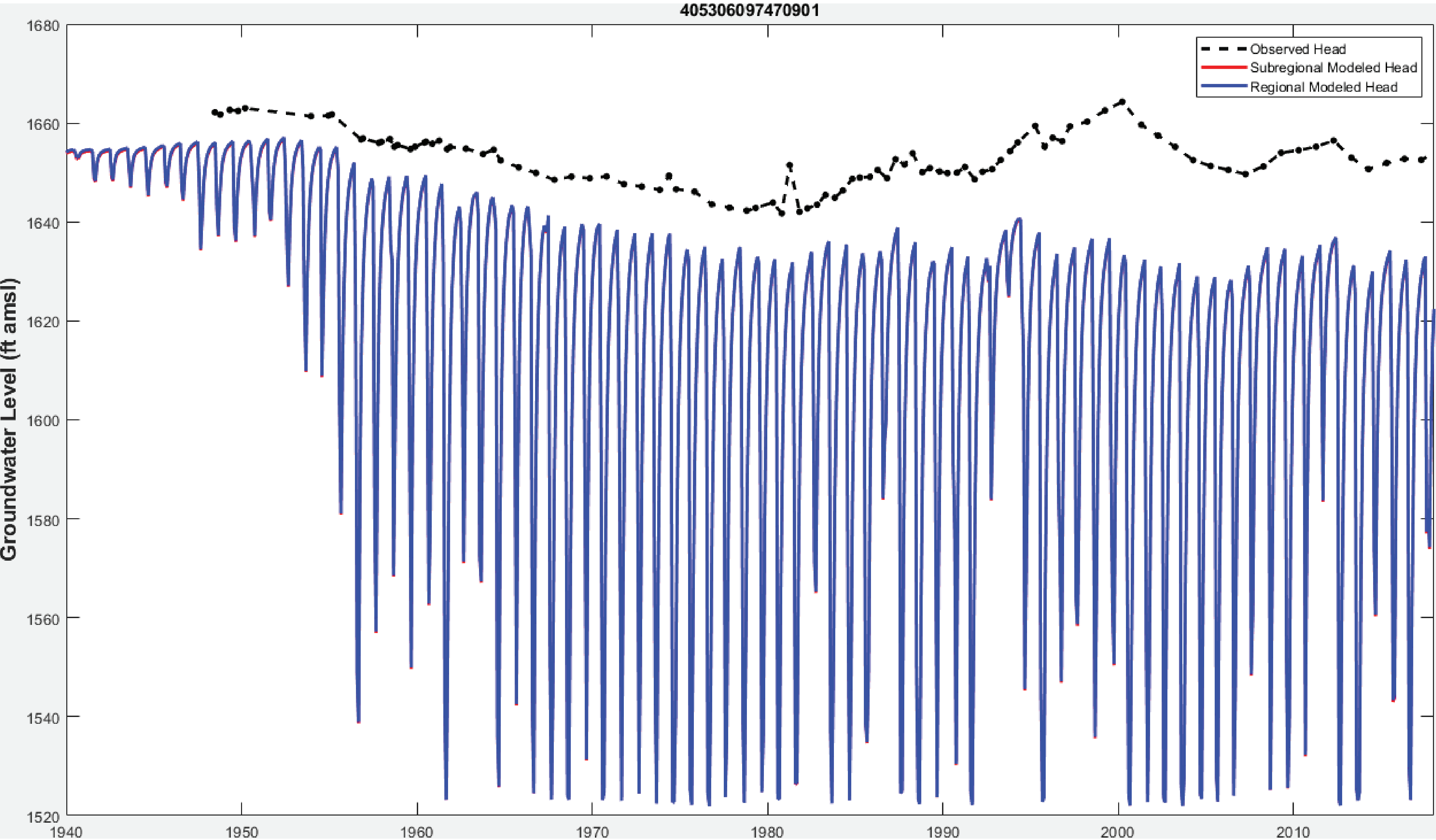
Groundwater Level (ft amsl)
1830
1825
1820
1815
1810
1805
1800
1940
1950
1960
1970
1980
1990
2000
2010
Observed Head
Subregional Modeled Head
Regional Modeled Head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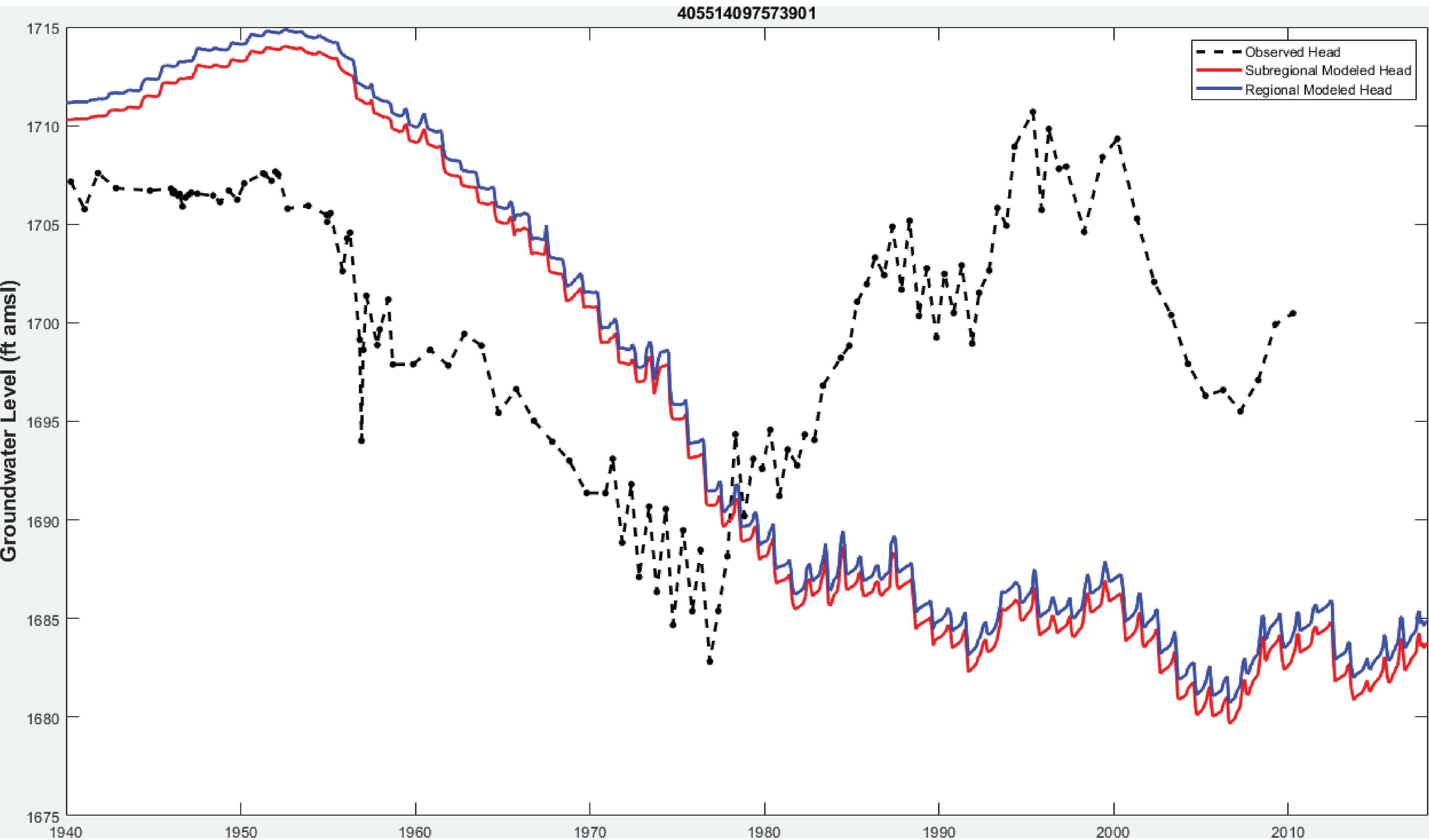
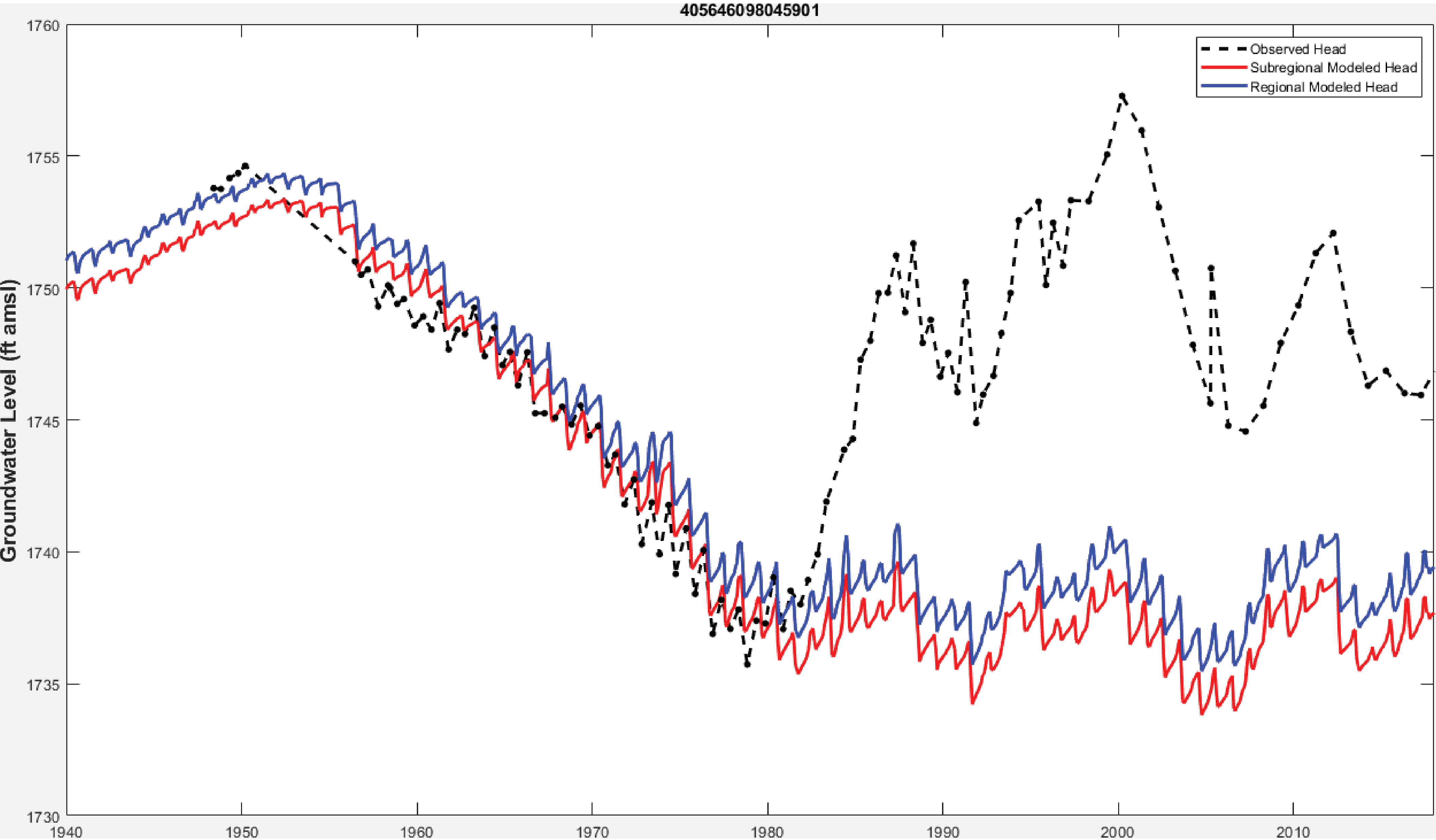
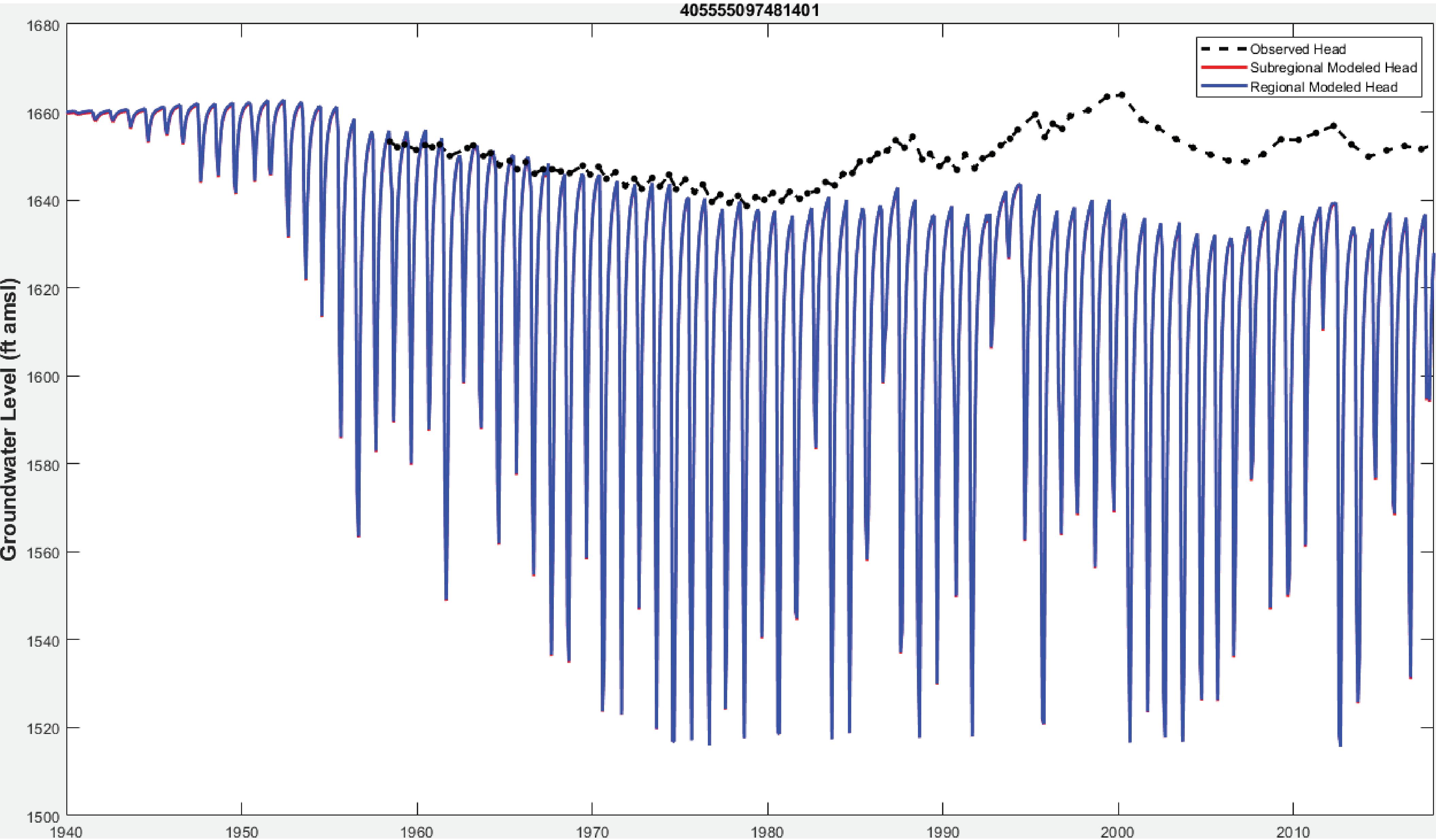
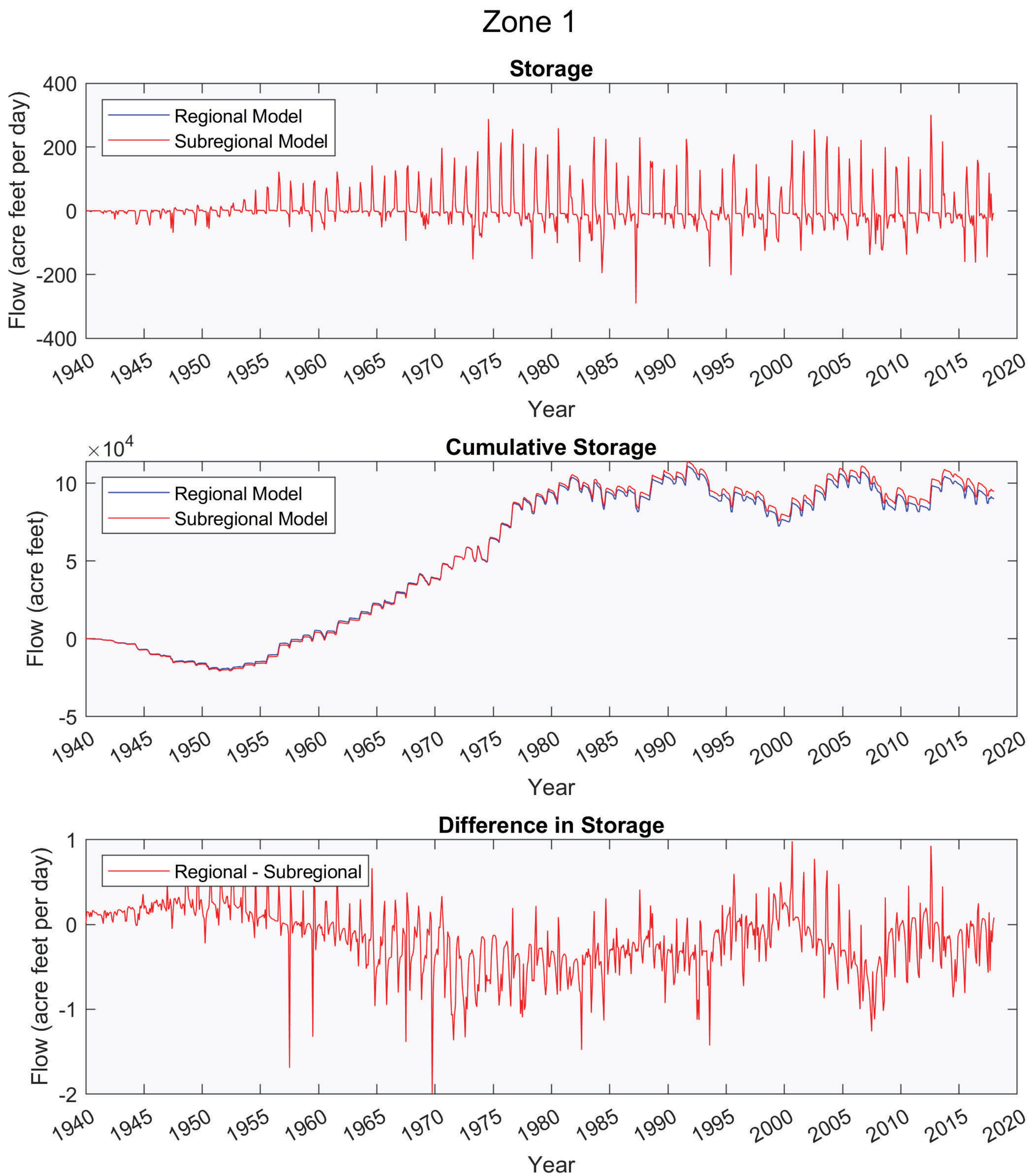
Observed Head
Subregional Modeled Head
Regional Modeled Head
Groundwater Level (ft amsl)
1680
1660
1640
1620
1600
1580
1560
1540
1520
1940
1950
1960
1970
1980
1990
2000
2010


405514097573901
Groundwater Level (ft amsl)
1715
1710
1705
1700
1695
1690
1685
1680
1675
1940
1950
1960
1970
1980
1990
2000
2010
Observed Head
Subregional Modeled Head
Regional Modeled Head

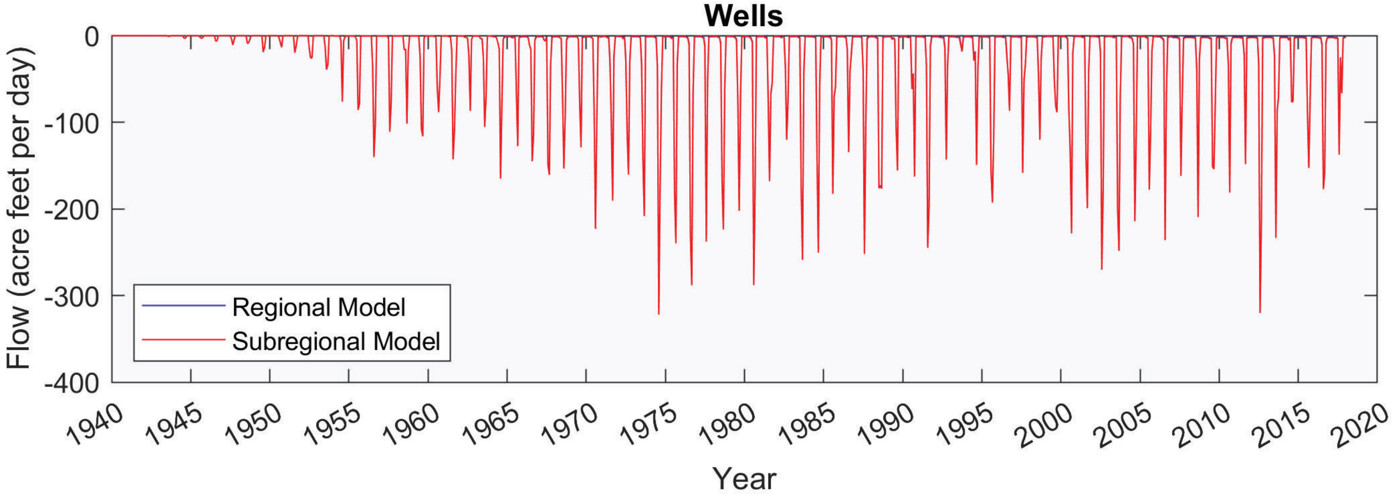

405646098045901
Observed Head
Subregional Modeled Head
Regional Modeled Head
Groundwater Level (ft amsl)
1760
1755
1750
1745
1740
1735
1730
1940
1950
1960
1970
1980
1990
2000
2010


405555097481401
Observed Head
Subregional Modeled Head
Regional Modeled Head
Groundwater Level (ft amsl)
1680
1660
1640
1620
1600
1580
1560
1540
1520
1500
1940
1950
1960
1970
1980
1990
2000
2010

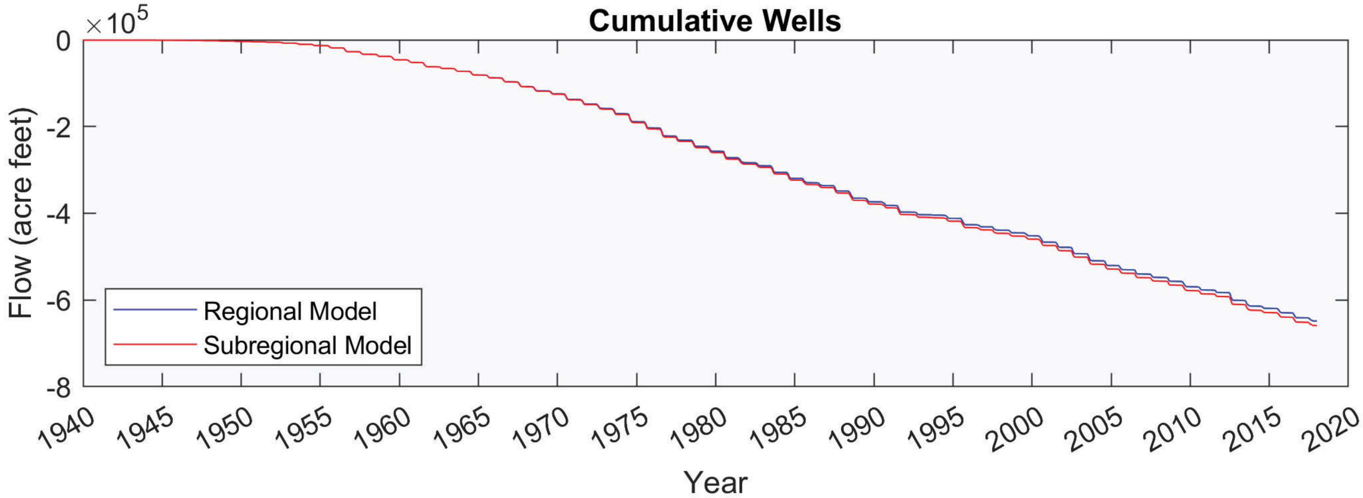
APPENDIX B
DIFFERENCE IN ZONE BUDGET FIGURES


Zone 1
Storage
Regional Model
Subregional Model
Flow (acre feet per day)
400
200
0
-200
-400
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Cumulative Storage
×10^4
Regional Model
Subregional Model
Flow (acre feet)
10
5
0
-5
Year
Difference in Storage
Regional - Subregional
Flow (acre feet per day)
1
0
-1
-2
Year

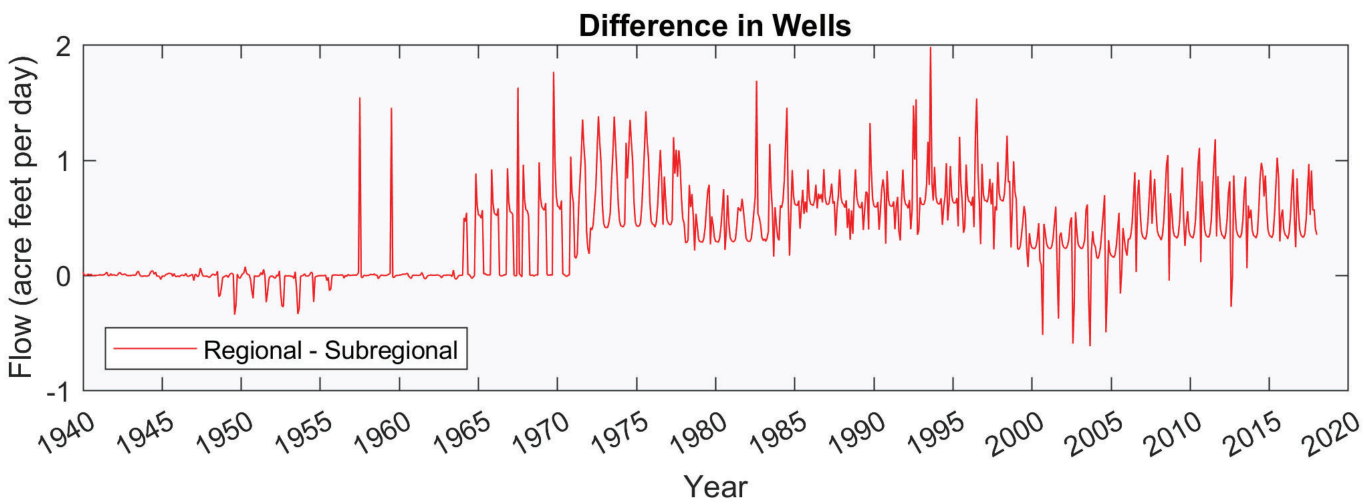
Zone 1



Wells
Flow (acre feet per day)
0
-100
-200
-300
-400
Regional Model
Subregional Model
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

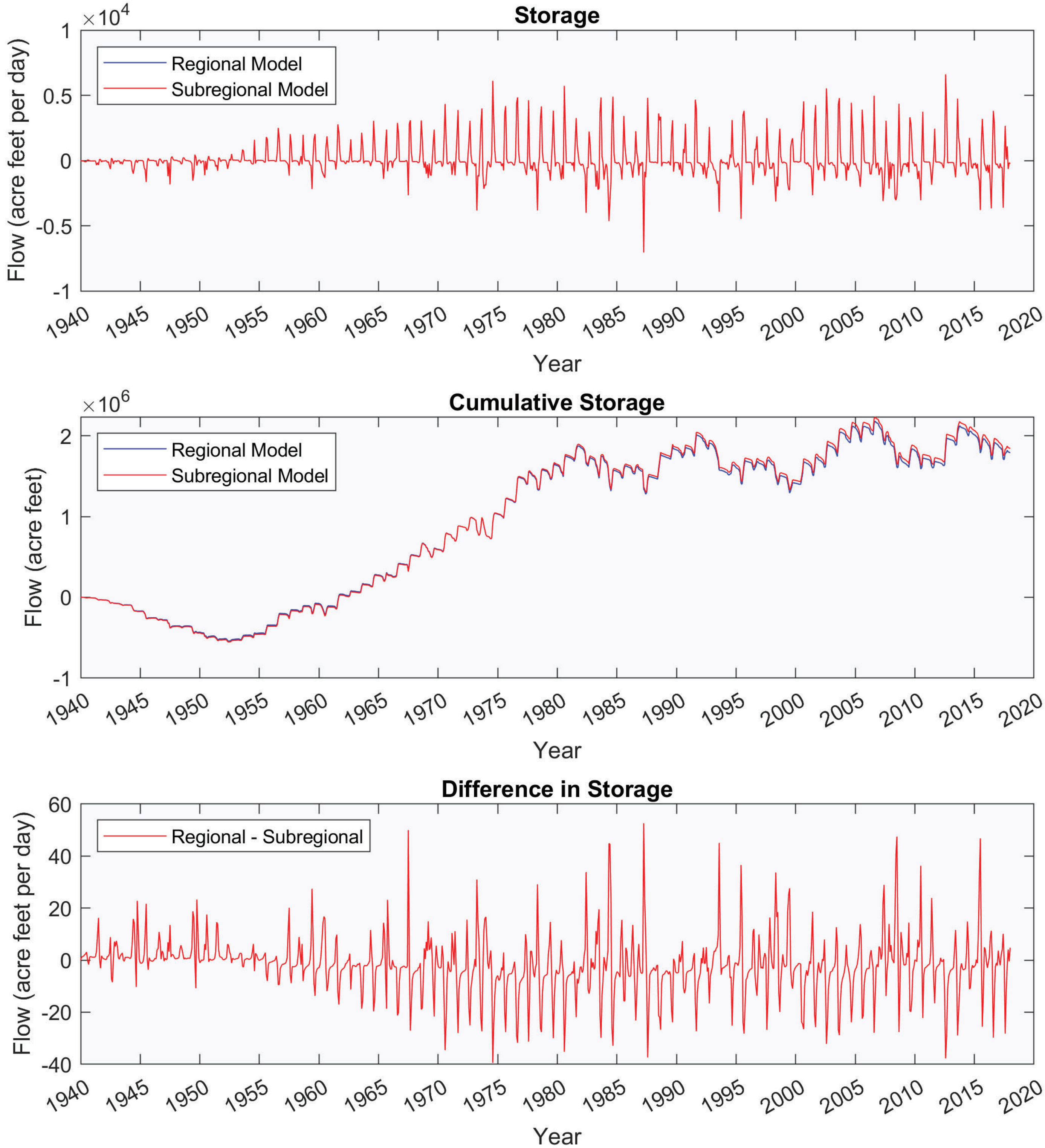


Cumulative Wells
$\times 10^5$
Flow (acre feet)
0
-2
-4
-6
-8
Regional Model
Subregional Model
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

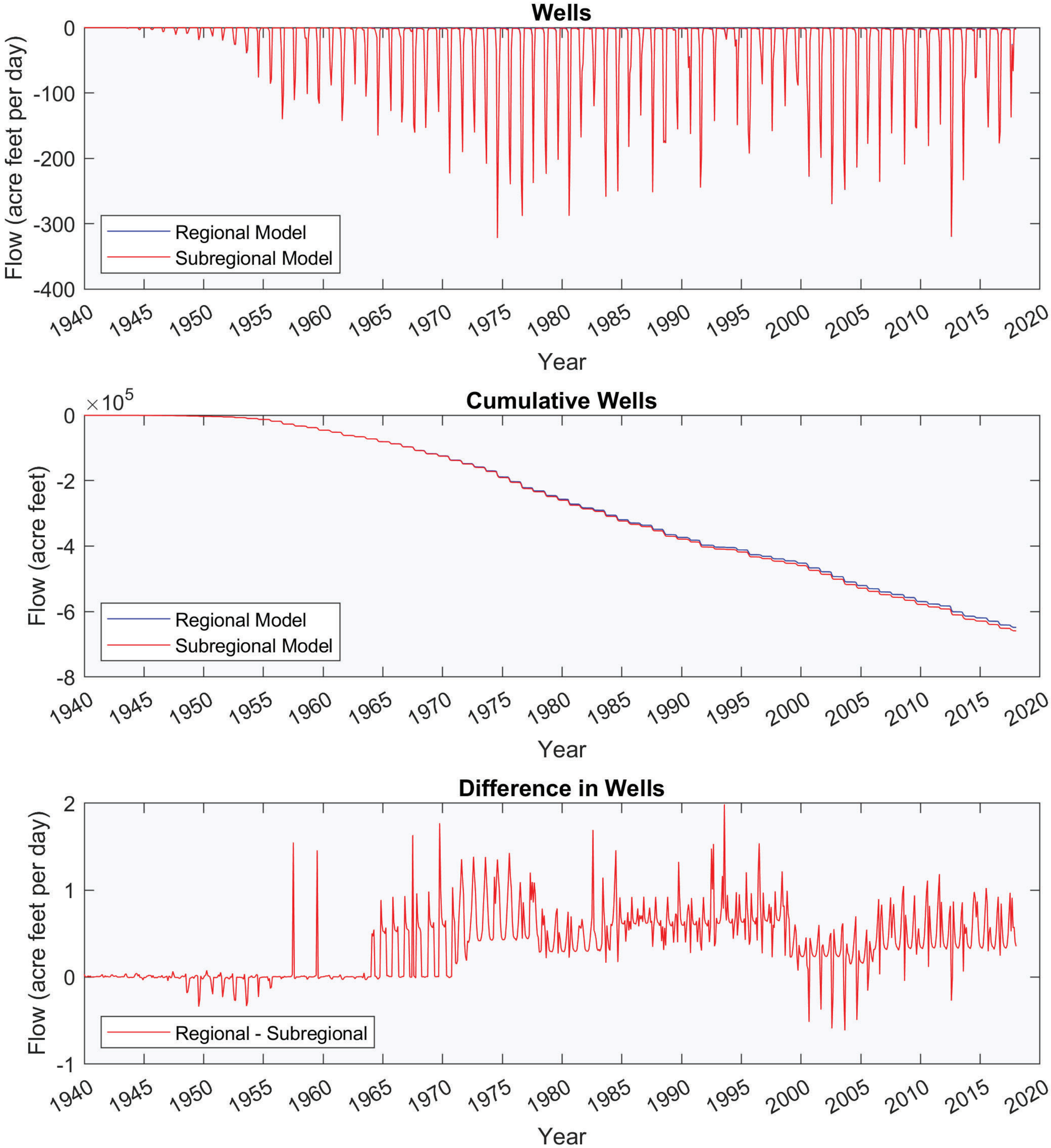


Difference in Wells
Flow (acre feet per day)
2
1
0
-1
Regional - Subregional
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

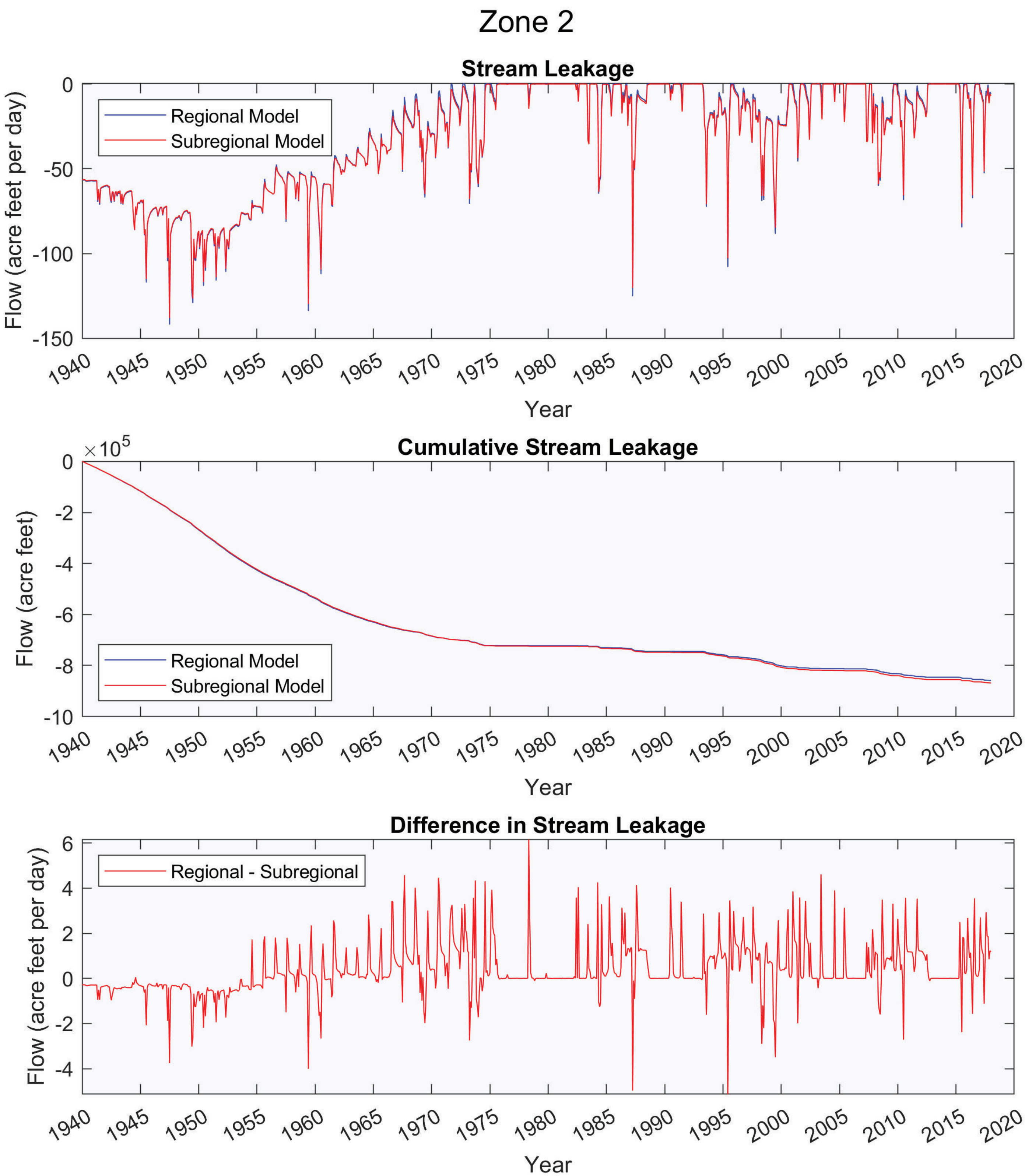
Zone 2


Storage
×10^4
Regional Model
Subregional Model
Flow (acre feet per day)
1
0.5
0
-0.5
-1
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Cumulative Storage
×10^6
Regional Model
Subregional Model
Flow (acre feet)
2
1
0
-1
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Difference in Storage
Regional - Subregional
Flow (acre feet per day)
60
40
20
0
-20
-40
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

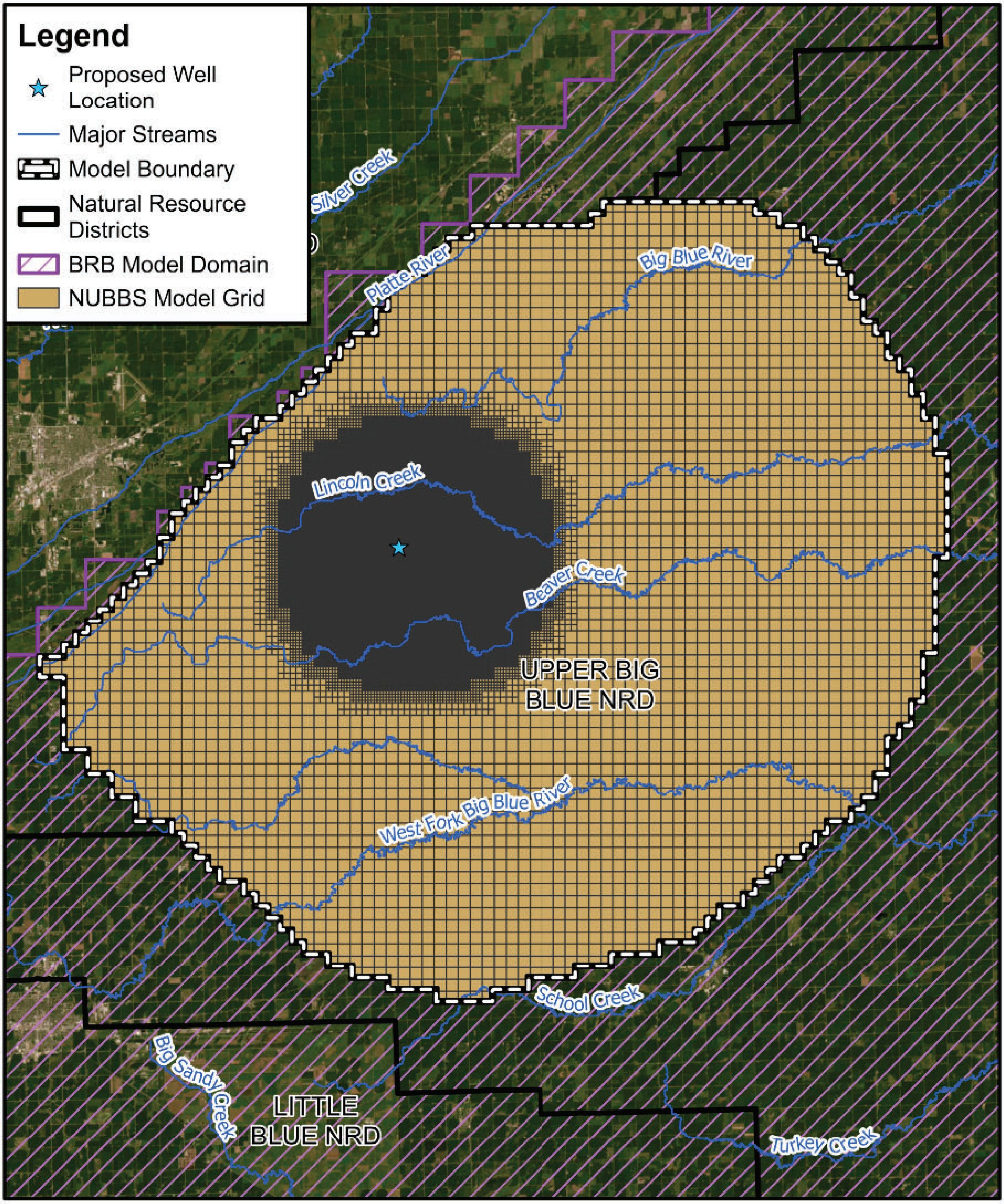
Zone 2



Wells
Flow (acre feet per day)
0
-100
-200
-300
-400
Regional Model
Subregional Model
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Cumulative Wells
×10^5
Flow (acre feet)
0
-2
-4
-6
-8
Regional Model
Subregional Model
Year
Difference in Wells
Flow (acre feet per day)
2
1
0
-1
Regional - Subregional
Year


Zone 2
Stream Leakage
Regional Model
Subregional Model
Flow (acre feet per day)
0
-50
-100
-150
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
Cumulative Stream Leakage
×10^5
Flow (acre feet)
0
-2
-4
-6
-8
-10
Regional Model
Subregional Model
Year
Difference in Stream Leakage
Regional - Subregional
Flow (acre feet per day)
6
4
2
0
-2
-4
Year

APPENDIX C
FIGURES



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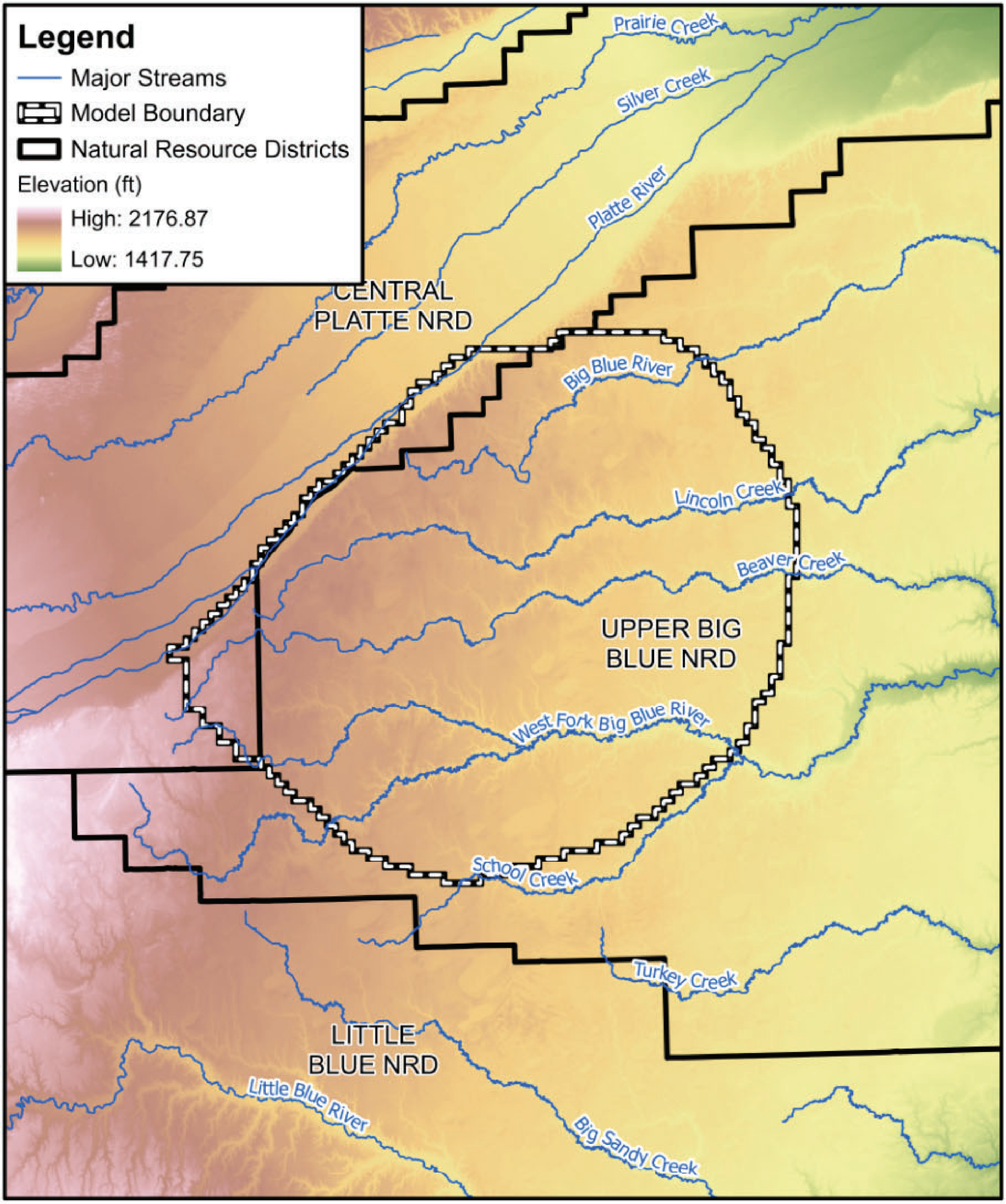
F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: October 16, 2023

NUBBS MODEL LOCATION MAP

LARGE WATER USER
NEAR AURORA, NE

FIGURE
1



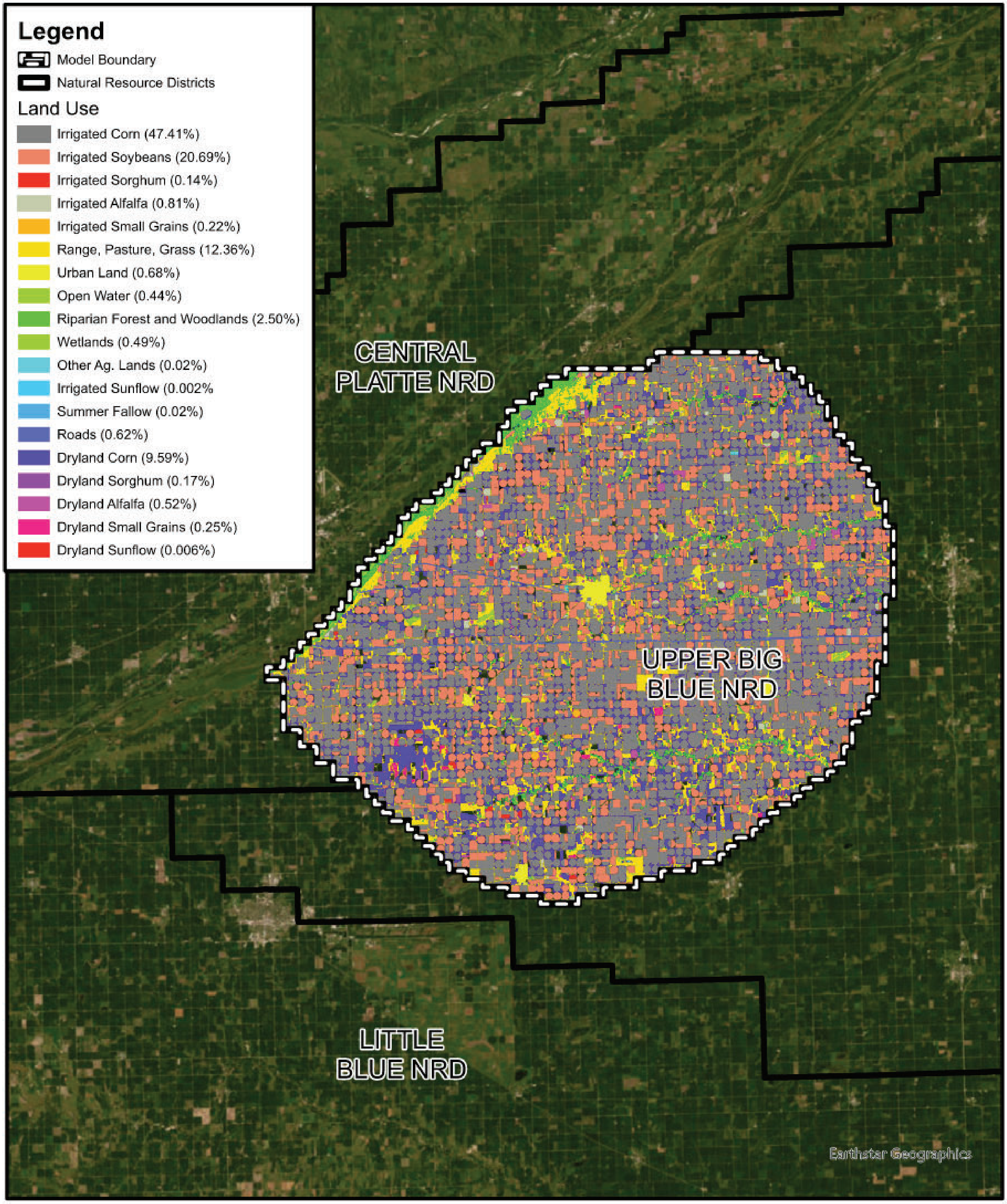
olsson

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

LARGE WATER USER NEAR AURORA, NE

FIGURE 2

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 21, 2023



N

0 4 8 Miles
1 INCH = 8 MILES

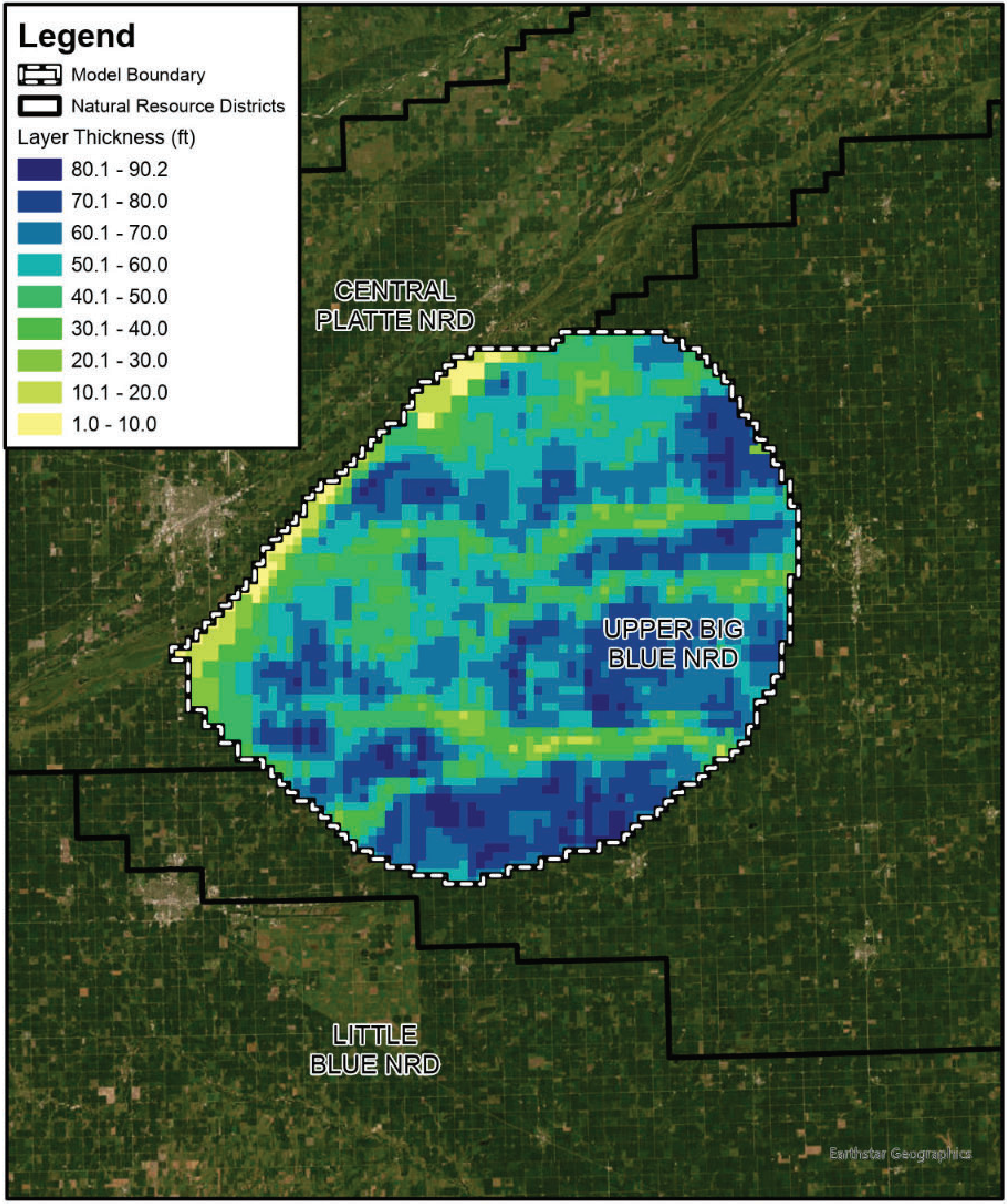
NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

LAND USE CLASSIFICATION

LARGE WATER USER
NEAR AURORA, NE

FIGURE
3

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY_LU.aprx PUBLISHED BY: bstarns DATE: September 14, 2023



olsson

N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane Nebraska FIPS 2600 Feet

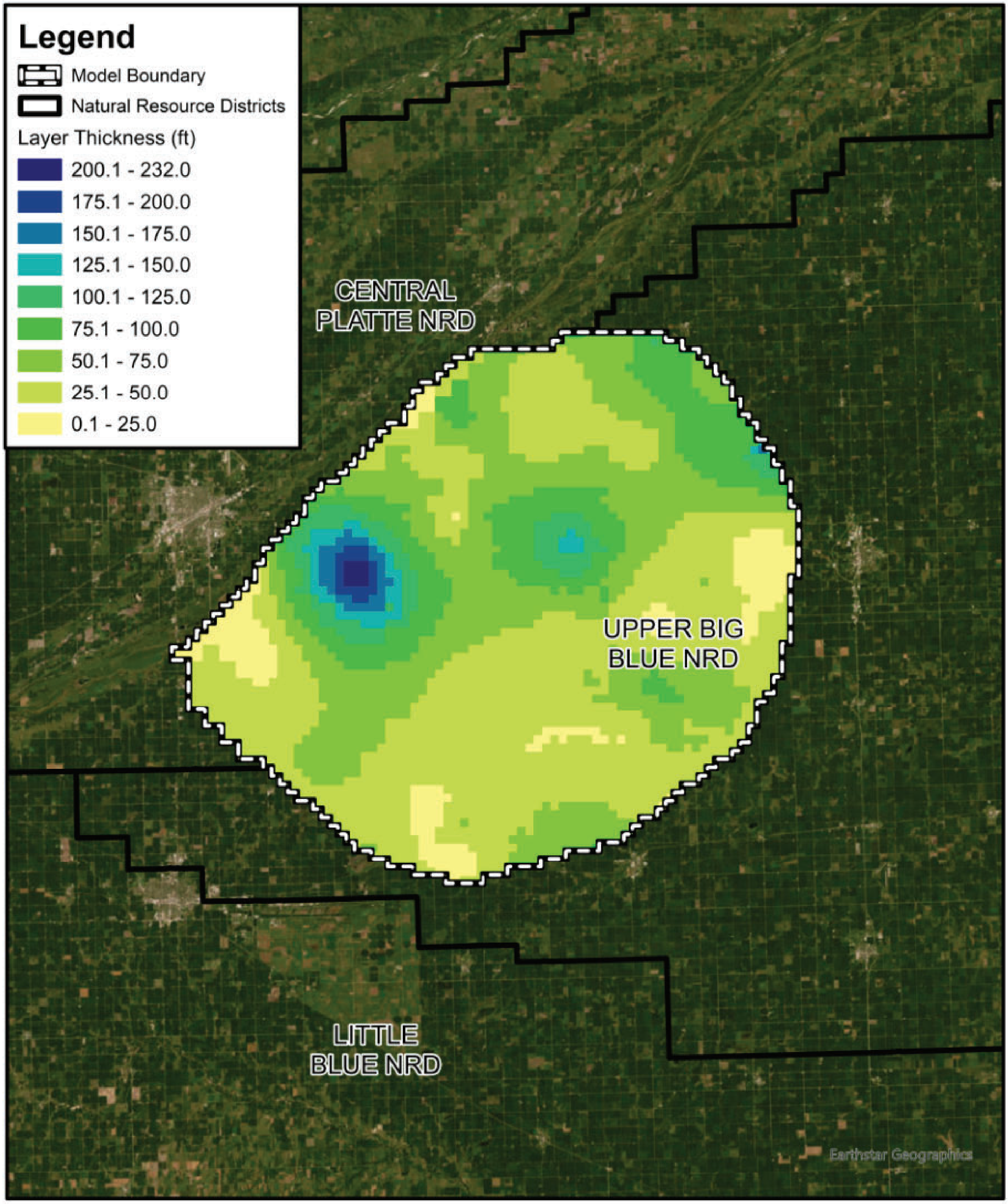
LAYER 1 THICKNESS

LARGE WATER USER NEAR AURORA, NE

FIGURE

4

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

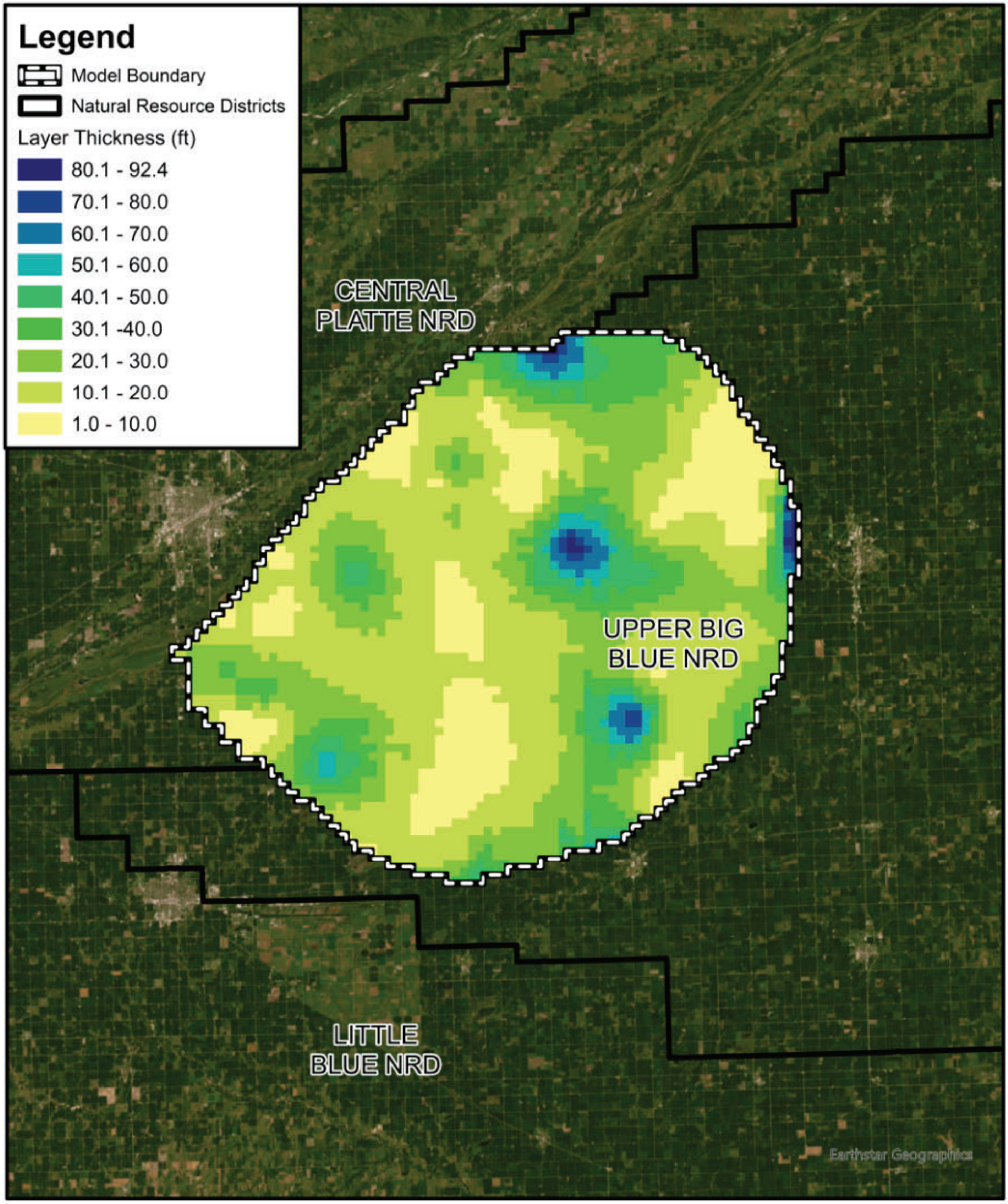
LAYER 2 THICKNESS

LARGE WATER USER
NEAR AURORA, NE

FIGURE

5

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023

olsson

N

0 4 8 Miles

1 INCH = 8 MILES

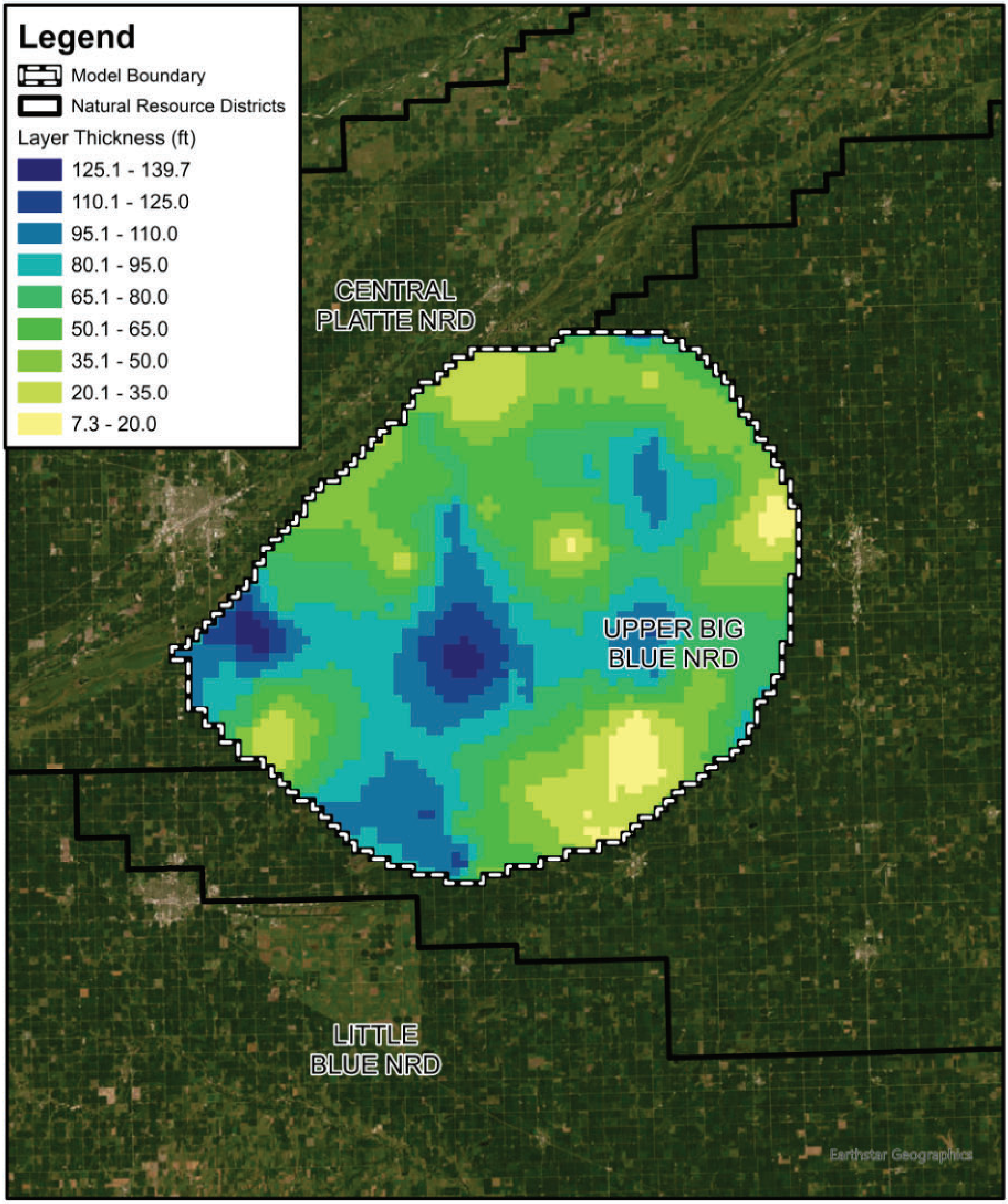
NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

LAYER 3 THICKNESS

LARGE WATER USER
NEAR AURORA, NE

FIGURE

6



olsson

N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

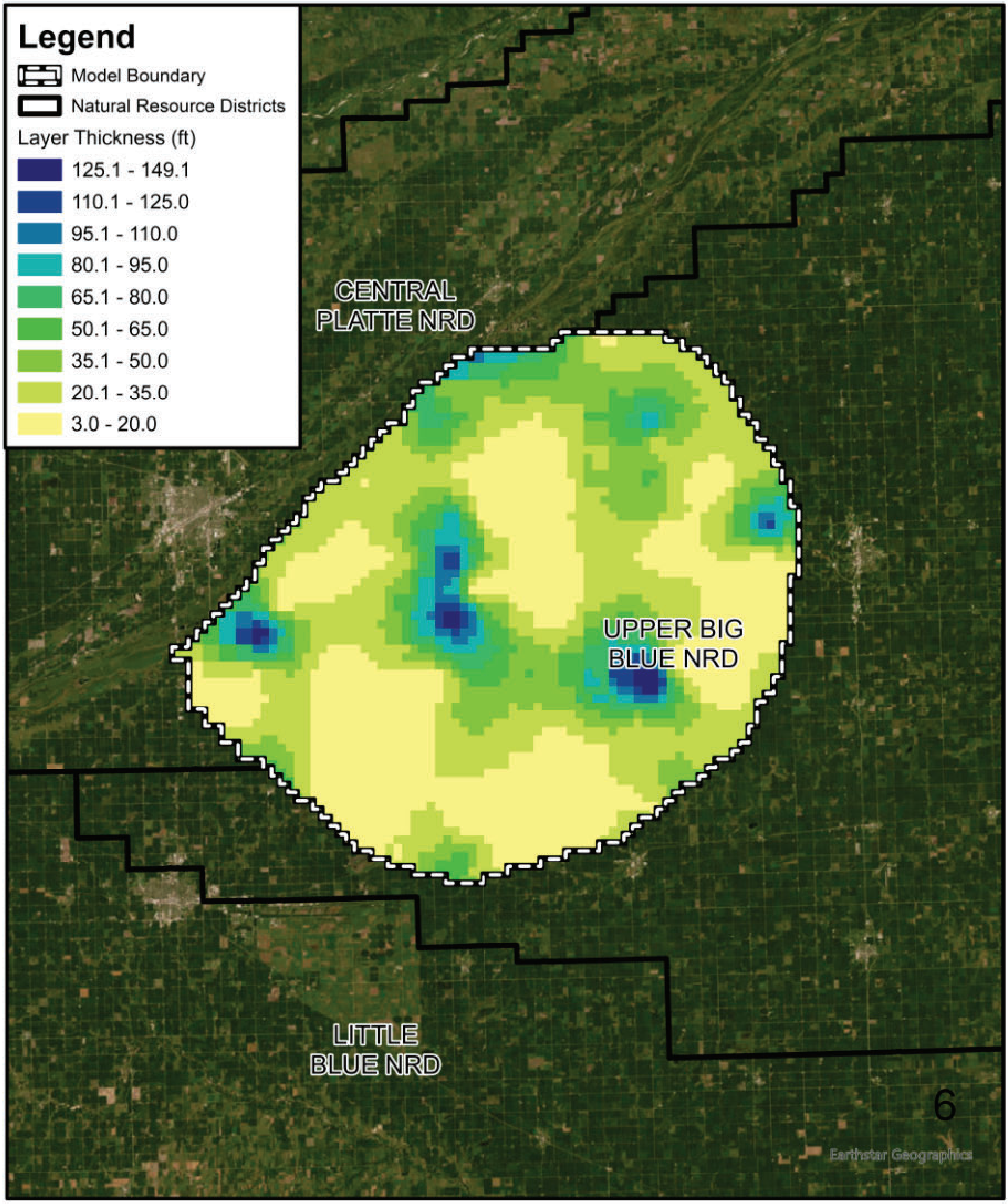
LAYER 4 THICKNESS

LARGE WATER USER
NEAR AURORA, NE

FIGURE

7

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023

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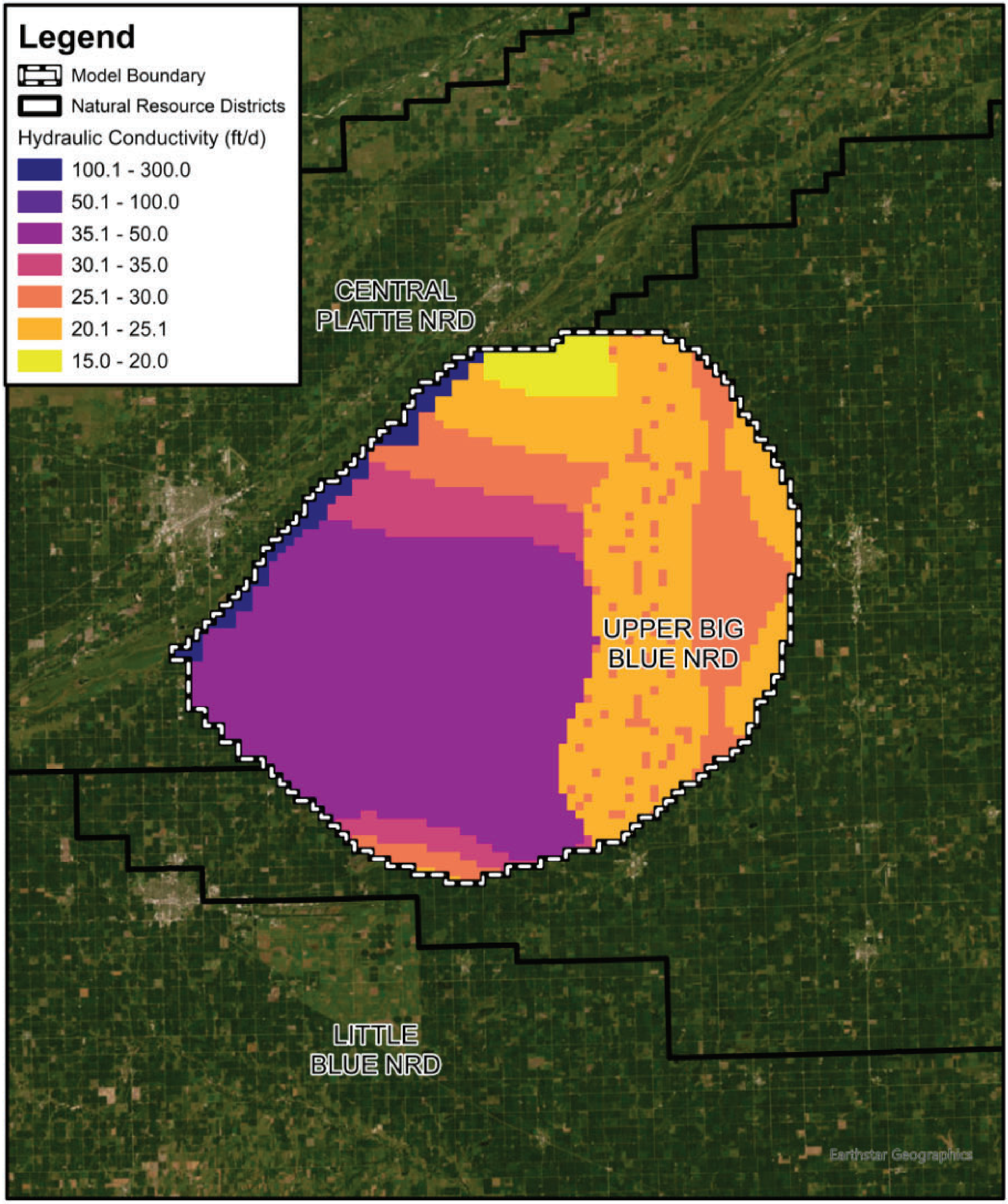
N

0 4 8 Miles
1 INCH = 8 MILES
NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

LAYER 5 THICKNESS

LARGE WATER USER
NEAR AURORA, NE

FIGURE
8



N

0 4 8 Miles

1 INCH = 8 MILES

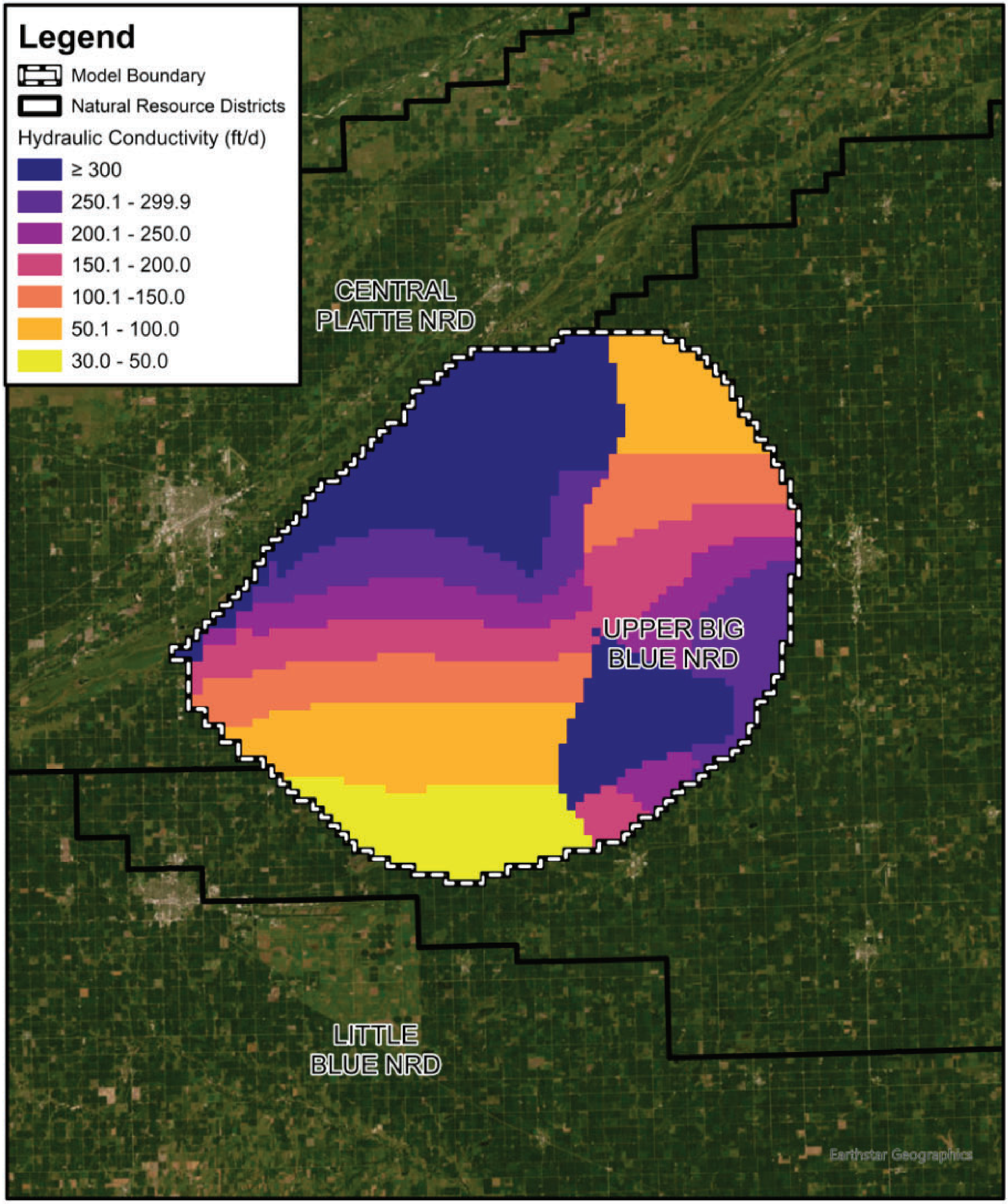
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 1 HYDRAULIC CONDUCTIVITY

LARGE WATER USER NEAR AURORA, NE

FIGURE 9

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 14, 2023



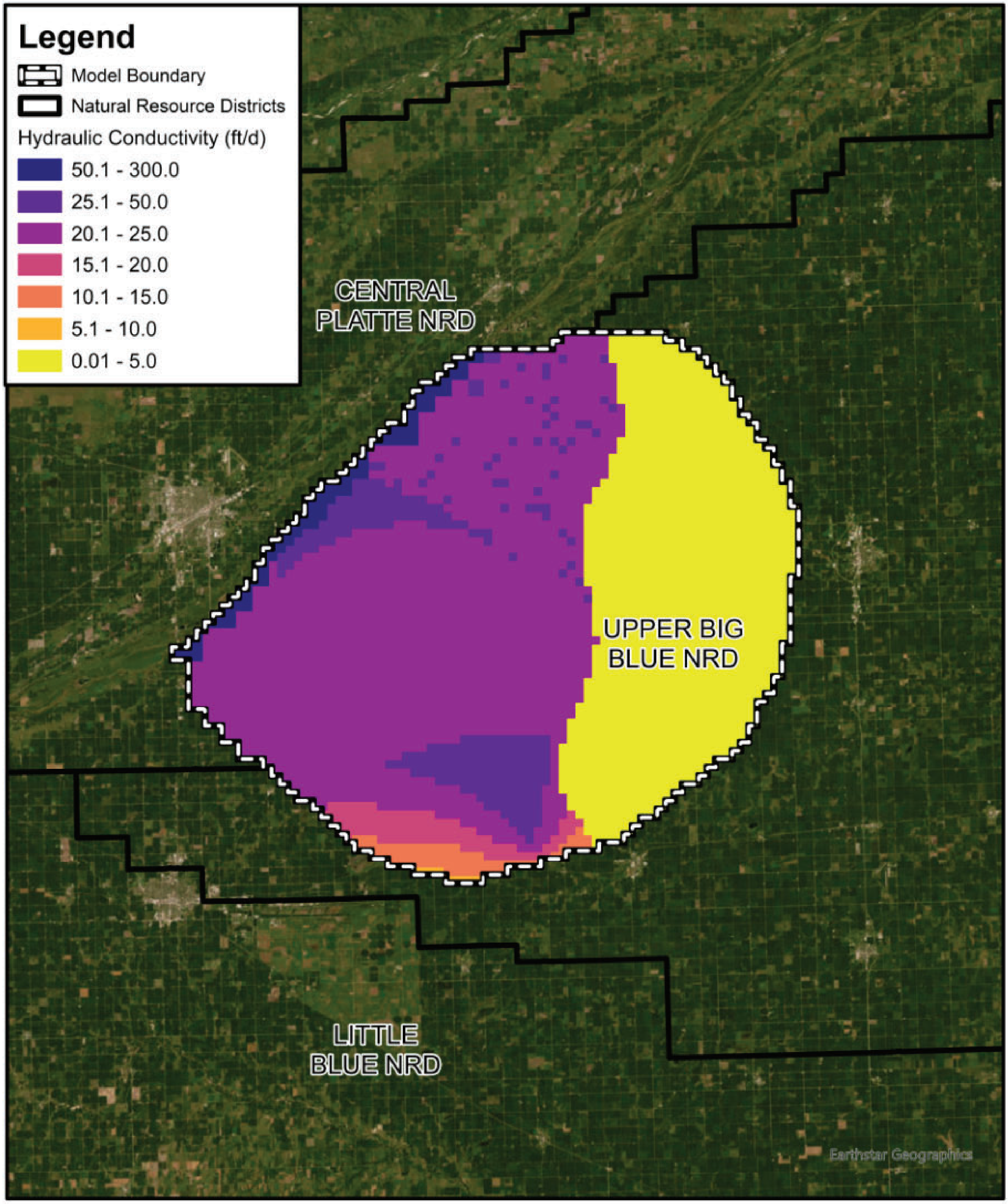
olsson

LAYER 2 HYDRAULIC CONDUCTIVITY

LARGE WATER USER NEAR AURORA, NE

FIGURE 10

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 14, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 14, 2023

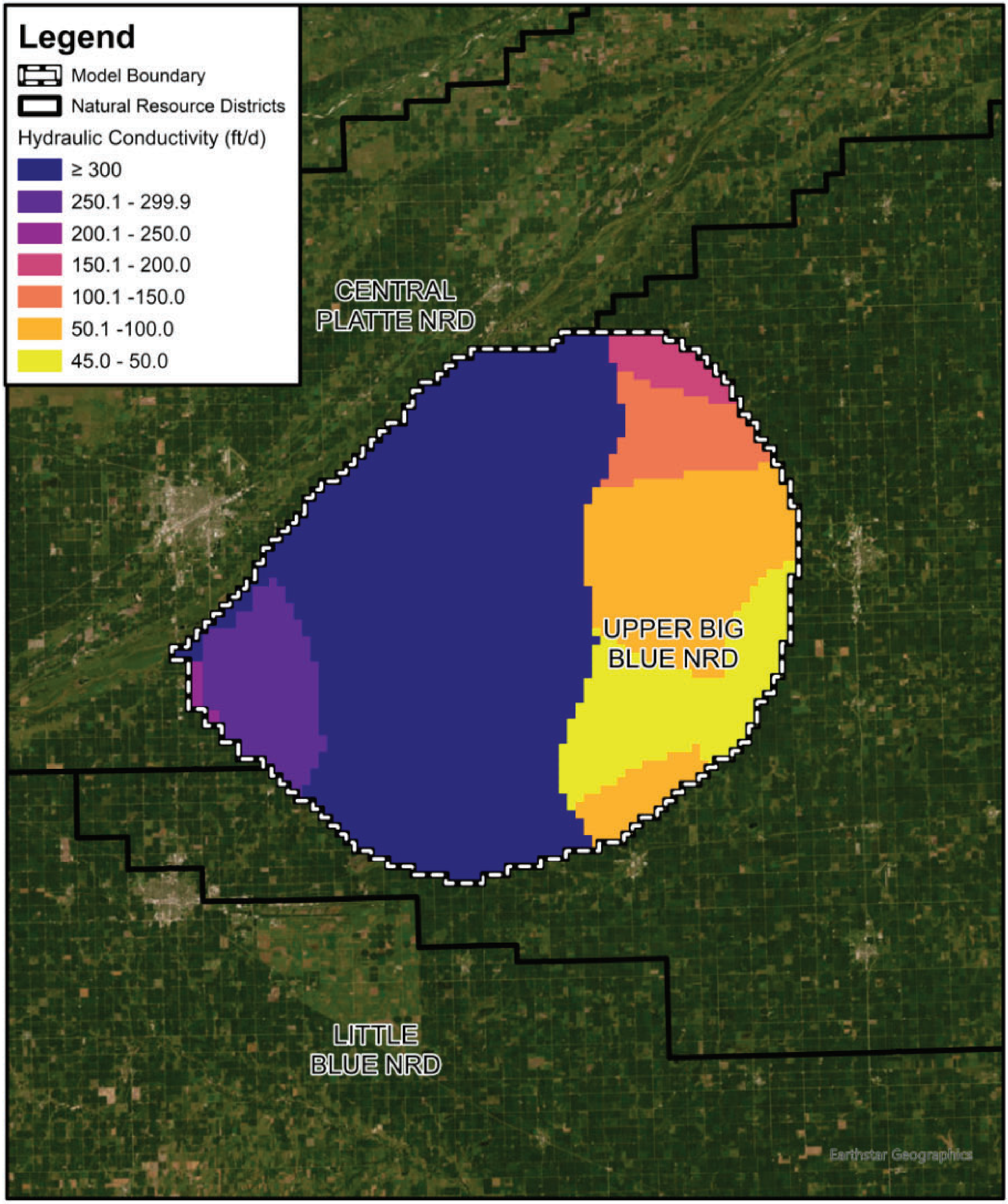
N
0 4 8 Miles
1 INCH = 8 MILES
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 3 HYDRAULIC CONDUCTIVITY

LARGE WATER USER NEAR AURORA, NE

FIGURE

11



olsson

N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

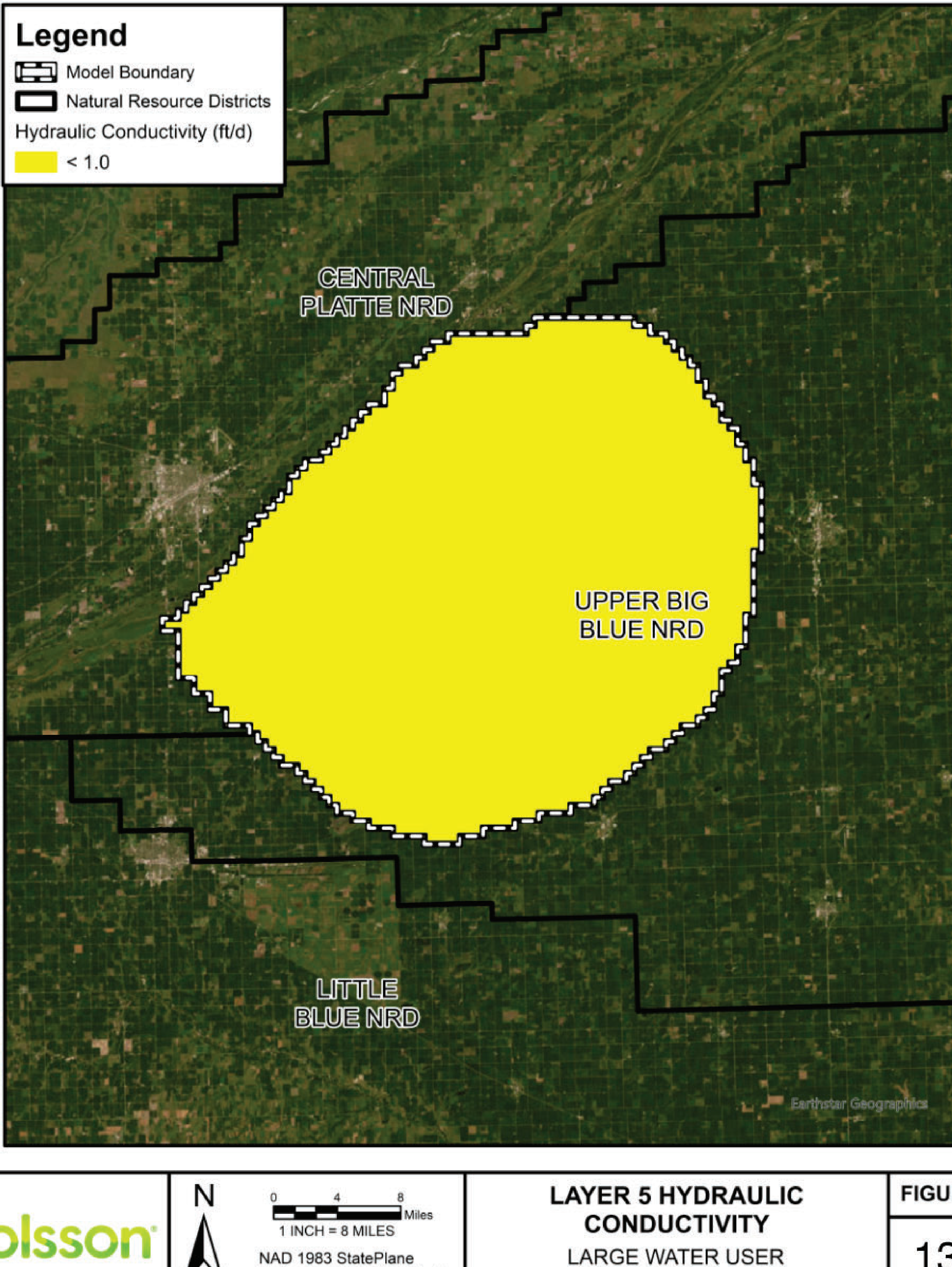
LAYER 4 HYDRAULIC CONDUCTIVITY

LARGE WATER USER
NEAR AURORA, NE

FIGURE

12

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 14, 2023



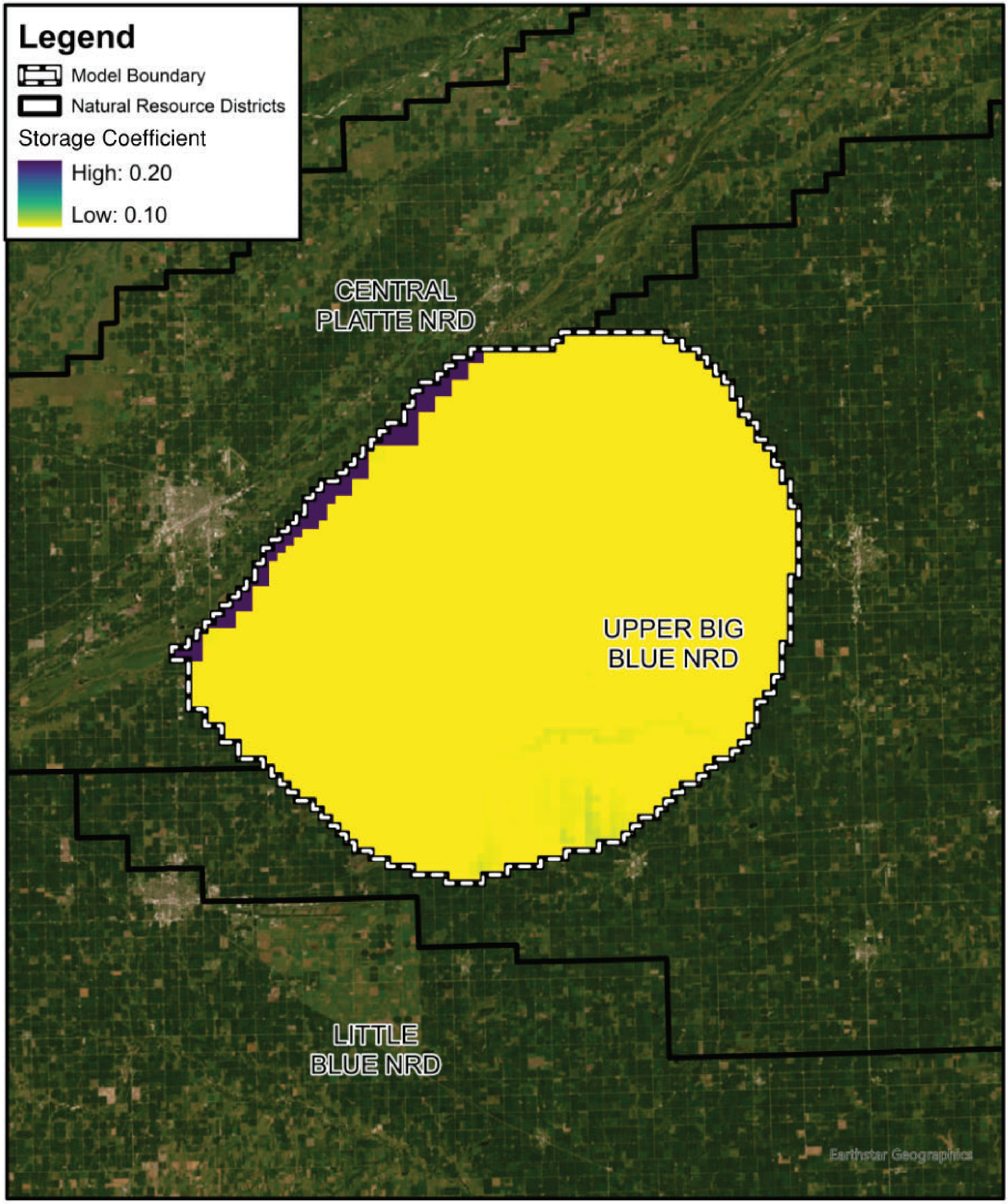
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 5 HYDRAULIC CONDUCTIVITY

LARGE WATER USER NEAR AURORA, NE

FIGURE 13

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 14, 2023



olsson

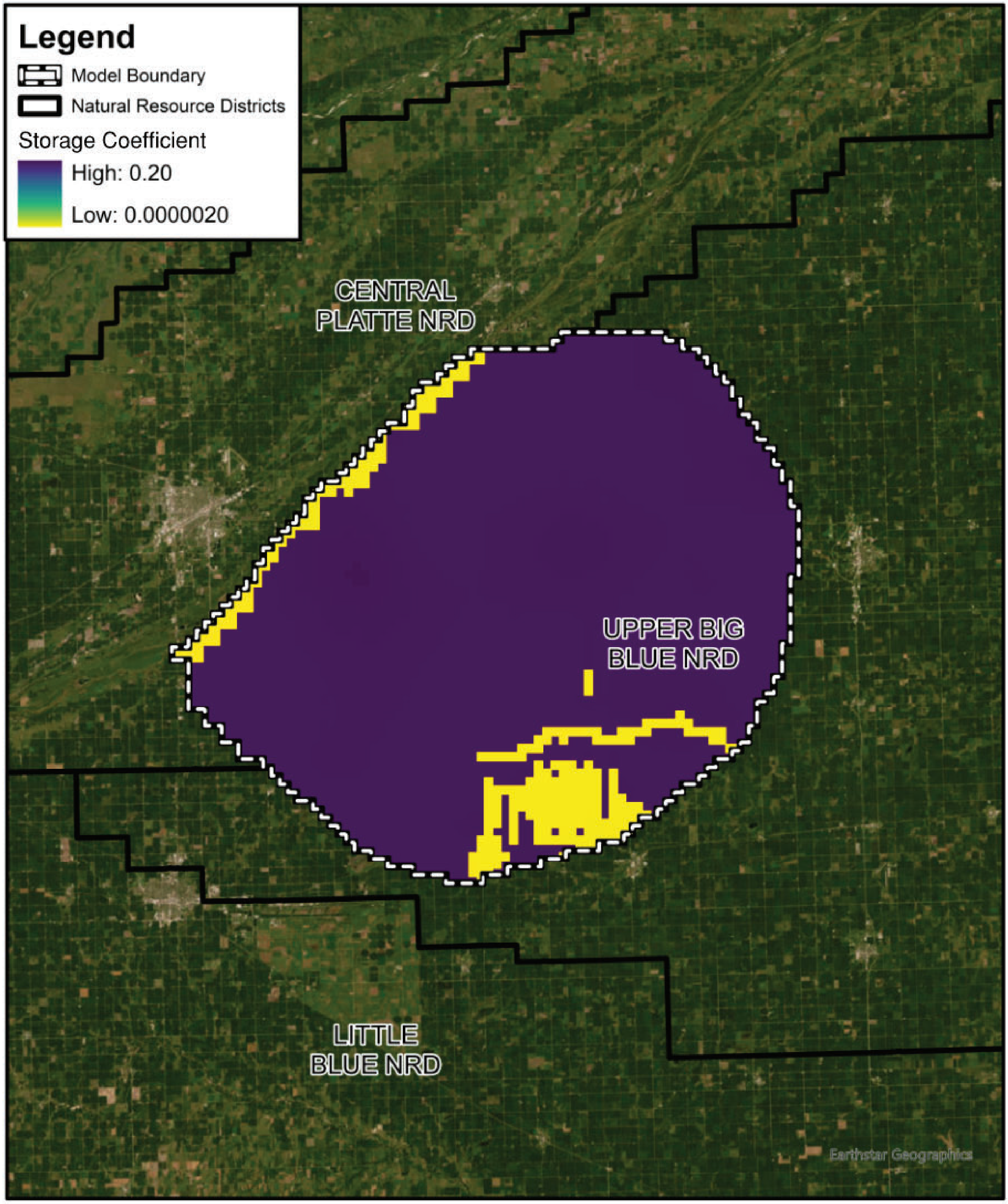
N

0 4 8 Miles
1 INCH = 8 MILES
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 1
STORAGE COEFFICIENT
LARGE WATER USER NEAR AURORA, NE

FIGURE 14

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023

olsson

N

0 4 8 Miles

1 INCH = 8 MILES

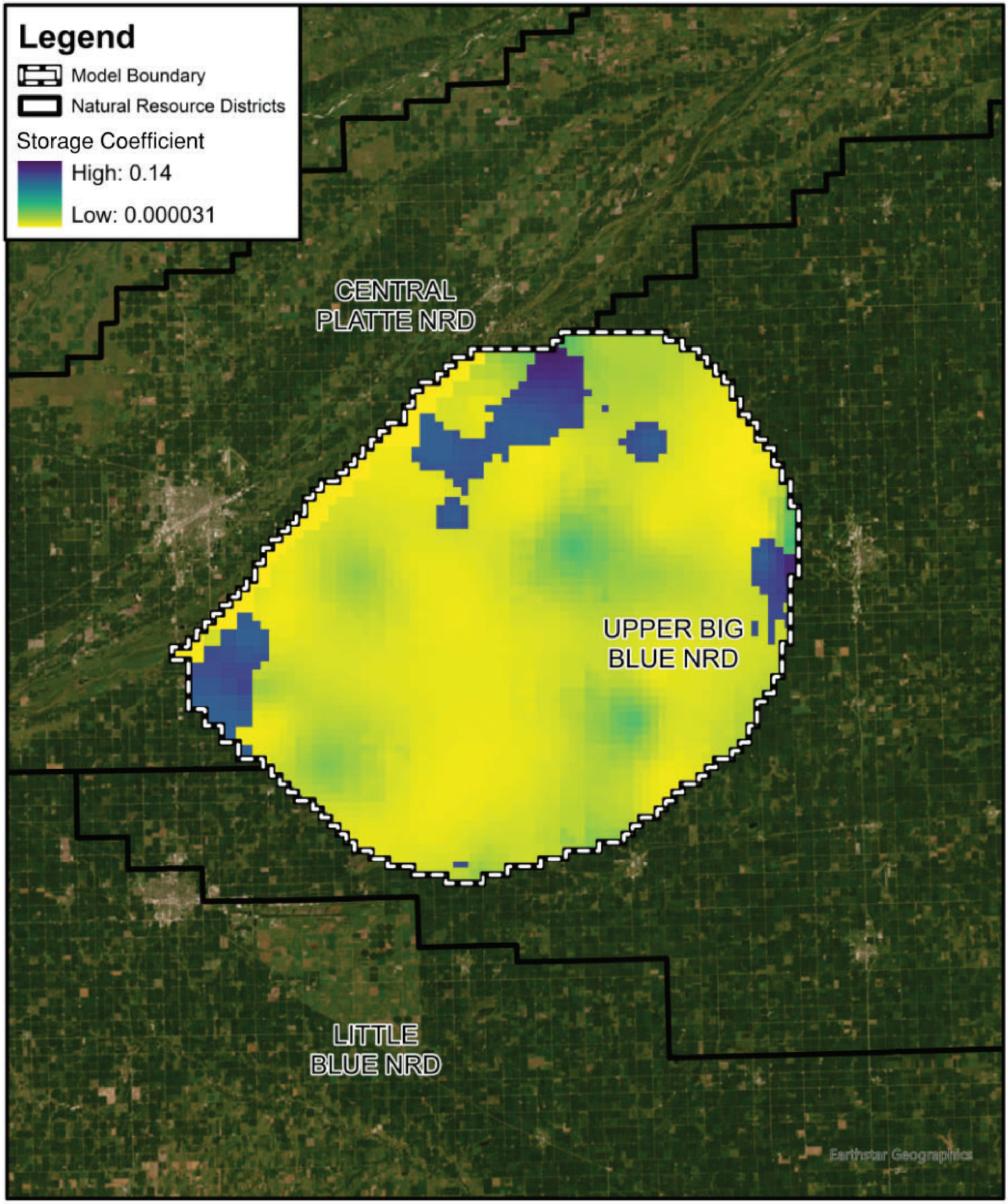
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 2
STORAGE COEFFICIENT

LARGE WATER USER NEAR AURORA, NE

FIGURE

15



N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

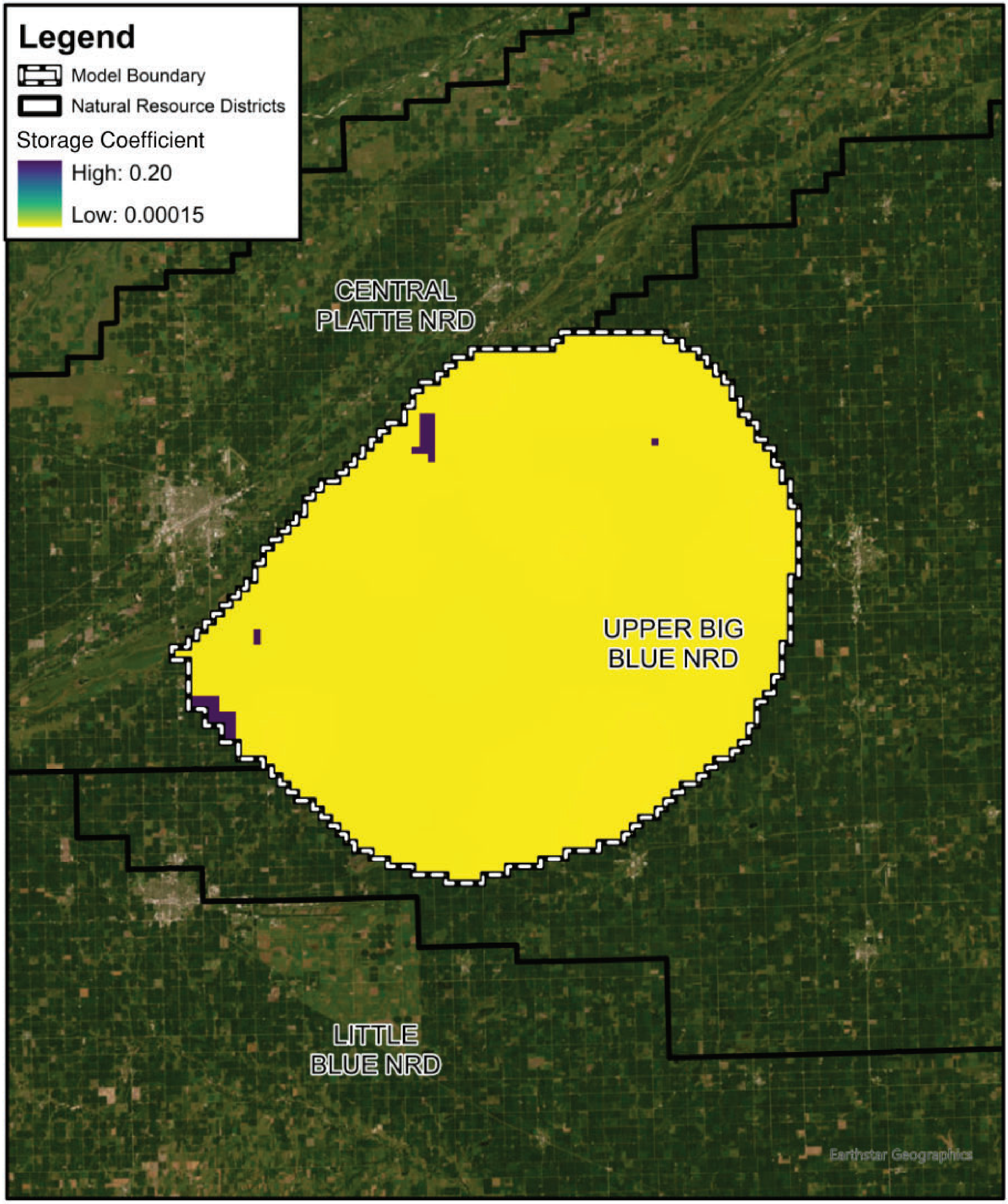
LAYER 3
STORAGE COEFFICIENT

LARGE WATER USER
NEAR AURORA, NE

FIGURE

16

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



olsson

N

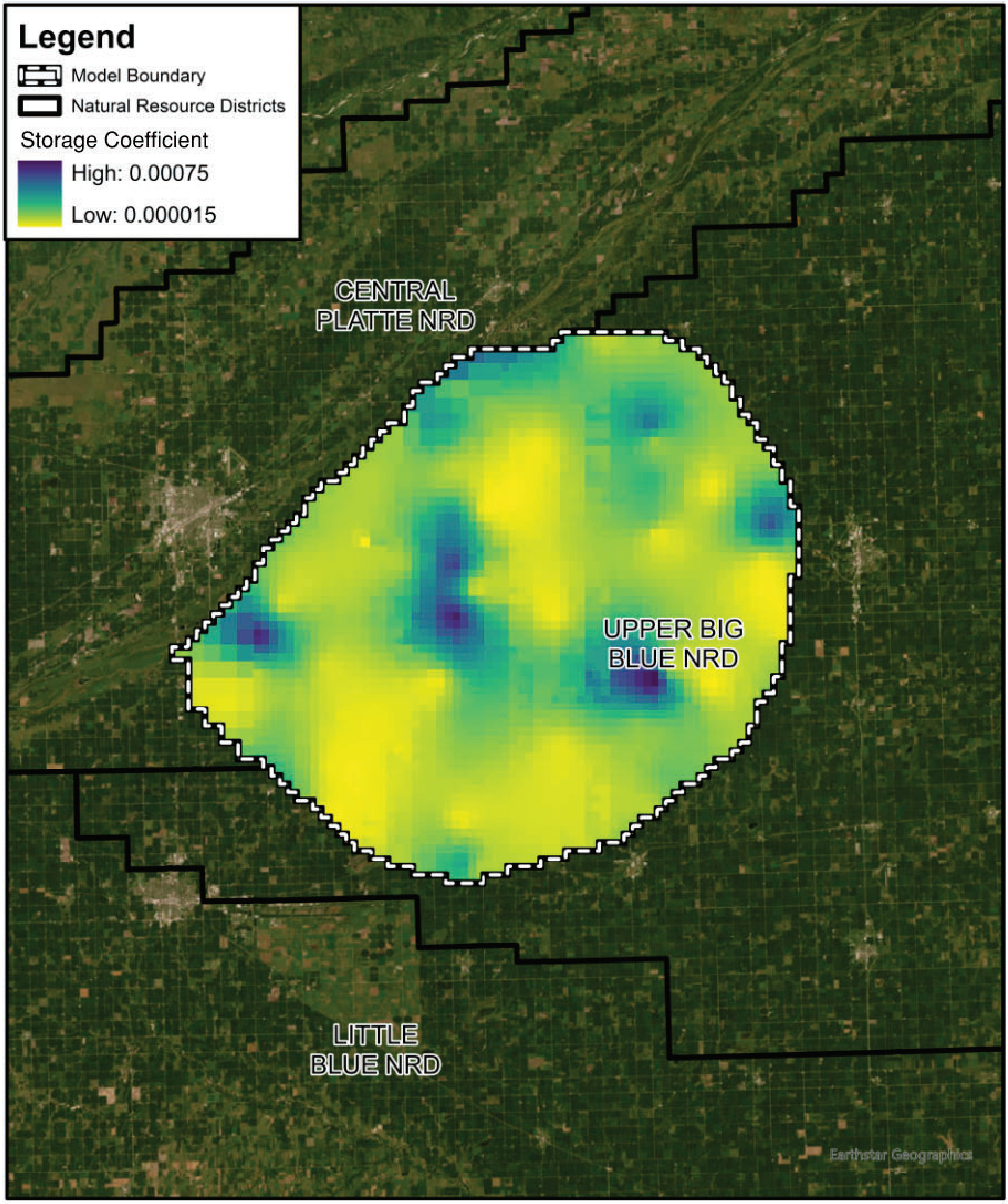
0 4 8 Miles
1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

LAYER 4
STORAGE COEFFICIENT
LARGE WATER USER
NEAR AURORA, NE

FIGURE
17

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



olsson

N

0 4 8 Miles

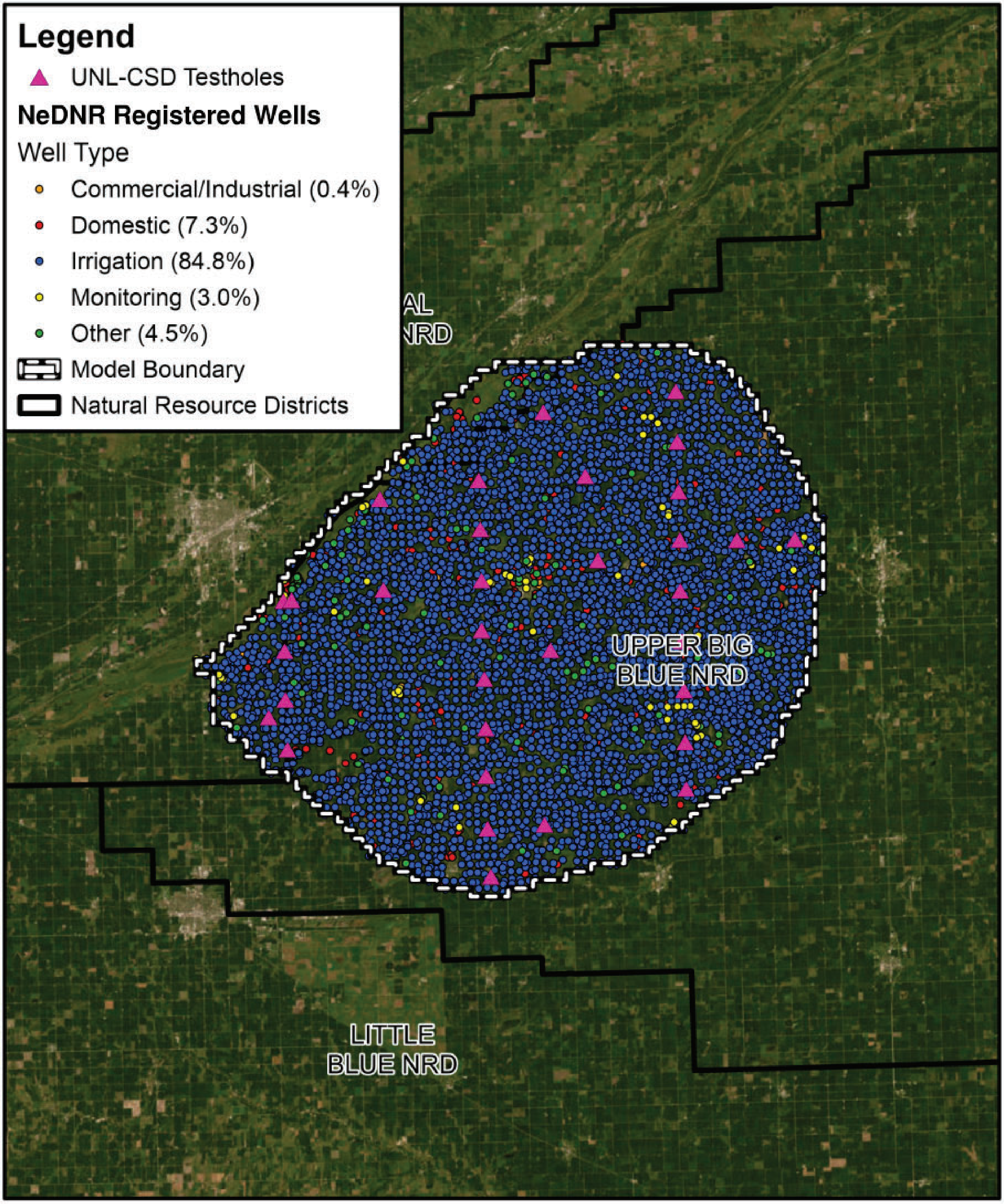
1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

LAYER 5
STORAGE COEFFICIENT
LARGE WATER USER
NEAR AURORA, NE

FIGURE
18

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 20, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 26, 2023

olsson

N

0 4 8 Miles

1 INCH = 8 MILES

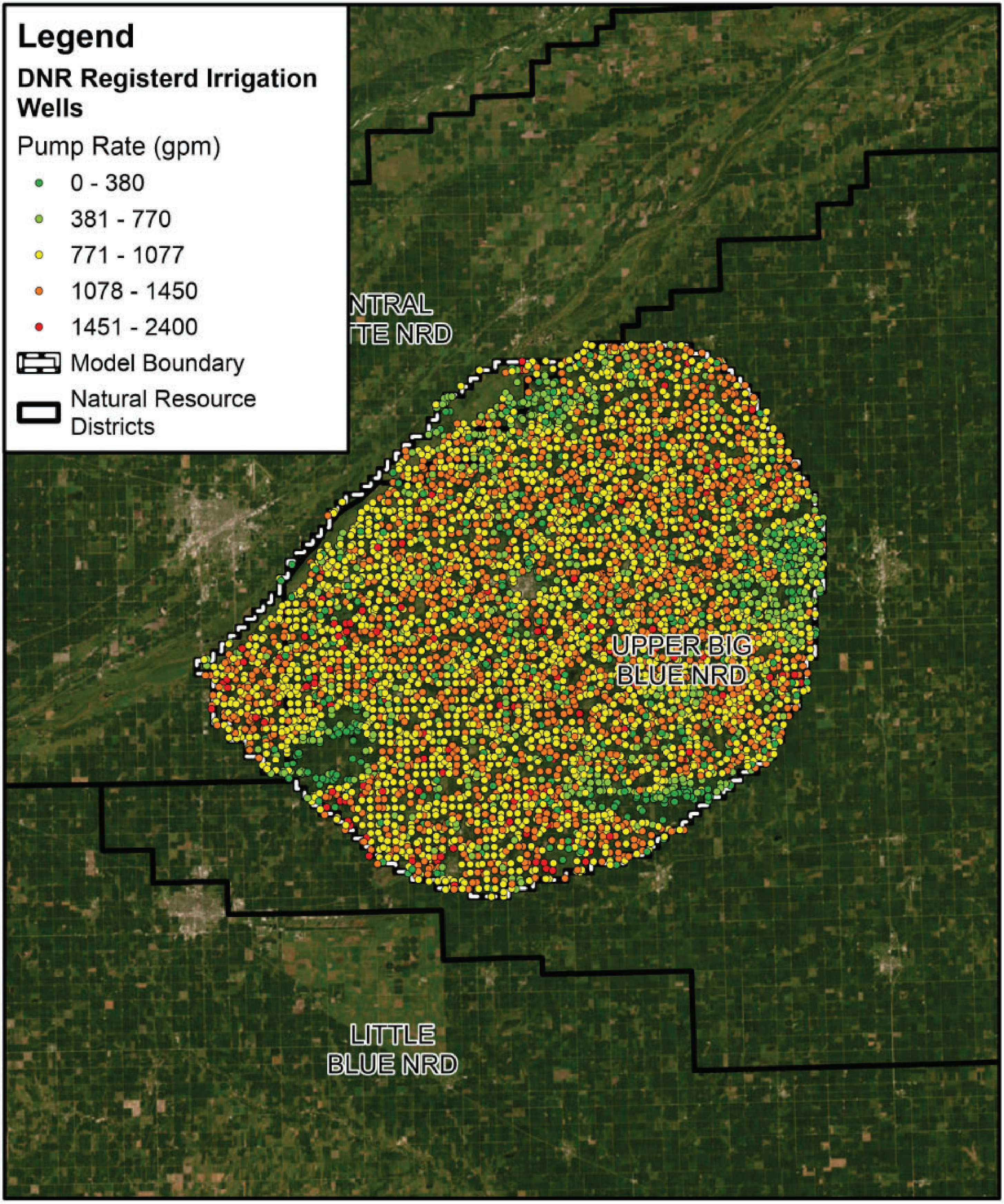
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

NeDNR REGISTERED WELLS AND UNL-CSD TESTHOLES

LARGE WATER USER NEAR AURORA, NE

FIGURE

19



N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane Nebraska FIPS 2600 Feet

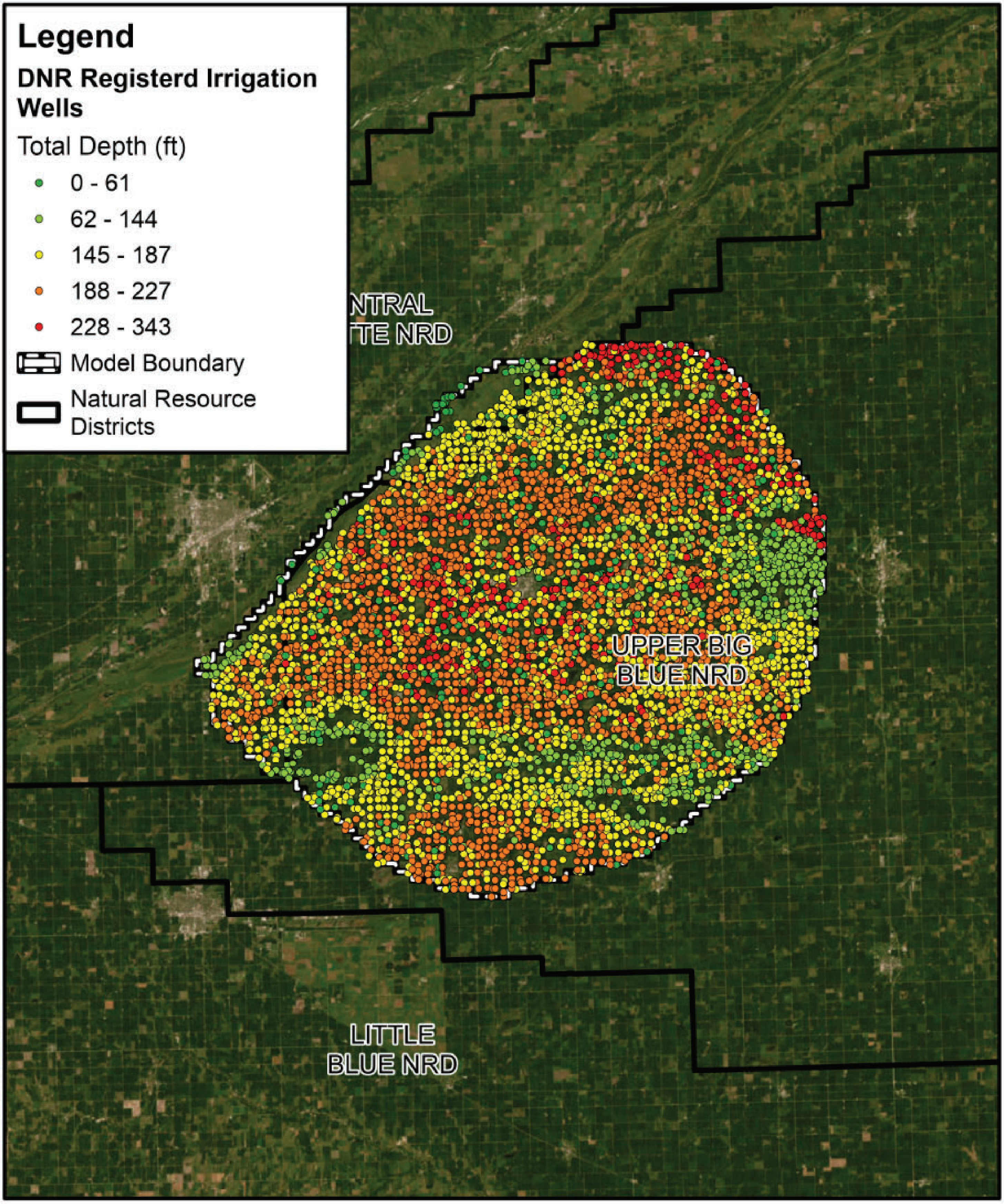
IRRIGATION WELLS WITH PUMPING RATE

LARGE WATER USER NEAR AURORA, NE

FIGURE

20

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 26, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 26, 2023

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N

0 4 8 Miles

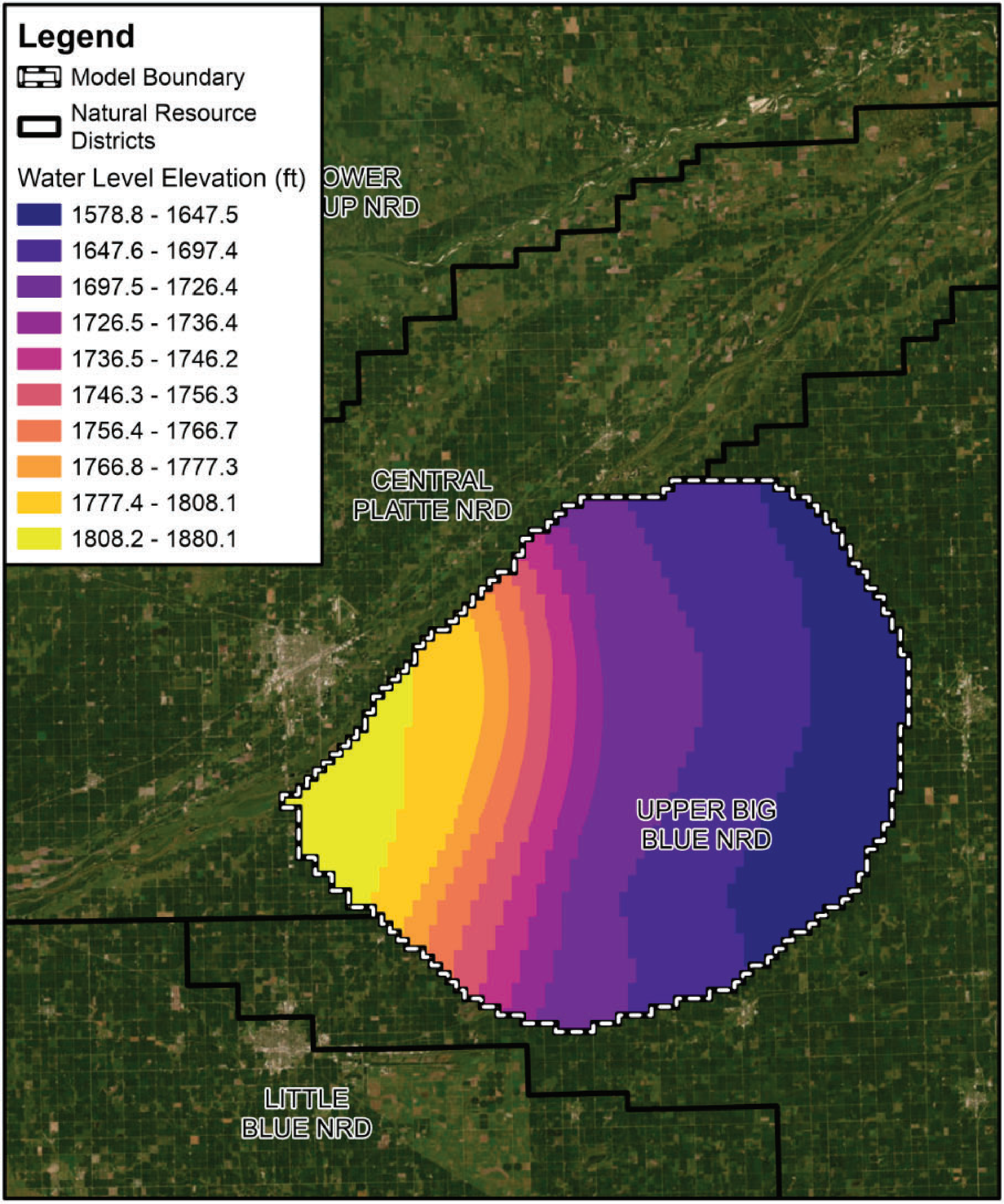
1 INCH = 8 MILES

NAD 1983 StatePlane Nebraska FIPS 2600 Feet

IRRIGATION WELLS WITH TOTAL DEPTH

LARGE WATER USER NEAR AURORA, NE

FIGURE 21



N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

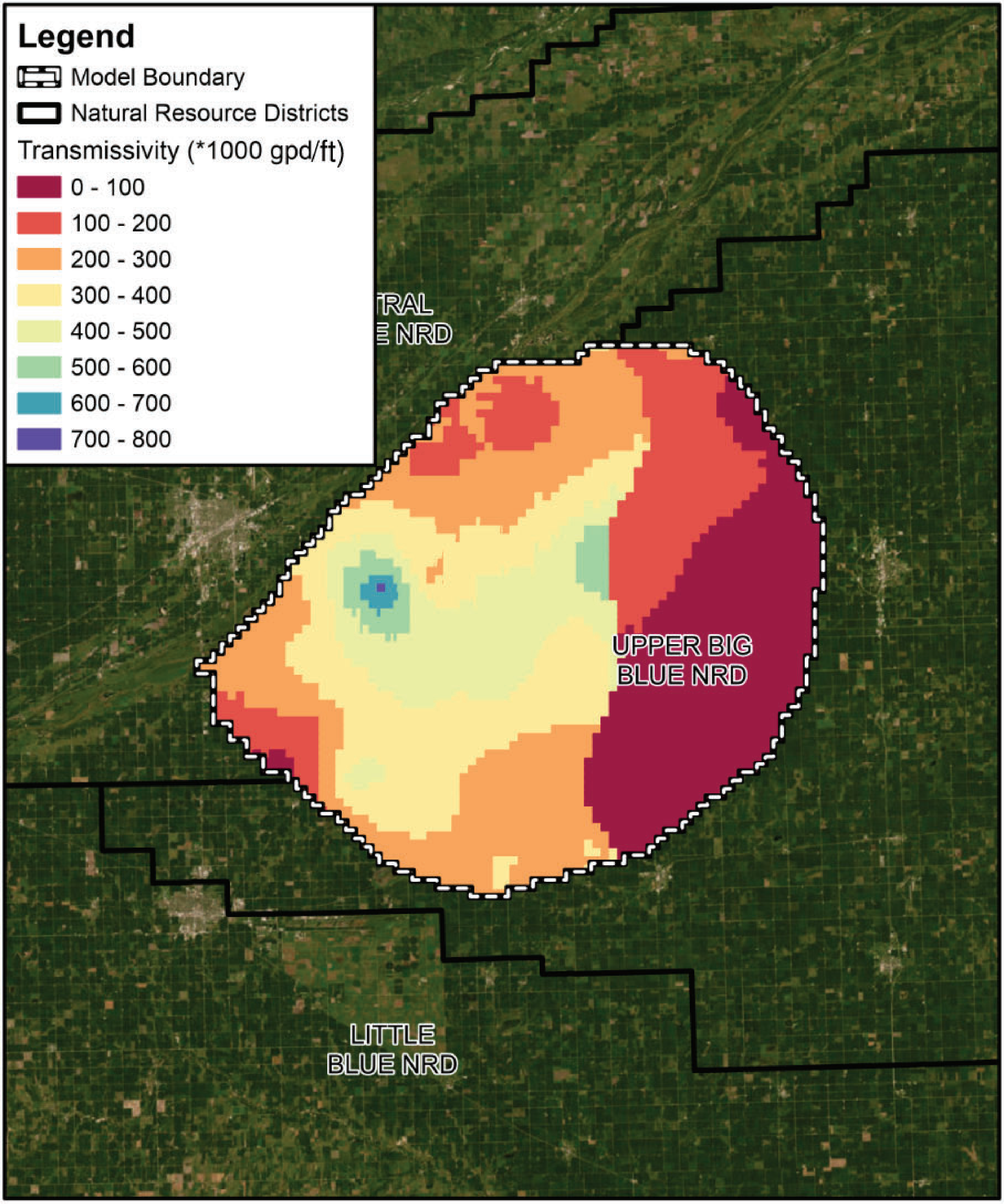
LAYER 4 WATER LEVEL ELEVATION - STEADY STATE

LARGE WATER USER
NEAR AURORA, NE

FIGURE

22

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 26, 2023



olsson

N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

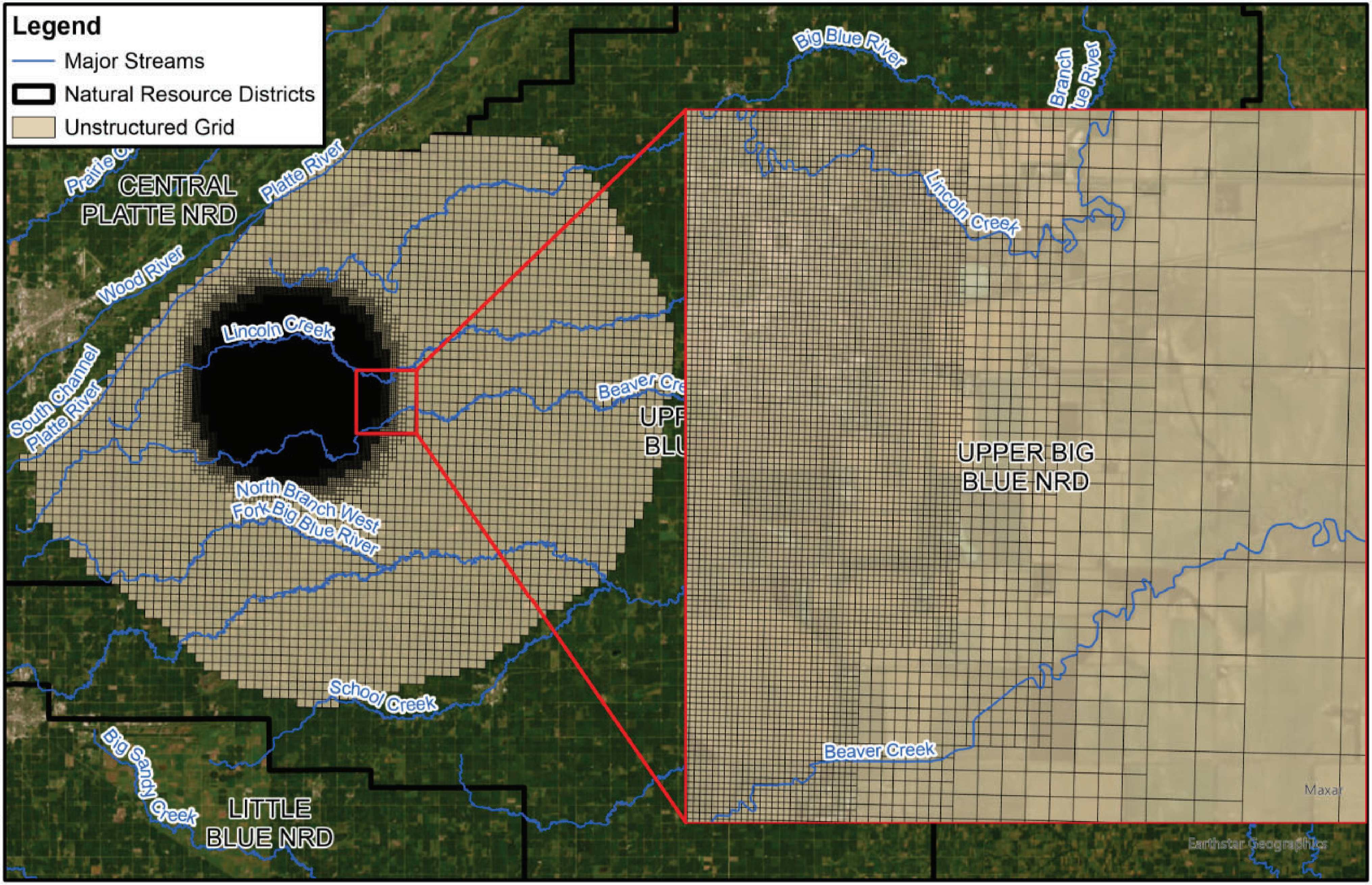
TRANSMISSIVITY OF PRINCIPAL AQUIFER

LARGE WATER USER
NEAR AURORA, NE

FIGURE

23

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 26, 2023



N

0 2.5 5 10

1 INCH = 10 MILES

Original Published Resolution
WGS 1984 Web Mercator Auxiliary Sphere
ESRI World Imagery

olsson

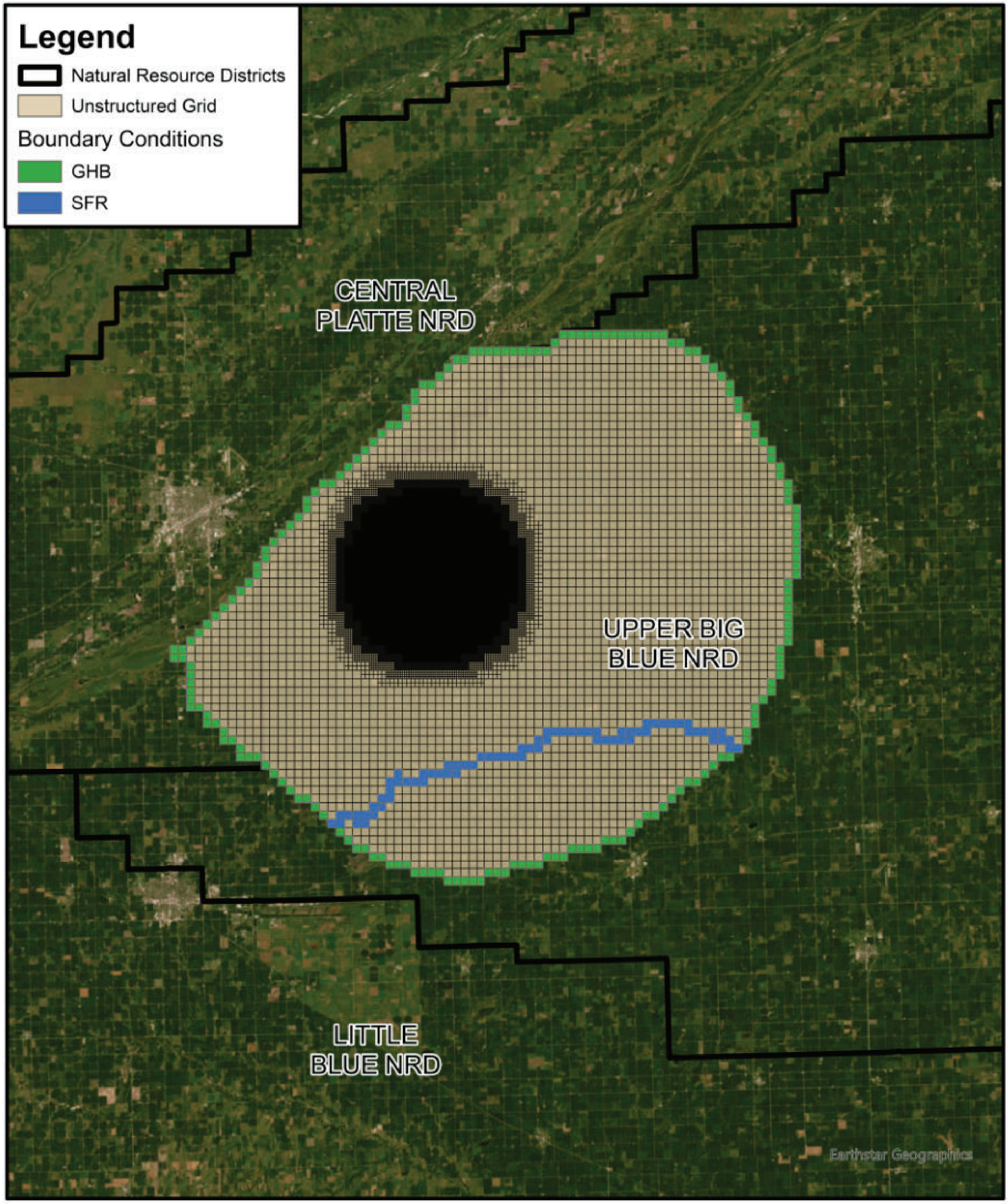
REFINED MODEL GRID

LARGE WATER USER
NEAR AURORA, NE

FIGURE

24

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: 9/7/2023



olsson

N

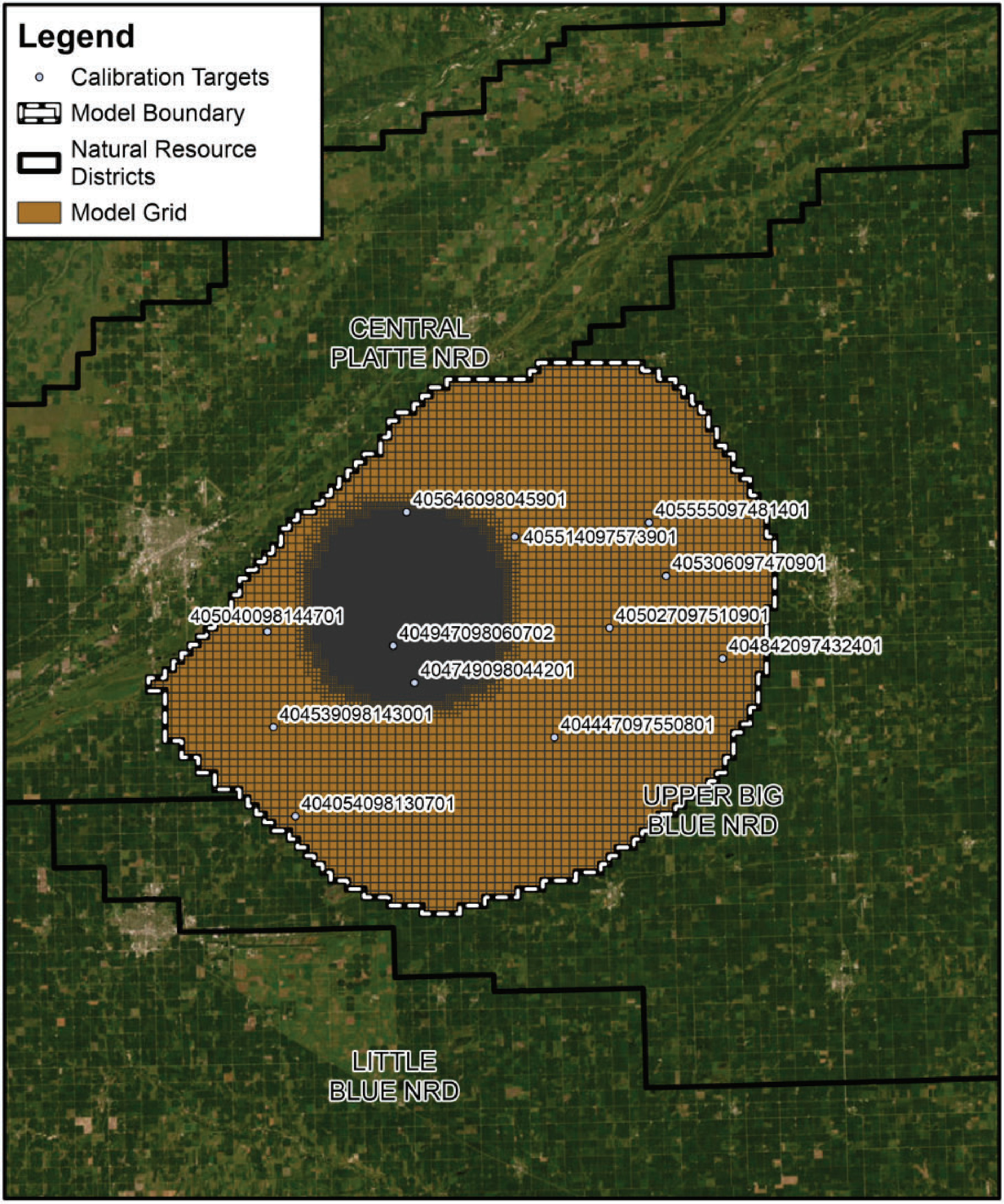
0 4 8 Miles
1 INCH = 8 MILES
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

BOUNDARY CONDITIONS

LARGE WATER USER NEAR AURORA, NE

FIGURE 25

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: September 14, 2023



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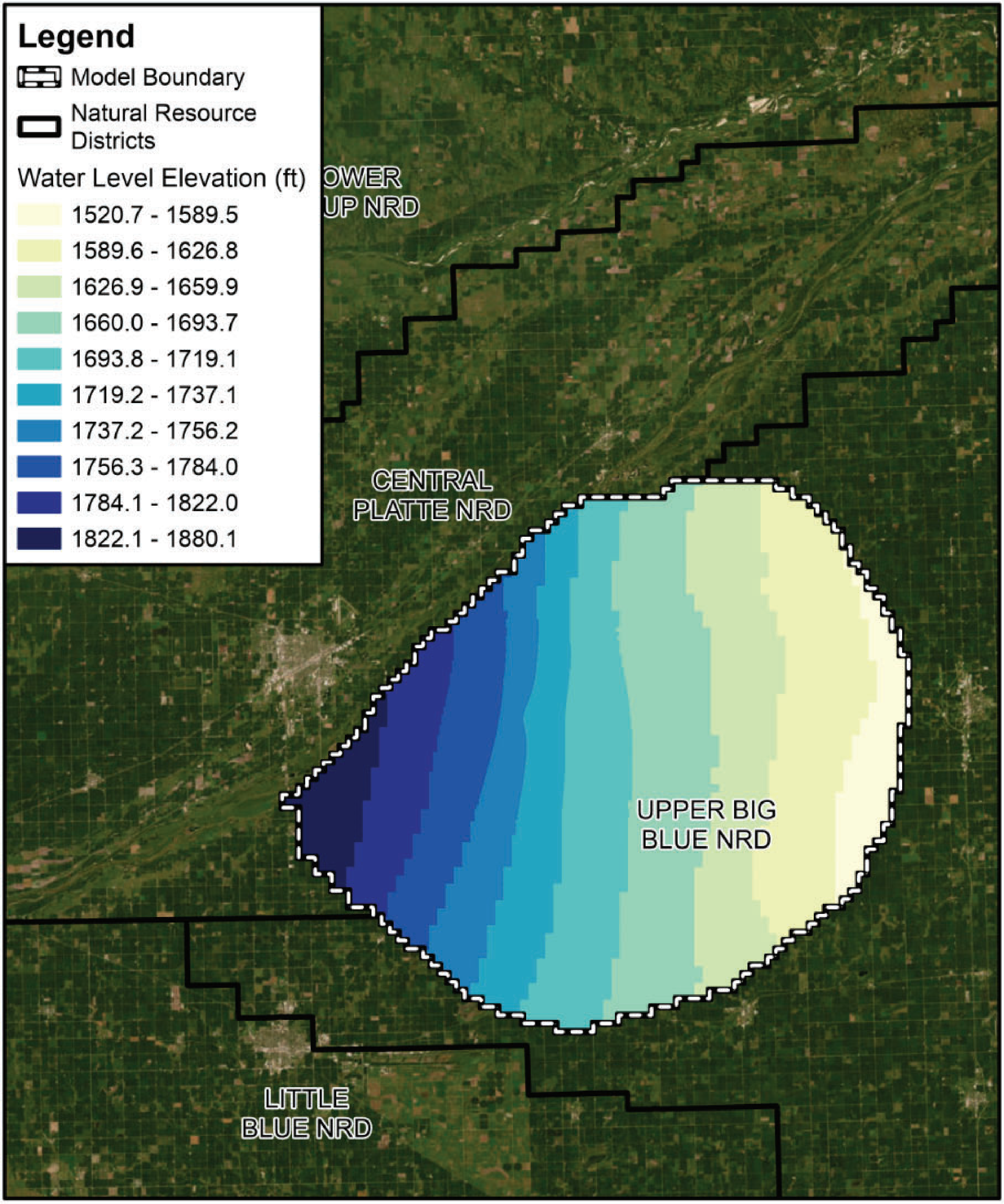
WATER LEVEL CALIBRATION TARGETS

LARGE WATER USER NEAR AURORA, NE

FIGURE 26

F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 28, 2023



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: tmarx DATE: September 26, 2023

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N

0 4 8 Miles

1 INCH = 8 MILES

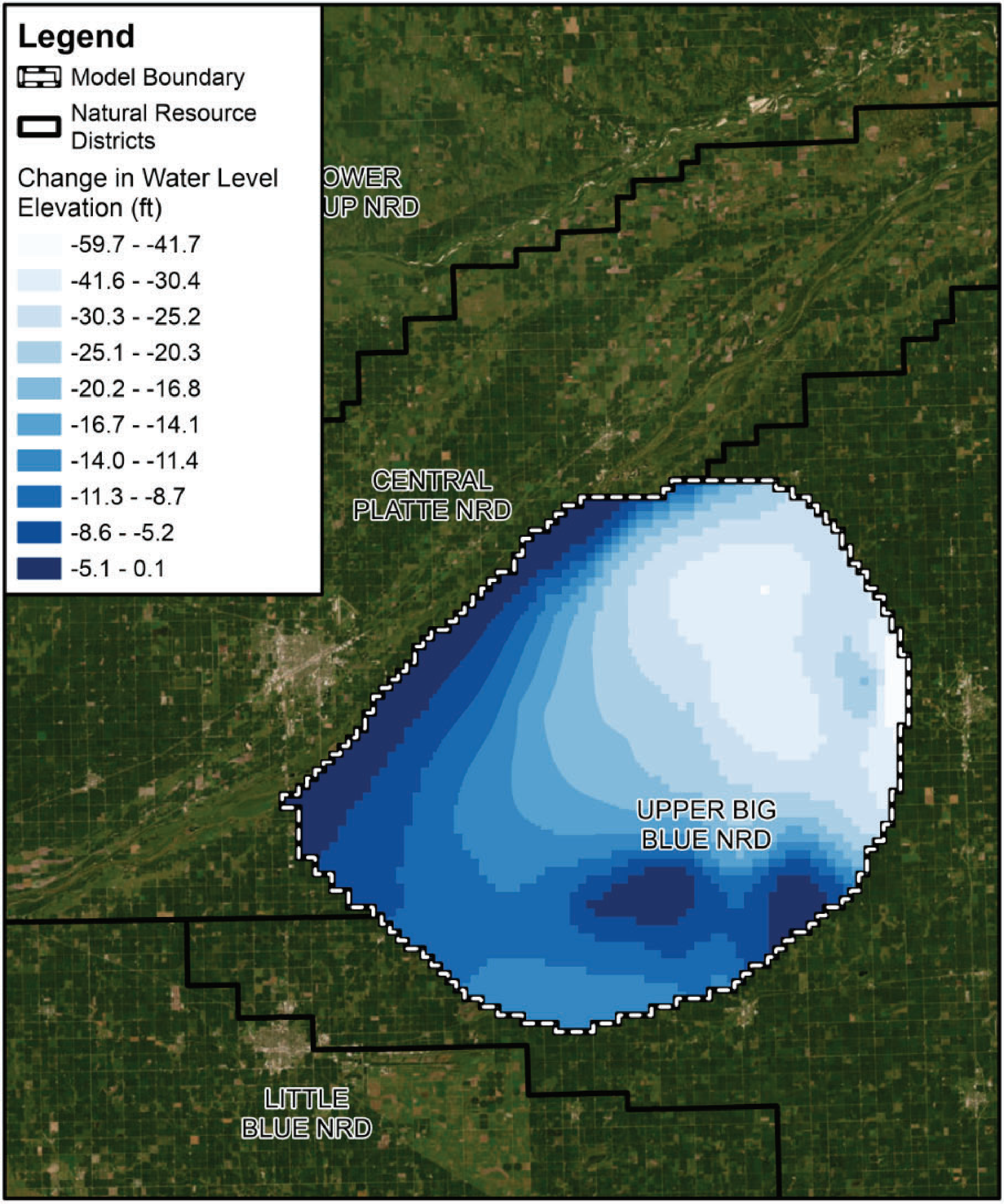
NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 4 WATER LEVEL ELEVATION - TRANSIENT

LARGE WATER USER NEAR AURORA, NE

FIGURE

27



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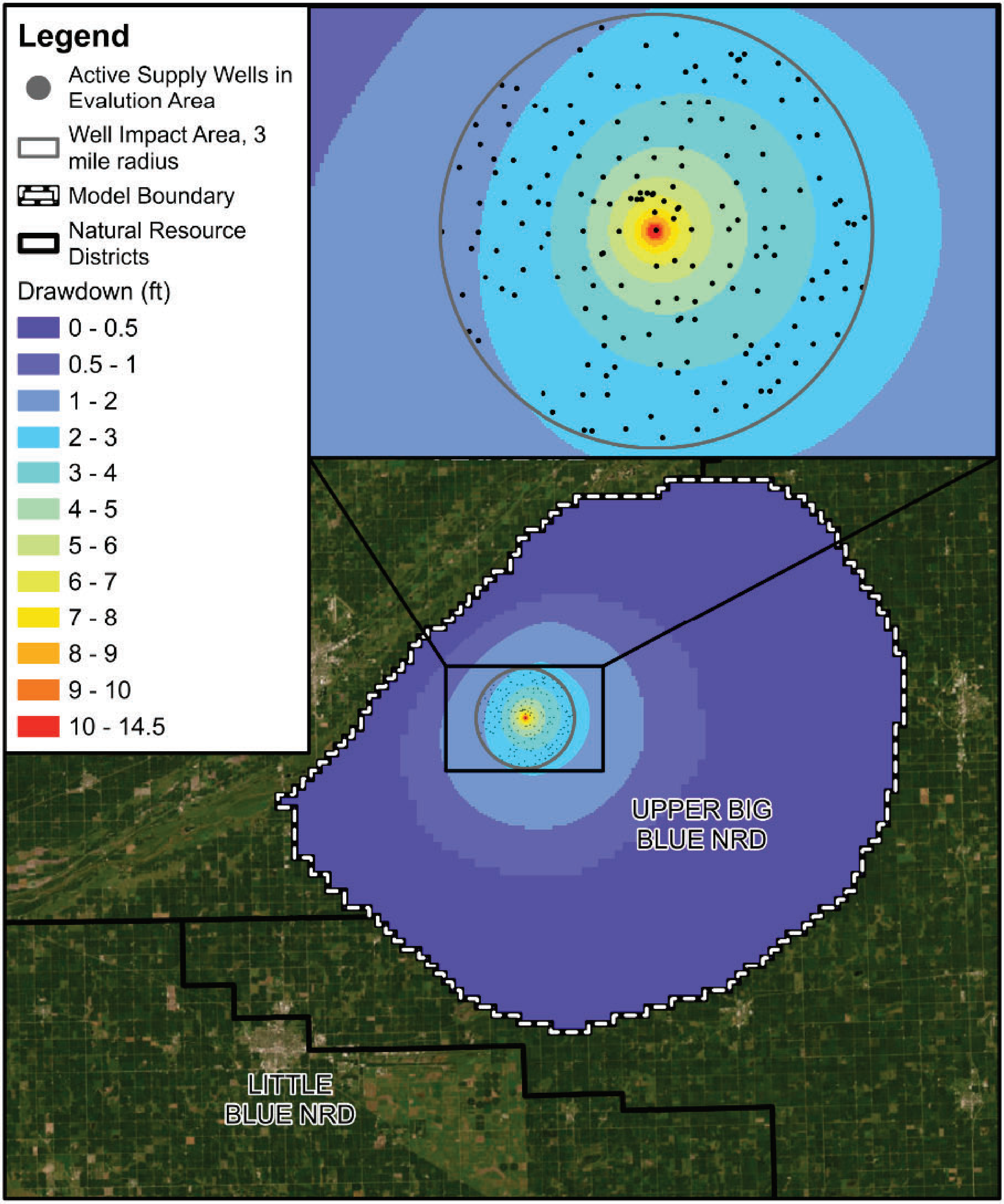
NAD 1983 StatePlane
Nebraska FIPS 2600 Feet

LAYER 4 CHANGE IN WATER LEVEL ELEVATION

LARGE WATER USER
NEAR AURORA, NE

FIGURE

28



F:\2023\04001-04500\023-04443\40-Design\GIS\Maps\NUBBY.aprx PUBLISHED BY: jhinnant DATE: October 16, 2023

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N

0 4 8 Miles

1 INCH = 8 MILES

NAD 1983 StatePlane Nebraska FIPS 2600 Feet

LAYER 4 DRAWDOWN

LARGE WATER USER NEAR AURORA, NE

FIGURE

29

SYNERGEN WELL PERMIT HYDROLOGIC EVALUATION

Lincoln, Nebraska - 2023

December 2023

Olsson Project No. 023-04443