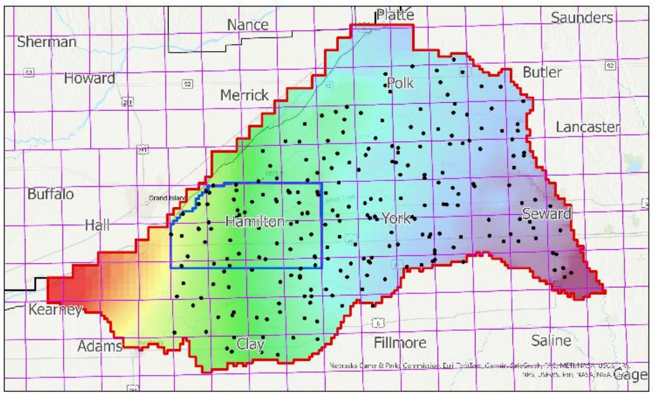

Hamilton County Groundwater Sustainability Study

Final Report

Upper Big Blue Natural Resources District, Nebraska

January 8, 2026

Executive Summary

The Upper Big Blue Natural Resources District of Nebraska (UBBNRD) in conjunction with the City of Aurora (Aurora) and Hamilton County organized a groundwater (GW) sustainability study in Hamilton County, focused on the area around Aurora. Groundwater serves as the primary source of water for domestic, municipal, commercial/industrial, and agricultural uses in the region. The UBBNRD is responsible for the management and protection of GW resources within its jurisdiction. In anticipation of potential future industrial and municipal growth, the UBBNRD, partnering with Aurora and Hamilton County, has contracted HDR, Inc. (HDR) to evaluate the sustainability of GW resources under various development scenarios.

A numerical GW flow model was created by subsetting the existing Blue River Basin Groundwater Model (BRBGWM) (GSI 2023) to a study area containing Hamilton County and surrounding areas. The local model grid was refined spatially in the areas surrounding Aurora to allow for more accurate simulation of water-table level (WTL) in the area of interest (AOI). Figure ES-1 shows the model extent of the BRBGWM, the revised model extent for this study (study area), and the AOI within Hamilton County. The GW model developed as the tool for this study is to be used by UBBNRD and their partners in future GW modeling efforts.

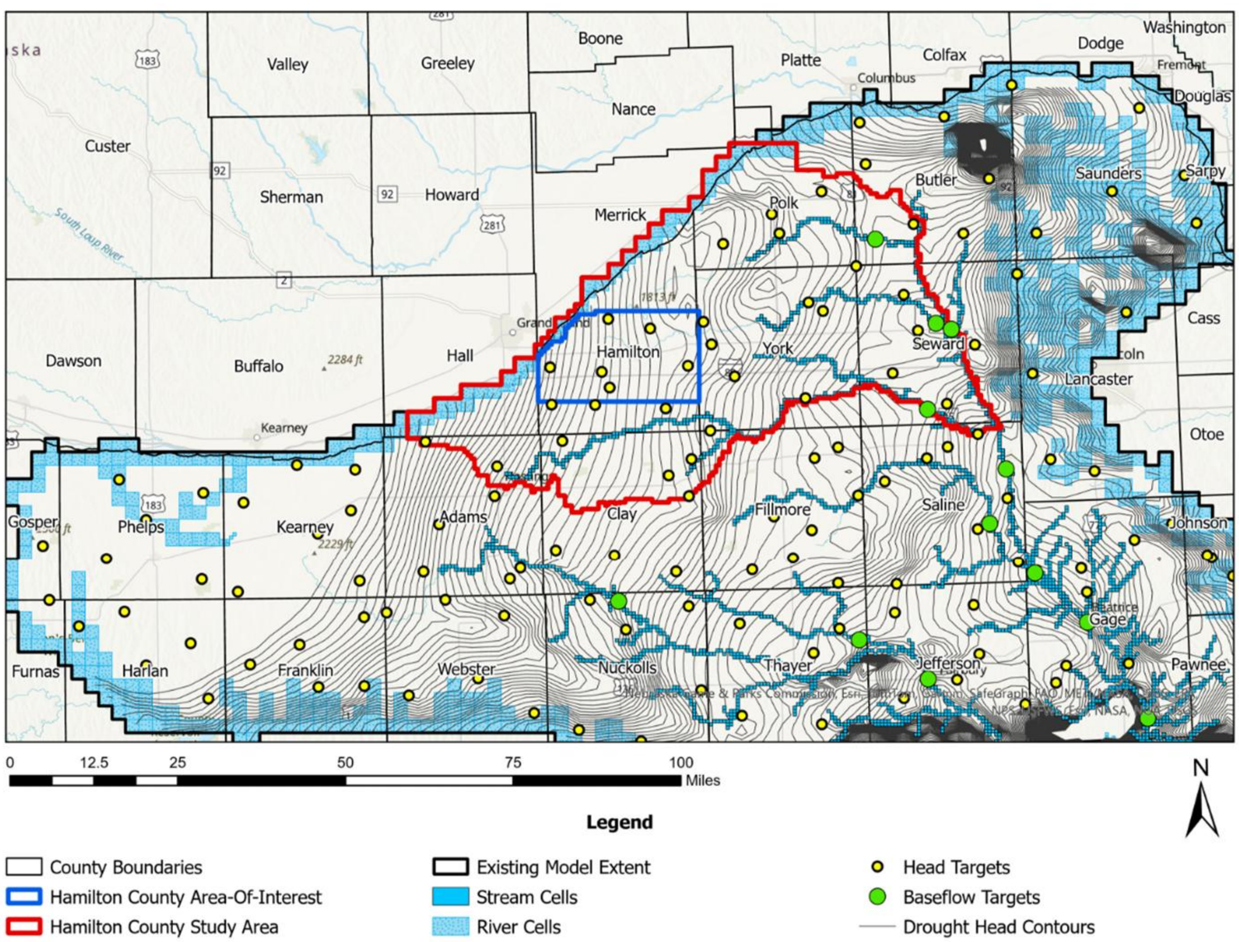

Figure ES-1. Location Map of Model Extents and Area of Interest

Scenario testing was performed to discern the maximum sustainable GW development (pumping) in the AOI. Maximum sustainable GW development was defined as the amount of water that could be pumped without bringing the spring (April) WTL, at any time during the projection period, below the modeled April 1978 WTL (at the model grid-cell scale). The spring 1978 WTL is designated by UBBNRD as the trigger GW level indicating the need for water conservation management actions (i.e., when GW levels decline to this level or below). The baseline model historical period is January 1940 through December 2024, and the modeled projection period is from January 2025 through December 2074.

Three GW development scenarios were conceptualized in the study: (1) maximum pumping in the Aurora area; (2) maximum pumping in the Aurora area with increased pumping in the surrounding townships; and (3) projected pumping at existing Aurora well locations with maximum development in the Aurora area and in the surrounding townships. Scenario 1 simulated Aurora's seven existing municipal wells and eight new wells for a total constant pumping rate of 2,476 gallons per minute (3,996 acre-feet per year). For reference, the City of Aurora pumped 719 gallons per minute (1,160 acre-feet per year) in 2024. Scenario 2 modeled the same fifteen wells in the Aurora area and seven new wells in the townships that surround Aurora at a combined constant pumping rate of 2,784 gallons per minute (4,490 acre-feet per year). Pumping rates increase annually in Scenario 3, so that the total pumping reaches 3,001 gallons per minute (4,841 acre-feet per year) in the last simulation year, 2074.

Multiple study wells in all GW development scenarios reached or fell below the modeled April 1978 WTL. However, GW levels did recover at all well locations during periods with relatively high recharge and/or low agricultural pumping. The total supply from wells simulated in this study is greater than Aurora's current municipal demands (1,160 acre-feet per year), and greater than the linear projection of their recent 20 years of growth, reaching 1,668 acre-feet per year in 2074. These model results suggest that there is available GW for sustainable development in the Aurora area and in the surrounding townships.

Preliminary assessments indicate that the southeastern portion of the AOI has greater GW availability compared to other areas, making it a favorable location for future additional development. For new wells, an average pumping rate of approximately 150 gallons per minute (242 acre-feet per year) is recommended as the maximum sustainable rate.

Groundwater nitrate concentrations indicate that the Aurora area and its surrounding townships have a mean of 7.1 parts per million and that they are in a Phase II Ground Water Quality Management Zone. The measurements of nitrate in GW indicate that nitrate pollution is present both upgradient and downgradient of study well locations. Additional nitrate measurements are recommended to be made to confirm values at any new well locations.

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1 Introduction

The Upper Big Blue Natural Resources District of Nebraska (UBBNRD) in conjunction with the City of Aurora (Aurora) and Hamilton County organized a groundwater (GW) sustainability study in Hamilton County, focused on Aurora and the immediate surrounding areas. The UBBNRD is responsible for the management and protection of GW resources within its jurisdiction. Groundwater serves as the primary source of water for domestic, municipal, industrial, and agricultural uses in the region, with agricultural irrigation representing the most significant demand. In anticipation of potential future industrial and municipal growth, and associated GW development, the UBBNRD, partnering with the City of Aurora and Hamilton County, has contracted HDR, Inc. (HDR) to evaluate the sustainability of GW resources under various GW development scenarios.

Aurora owns and operates seven municipal wells that produce approximately 1,000 acre-feet (330 million gallons) combined annually. The most recent 20 years of data (2005 through 2024) suggest that Aurora's municipal demand for water is increasing by approximately 10.5 acre-feet per year (ac-ft/yr) annually. Prior to recent growth, Aurora's annual water use was down in the late 2000s and early 2010s following its historical all-time high of 1,368 ac-ft in 2000. Recent years are approaching the historical high with Aurora using 1,160 ac-ft in 2024 and 1,256 ac-ft in 2023. Additionally, new industrial water users may require GW in the future. A single large industrial user could consume more water than the City of Aurora itself, depending on the scale of the project and the industry.

The goal of this study is to quantify the available GW for sustainable development, both for Aurora's municipal uses and for any new potential users in Hamilton County. UBBNRD rules stipulate that the total GW withdrawn should not cause static GW levels to fall below 1978 water-table levels (in the spring, prior to the irrigation season). These water levels were established as the "trigger" used in scenario testing to identify when simulated GW stresses (caused by additional hypothetical future pumping) are too great to be sustainable. The GW model developed as the tool for this study is to be used by UBBNRD and their partners in future GW modeling efforts.

UBBNRD proposed leveraging the existing Blue River Basin Groundwater Model (BRBGWM) as a foundational tool for the sustainability study. The BRBGWM was developed by GSI Environmental Inc. (GSI 2023). To enhance the model's applicability to the area of interest (AOI), the BRBGWM was reduced in size by subsetting it to a smaller, more manageable domain. Throughout this report, the existing BRBGWM is referred to as the "regional model," and the newly developed subset model is referred to as the "local model." Model grid resolution was increased in the AOI to improve accuracy of model outputs from the numerical model. The regional model was calibrated to groundwater system measurements during the historical 1940 through 2017 time period (GSI 2023), a period which was also simulated using the local model to compare calibration performance. The local model simulation period was then extended from January 2018 through 2024 with new municipal pumping data, and extended beyond that from 2025 through 2074, which constitutes the projection period. The purpose of the projection period is to allow for comparative analysis of multiple GW demand growth scenarios, aiming to inform the UBBNRD, Aurora, and Hamilton County with respect to future water resource planning and management.

The primary tasks conducted in the current modeling study are as follows:

1. Collection of hydrogeological and GW use data and review of recent GW modeling studies in the region, especially the BRBGWM development report (GSI 2023),
2. Construct GW model local to Hamilton County with refined resolution around Aurora and surrounding areas by subsetting the existing calibrated BRBGWM,
3. Extend the newly developed local model from 2018 through 2024 with new municipal pumping data, and then from 2025 through 2074 for scenario testing,
4. Develop GW development scenarios and perform model simulations to quantify the amount of available GW for new development,
5. Identify priority locations for new GW wells for both municipal and industrial wells, and
6. Discuss water quality considerations to be made for known existing nitrate pollution at priority locations for new GW development.

2 Conceptual Model

As described in the Introduction, the local model developed for UBBNRD and its partners as part of this study is a subset of the larger existing regional BRBGWM (GSI 2023). This section provides a brief summary of salient information, but the documentation of the BRBGWM (GSI 2023) should be referred to for more details. The BRBGWM and local model extents can be seen in Figure 1. The boundaries of the local model (study area) were determined by running the regional model and observing the resulting GW flow field. This analysis was done for the month with the lowest net recharge in modern times (after the year 2000) so that the boundaries would have the lowest impact on model performance when the simulated GW levels were under stress. November 2002 was the regional model stress period with the lowest recharge, so it served as the low-recharge period used to roughly identify groundwater divides when laying out the extent of the local model. The local model boundaries and low-recharge period water table contours can be seen in Figure 2.

2.1 Hydrogeologic Framework

The hydrogeology of the regional model is described in detail by GSI (2023) It is described as Pennsylvania-age to Tertiary-age bedrock and semi-consolidated materials overlain by Pliocene-age to Quaternary-age unconsolidated materials. Plains make up the vast majority of the study area's topographic description (Korus 2013). While not explicitly modeled, the soils in the study area are deep silty soils made up of the Hastings-Fillmore, Holder-Uly-Coly, and Hastings-Crete-Fillmore Associations (UNL-SNR n.d.) (GSI 2023). Bedrock in the study area is cretaceous age shale including predominantly the Niobrara and Carlile shales (Burchett 1986). The geologic units represented by the local model are described as alluvium gravelly sand and locally underlying lacustrine sand in the east and course-grained stratified Quaternary sediment in the west (Swinehart 1994) (Soller 2012). The break between the two primary geologic units follows a north-south line just inside of the AOI's eastern edge, meaning that the majority of the study area is alluvium gravelly sand and locally underlying lacustrine sand.

2.2 Groundwater Flow and Water Budget

The predominant hydrologic gradient trends from the west to east. This trend parallels the land surface elevation in the study area, show in Figure 3. The Platte River along the northwest boundary of the model is a source of recharge for the majority of its length. GW discharges to the West Fork in the south of the study area and into the North Fork of the Big Blue River in the east. The largest two fluxes of water over the study area are recharge and pumping from wells. Recharge is conceptualized as the net infiltration after surface process such as precipitation, runoff, and evapotranspiration have been accounted for. Agricultural pumping is wide-spread and makes up the majority of pumping within the study area, with cropland being the study area's majority land use type. Municipal and industrial pumping is much smaller in magnitude and isolated spatially.

3 Groundwater Model Development

3.1 Numerical Solver and Processing Software

MODFLOW 6, a 3D modular hydrologic model developed by the United States Geological Survey (USGS), was used to solve the GW flow equation, providing robust and stable simulation of unconfined GW flow. MODFLOW 6 is the sixth core version of MODFLOW released by the USGS (Hughes et al. 2017, Langevin et al. 2017). It uses a generalized control-volume finite-difference (CVFD) approach which provides the ability to use an unstructured model grid and can optionally utilize a Newton-Raphson formulation for complex water-table conditions. Both the regional model and the newly developed local model employ the Newton-Raphson functionality.

The MODFLOW suite of codes are the most widely used set of GW codes in the world and are the industry standard for a wide variety of site modeling applications with various purposes (Anderson et al. 2015). Groundwater model setup, simulations, and post-processing were conducted with Groundwater Vistas (version 9) (ESI 2024), with some pre-processing, post-processing and figure generation performed using Groundwater Modeling System (version 10.8) (Aquaveo 2025), Python (version 3.12.7) (Foundation 2016), FloPy (version 3.9.2) (Bakker 2016), and ArcGIS Pro (version 3.1.2) (Esri 2023). Groundwater Vistas writes MODFLOW input files that are compatible with standard USGS MODFLOW executables and directly reads the output files they produce.

3.2 Horizontal and Vertical Datums

The model coordinate system for the project is set up using the horizontal datum of the Nebraska State Plane, US Survey Feet, based on the North American Datum of 1983 (NAD83), and using the vertical datum of the North American Vertical Datum of 1988 (NAVD88).

3.3 Model Stress Periods

The local GW model was designed with monthly stress periods to reflect temporal changes in hydrologic conditions. Each stress period accounts for the actual number of days in each month, including adjustments for leap years, ensuring accurate representation of time-dependent processes. The simulation begins with a steady-state period for December 1939, which establishes initial conditions, followed by a transient simulation starting in January 1940. The transient period continues through the year 2017 for the historical baseline and comparison with the regional model. The model was extended from 2018 through 2024 to include new historical data for Aurora's municipal pumping; other variables had to be assumed for this extended historical period (see Section 3.8 and Section 5.1.2). A 50-year projection period follows extending from 2025 through 2074 for predictive scenario testing (see section 5.1.2—5.4).

3.4 Model Domain and Area of Interest

The local GW model domain covers the entire study area and is located entirely within the extents of the existing regional model domain (Figure 1). The boundaries of the study area were delineated based on review of the regional model head contours, model target locations, and simulated rivers and surface watershed boundaries. Head contours from the regional model reviewed were from November 2002, a period representing extreme drought conditions with minimal recharge (Figure 2). This selection was made to ensure that the model domain captures the full extent of aquifer stress during low-recharge conditions, which is critical for the intended modeling applications. Head contours were used to align the model boundaries with existing GW divides surface watershed boundaries, except where the boundaries align with rivers. The study area was extended well beyond the immediate AOI to provide adequate buffer space around simulated river, which are dynamic in terms of headwater extents, so they require additional spatial coverage. This extended domain also allows for the inclusion of a greater number of head targets, facilitating comparison with residuals from the regional model.

The total area of the local model domain is approximately 2,418 square miles. It is bounded to the northwest by the Platte River, to the east by the Big Blue River, and to the south by the surface water and groundwater divides of the West Fork of the Big Blue River. The AOI is a focused region within Hamilton County, spanning approximately 300 square miles. It extends from roughly six miles north of Highway 34 to four miles south of Interstate 80 and is bounded to the east and west by the Hamilton County boundaries. The AOI encompasses approximately eight townships and is intended for refined modeling efforts.

3.5 Model Grid and Layers

With finite difference, including CVFD methods, the model domain is divided into discrete grid cells within which the groundwater heads and fluxes are calculated. Similar to the regional model, the local model domain was divided into square grid cells with cell sizes that vary across the domain to accommodate different levels of detail using quadtree refinement (

Figure 4). Horizontal resolution varies across the model domain, ranging from 2-mile cells (2,560 acres) in less critical areas, to 1/4-mile cells (40 acres) within the AOI, allowing for increased spatial detail where needed for refined analysis. The areal dimensions of the grid cells were reduced from 160 acres to 40 acres within the AOI from the regional model (GSI 2023) to the local model. The expansion of grid cell dimensions outside of the AOI allows the perimeter boundaries of the model to be hydrologic boundaries primarily (e.g., the Platte River and Big Blue River), rather than artificial boundaries while still providing computational efficiency overall.

To maintain numerical stability and ensure representation of thin geologic units, a minimum layer thickness of one foot was applied throughout the domain. The local model consists of five layers, each varying in thickness to reflect subsurface heterogeneity. Model layer thicknesses are shown in Figure 5 through Figure 9. The model contains a total of 60,560 cells, distributed prismatically across the five layers, with 12,112 cells per layer. GSI (2023) describes the five model layers in the following way:

- *Layer 1: Upper Quaternary age silt and clay loess, with some sand and gravel at locations.*
- *Layer 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.*
- *Layer 3: Lower Quaternary age fine silt and clay layer, with some sand and gravel, that confines or partially confines Layer 4.*
- *Layer 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.*
- *Layer 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.*

3.6 Boundary Conditions

The local model incorporates a range of hydrologic features and stress inputs to simulate GW conditions, with the local model retaining many of the same boundary conditions as the regional model (refer to GSI [2023] Section 3.4 and Section 3.5 for detailed descriptions of boundary conditions and their setup). Regional model boundary conditions were applied in the local model where they overlapped with the local model's extent.

Local model boundary conditions are shown in Figure 2. A river boundary condition representing the Platte River bounds the model to the Northwest. The eastern and southeastern boundaries of the local model are defined by the Big Blue River and West Fork Big Blue River respectively and are represented as stream cells (the SFR package in MODLFOW). The southwestern border of the model is represented with a constant flow boundary with a specified flow of zero (a no-flow boundary). This was done because the boundary was delineated along a groundwater divide as described in 3.4. The same was done for the northeastern boundary, which spans the distance between the Platte River and the Big Blue River through Polk and Butler Counties. The bottom of the model was also modeled as a no-flow boundary. It should be noted that the local model and the regional model are two independent models and do not exchange information during simulation.

Within the local model, a total of 138 River (RIV) Package boundary cells represent the Platte River, while an additional 685 Stream (SFR) Package boundary cells are used to represent other streams internal and along the perimeter boundaries of the domain. The RIV Package represents a head-dependent boundary condition in which the surface-water feature stage and conductance term are used to calculate exchange flows between the surface-water feature and underlying groundwater in each model cell, but the stage is specified and simulated streamflow is not tracked. In contrast, the SFR Package, while also being a head-dependent boundary condition, differs from the RIV Package in that it provides the capability of tracking and accounting model-simulated (and model input) streamflow (Langevin et al. 2017). In addition, the SFR Package allows for losing portions of streams to dynamically have stages and infiltration fluxes lowered all the way to zero, allowing for realistic dynamics of the migration of extents of the flowing portion of headwater streams to be efficiently captured. Flow-depths for the SFR Package boundaries were treated as specified inputs, rather than being allowed to be calculated internally during simulations, as was the case for the regional model. This is because testing of the option to have the SFR Package calculate streamflow depths, with the regional model, resulted in no discernable improvements in model calibration and required additional execution time (GSI 2023).

The conductance term, applied to both the RIV and SFR Packages, depends on the area of the connection between the surface-water feature and the aquifer (e.g., length and width of a streambed) and the resistance to flow between the feature and the aquifer which depends on the permeability and thickness of the streambed. Note that use of head-dependent boundary conditions, such as the RIV and SFR Packages, is preferred over the use of specified-head boundary conditions because head-dependent boundary conditions provide a limit on flow between the aquifer and the boundary though the conductance term, whereas a specified-head boundary condition presents a potentially infinite source or sink of water (Anderson et al. 2015).

The model includes wells through the Well (WEL) Package, with the number of wells varying by scenario—some simulations include approximately 11,800 wells. Aurora’s groundwater use was modeled by pumping in existing well locations and in hypothetical new locations with those new locations selected based on proximity to Aurora, projected growth trends, and zoning considerations. Of the existing well locations, five wells are inherited from the regional model, which simulates through 2017, and two additional wells were added in the local model at the time of their construction between 2017 and the time of writing (2025). New historical pumping data was added for years 2018 through 2024, and scenario assumptions were made for the projection period from 2025 through 2074.

Groundwater recharge is applied across all 12,112 model cells at every time step, representing net recharge to the aquifer. Net recharge rates are applied meaning that precipitation and evapotranspiration are not simulated independently. Recharge rates were obtained from the regional model and applied over the historical period from 1940 through 2017. See sections 3.8 and 5.1.2 for recharge assumptions during the updated historical period from 2018 through 2024 and the projection period from 2025 through 2074.

3.7 Hydraulic Properties

Hydraulic properties in the local model were obtained from the regional model. The regional model was calibrated to historical groundwater levels and baseflow data, through adjustments made to lateral hydraulic conductivity, the ratio of lateral to vertical hydraulic conductivity, streambed leakance, and recharge rates in the initial steady-state stress period, using PEST (GSI 2023). Hydraulic Properties were not modified during or after the development of the local model (this study). Lateral hydraulic conductivity in each model layer is shown in Figure 10 through Figure 14. Vertical hydraulic conductivity in each model layer is shown in Figure 15 through Figure 19.

The storage coefficient, as provided by the reginal model, was applied as a single term representing values for specific yield in upper layers and specific storage (multiplied by depth to be unitless storativity) in lower layers (Figure 20 through Figure 24). The model itself does not include any layers explicitly treated like confined units, instead, vertical flow was restricted by assigning relatively low lateral or vertical hydraulic conductivity or low storage coefficients to some areas/layers of the model. Refer to GIS (2023) for more details.

3.8 Stresses (Recharge and Well Withdrawal)

The local model uses monthly stress periods, which account for the varying number of days in each month, including leap years. It begins with a steady-state simulation with stresses from December 1939, followed by a transient simulation starting in January 1940 with initial heads from the steady-state simulation. The regional and baseline local model simulate through 2017. The local model was later extended through 2074 using projection assumptions for forcing data. No new recharge or agricultural pumping data is added to the historical period from 2018 through 2024—instead it is modeled with historical data as is done in the projection period from 2025 through 2074. Average annual recharge during the historical period of simulation (1940–2017) can be seen in Figure 25 and average annual recharge during the historical period from 2018–2024 and the projection period from 2025–2074 can be seen in Figure 26. GW pumping in the study area over the same two averaging periods can be seen in Figure 27 and Figure 28.

4 Model Calibration

4.1 Calibration Approach

While no formal calibration was conducted for this study with the local model, the model was developed by replicating the previously calibrated regional model (GSI 2023), and the performance between the two models was compared within the limits of the study area for the local model. The regional model was calibrated to historical data, including hydraulic head measurements, changes in head over time, estimated (separated) stream baseflow from daily streamflow at gauging locations, and reach baseflow gains/losses, using PEST (GSI 2023). Any changes in model calibration performance are the result of the change in model extents (from regional to the local model) and necessary adjustments to perimeter boundary conditions, as described in Section 3.6.

4.2 Calibration Performance

The ability of the local model to match observed hydraulic heads was compared with that from the regional model (at the original regional model head targets) to check whether or not the local model was performing as expected. The comparison of hydraulic head calibration statistics, based on 32 head target locations with a combined 2,817 head measurements (for head target locations see Figure 2), within the study area are shown in Table 1 and Figure 29. The R-squared value for the local model is 0.993, indicating a strong fit, which compares closely the R-squared value of 0.996 for the regional model calibration. The local model performs better within the AOI than in areas outside of it. Additionally, the local model appears to better capture the signal in hydrographs for wells located in the AOI (see Figure 30 through Figure 35). The observed differences are attributed to the absence of underflow at the perimeter model boundaries (no-flows where the boundaries do not follow rivers), the cause of mostly lower simulated heads with the local model than with the regional model (conservatively underpredicting heads). This, along with the increased spatial resolution (finer resolution grid cells) in the AOI, are likely the causes of WTLs being more responsive (more variability) to local recharge and pumping.

Table 1. Calibration Performance of the Regional and Local Models at Head Targets Within the Study Area

Statistic	Regional Model	Local Model
Number of Observations	2,817	2,817
Residual Mean	1.06	0.98
Absolute Residual Mean	6.3	7.9
Residual Std. Deviation	8.2	10.4
Sum of Squares	191,882	309,540
Root Mean Squared Error	8.3	10.5
Min. Residual	-23	-28
Max. Residual	28	60
Range in Observations	548	548
Scaled Residual Std. Deviation	1.5%	1.9%
Scaled Root Mean Squared Error	1.5%	1.9%

4.3 Calibrated Model Water Budget

The model gains storage early in simulation, then loses a large amount of storage between the early 1950s and early 1980s before it recovers slightly and reaches what appears to be a quasi-equilibrium from the 1980s until the end of the historic (regional model calibration) period (2017). See Figure 36 for the water budget by year and net change in storage over the study area. The historic period simulation ends with less water in storage, in 2017, than was present at the beginning, in 1940. However, this change in storage does not reflect a large change in the WTL and is likely representative of actual trends in the study area. Agricultural pumping increases during the first 30 to 40 years before approximately leveling out, which matches the timing of the trend in modeled GW storage.

The local model's baseline water budget receives roughly 86% of its inflow from recharge (from precipitation and excess irrigation infiltration) and 14% from the infiltration from the Platte River. Agricultural pumping accounts for 88% of the net outflow. Municipal and industrial pumping make up a combined 3% of outflow. Finally, the stream boundaries in the model, which represent the Big Blue River and a number of its tributaries, account for 9% of outflow from the GW system. The total net change in storage over the 78-year calibration period simulation (from 1940–2017) is just under 1.2 million ac-ft for the entire the 1.6-million-acre study area. This represents an average net decrease in storage of just over 15,000 ac-ft/yr; although, it should be noted that the trend is far from linear through time.

The summary-level modeled GW flows, averaged spatially over the entire study area and temporally from 1940 through 2017, are as follows:

- Net Recharge Inflow: +379,915 (ac-ft/yr)
- Net River Inflow: +61,694 (ac-ft/yr)
- Net Stream Outflow: -42,502 (ac-ft/yr)
- Agricultural Pumping Outflow: -400,928 (ac-ft/yr)
- Municipal and Industrial Pumping Outflow: -13,341 (ac-ft/yr)

As referenced above, the resulting average net change in the aquifer's storage is then -15,163 ac-ft/yr, which corresponds to roughly -0.01 ft/yr or -0.12 in/yr over the study area in terms of depth of water (these values are slightly smaller when compared to what this would equate to for the effects of the change in WTL within the aquifer when porosity is accounted for).

5 Scenarios: Well Configuration and Pumping Rates

Scenario testing was performed to discern sustainable GW development (pumping) in the area of interest. Simulations for the purpose of scenario testing begin in January 1940 and run through December 2074, with the period from January 2025 through December 2074 representing the projection period. Baseline simulations were run prior to scenario testing to establish forcing parameters (i.e., recharge and agricultural pumping) for the projection period of the scenarios, and for direct comparison against GW development scenarios to quantify the impacts of additional pumping representing possible GW development future conditions.

Maximum sustainable GW development was defined as the amount of water that could be pumped without bringing the simulated April WTL below the April 1978 WTL during the projection period, locally (at the model grid-cell scale). The spring (April) 1978 WTL is used by UBBNRD as a means to quantify when management is triggered that calls for curtailment of water usage and indicates low GW levels. See Figure 37 for the model April 1978 WTL used by this study as the trigger for over-pumping.

For an “apples to apples” comparison, the April 1978 WTLs, the modeled lowest future projection period WTLs are compared with the simulated April 1978 WTL, rather than comparing against an interpolated spring 1978 water-table surface elevations from measured GW levels. In fact, an interpolated surface of measured spring 1978 WTLs was made and compared against modeled WTLs at the measurement well locations (see Figure 38)—BBNRD rules specify that the static water level is to be used (i.e., unaffected by large-scale pumping). April was selected because irrigators in the study area do not typically run their pumps during this time, making the conditions largely representative of the WTL that is highest before being lowered by high-demand pumping.

Maximum sustainable pumping rates were estimated for three categories of wells:

1) existing municipal wells in Aurora,
2) hypothetical (new) wells in the Aurora area, and
3) new wells that were located further from Aurora but within the AOI, referred to as “township” wells; these were arbitrarily located in grid cells at the center of the townships.

Aurora currently owns and operates seven municipal wells. Their locations and recorded pumping rates were provided to HDR for this study. An additional eight new wells were modeled in the Aurora area. For the purposes of this study, the Aurora area includes well locations in the city limits but also includes several locations along Highway 34, just beyond the Aurora city limits. Additional pumping was simulated at the centers of the seven townships that lie within the AOI.

5.1 Baseline Scenarios: Historical Conditions and Projections

5.1.1 Historical Baseline for Establishing the Modeled Spring 1978 Water-Table Level

A historical period baseline model run was created to compare the performance of the local model with the regional model. This was done to ensure that the model was functioning as intended. The existing conditions baseline performs a steady-state calculation to establish an initial condition, then runs a transient simulation from 1940 through 2017. The spring (April) 1978 WTL from this baseline simulation is used as the reference trigger for other simulations; however, all simulations are identical up to January 2018, when the model was extended thereafter (for other simulations).

5.1.2 Projection Baselines for Forcing Assumptions

Several baseline scenarios were run to establish the sensitivity of the model to different assumptions on forcing and pumping rates within and around the Aurora (the AOI). The baseline scenarios do not add any additional well locations. However, different assumptions are made for Aurora's municipal water use and other boundary conditions during the projected period. Boundary conditions, including recharge, agricultural pumping, river stage, stream stage, and municipal pumping (outside of Aurora), have their data sourced from earlier years in the simulation, from 1940 through 2017.

Repeating agricultural pumping and recharge from 1989–2017 twice for simulated years 2018 through 2074 was found to be the most representative of the configurations tested. There are an odd number of years (57) in the period from 2018 through 2074, meaning that there is an extra year when 1989 through 2017 data is repeated twice. Consequently, the second repetition of 2017 is excluded from the projection period. Stage of the Platte River modeled stream stages repeat the most recent 57 years as well. Pumping data from the existing baseline for 2017 for municipal and industrial wells, excluding Aurora's, is repeated. New municipal pumping data for the years between 2017 and 2025 were added for Aurora's wells.

After the final projection assumptions (above) were determined, two assumptions for Aurora's future pumping were tested to bracket the range of likely future realities. In the first projection baseline, Aurora's 2024 pumping rates were repeated every year for the duration of the projection period, representing zero growth or decay, a constant future municipal water demand. The second baseline applied a linear increase of 10.5 ac-ft/yr to Aurora's municipal water demand. This rate was calculated from Aurora's reported water use from 2005 through 2024 (Figure 39).

5.2 Scenario 1: Maximum Groundwater Development in the Aurora Area

Scenario 1 was also used to test the model's sensitivity to various assumptions. The sole objective of Scenario 1 and all of the runs that fall under its umbrella was to identify the maximum pumping rates that could be sustained in the Aurora area, inclusive of existing municipal wells and additional industrial or municipal wells. Scenario 1 simulates wells at Aurora's seven existing well locations and at eight new locations selected due to their proximity to the city, Highway 34, or the railway (i.e., areas identified as most likely locations where future GW development will occur).

During early stages of scenario 1, future pumping was modeled both with wells and with drains (DRN Package). Employing the use of drains was helpful in identifying the maximum volume of water the model could produce above a certain elevation in a model cell—using the April 1978 WTLs as the drain elevations. Ultimately, the use of wells (WEL Package) proved to be more accurate in terms of identifying the maximum pumping rates that could be sustained in the Aurora area because the drains would stop extracting water from the GW system when the WTLs fell below the drain elevations.

To identify the maximum pumping rate at each of the existing and new wells, six simulations were run having constant pumping rates across all wells of 0, 100, 250, 500, 1,000, and 2,000 gallons per minute (gpm). The lowest projection period WTLs were plotted as a function of pumping rate for each well. The resulting plots were roughly linear, allowing linear regression to be used to identify the approximate maximum pumping rates without allowing the projected water table to fall beneath the April 1978 WTL at any time during the simulation. This value was different for each well due to heterogeneity in the hydrologic properties of the model as well as each well location's proximity to existing agricultural water users.

The calculated pumping rates were multiplied by factors of 0.90, 0.95, 1.00, 1.05, and 1.10, then applied to their respective well locations for a set of refinement simulations. The expansion of the calculated rates to a range of rates was performed to assess sensitivity in simulated results. Finally, the results from the refinement simulations were used to determine final pumping rates for all 15 wells in the Aurora area. A simulation was run with the final pumping rates to observe the effect on local WTLs.

5.3 Scenario 2: Maximum Groundwater Development in the Aurora Area and in Neighboring Townships

The distinction between Scenario 2 and Scenario 1 is the addition of wells to the centers of townships neighboring Aurora. The procedure from Scenario 1 was followed at the township well locations. Six simulations were run having ***constant*** pumping rates across the township wells of 0, 100, 250, 500, 1,000, and 2,000 gpm. Wells in the Aurora area were simulated with calculated pumping rates from Scenario 1. The maximum pumping rate for each township well was found through linear regression to identify the maximum pumping rate without allowing the projected WTLs to fall beneath the April 1978 WTL at any time during the simulation. Then, for each location, the pumping rate from the linear regression was multiplied by factors of 0.90, 0.95, 1.00, 1.05, and 1.10. Final pumping rates were determined through linear regression of the refinement runs. A final Scenario 2 was run with calculated pumping rates from the above steps.

5.4 Scenario 3: Projected Groundwater Development in the Aurora Area and in Neighboring Townships

Scenario 3 applies a linear growth trend based on the past 20-years of historical data, 2005 through 2024, to the seven existing well locations within the Aurora area (Figure 39). The projected demand is 1,156 ac-ft/yr (716 gpm) in 2025 and increases approximately 10.5 ac-ft/yr (6.46 gpm) every year reaching 1,669 ac-ft/yr (1,035 gpm) in 2074. The annual demand is distributed to each month based on the City's historical monthly use from 2000 through 2024. The average peaking factor (peak demand divided by average demand) is 1.66 over this time period and peak monthly demand occurred in July. The eight new wells in the Aurora area pump at a constant rate determined in Scenario 1. The wells in the townships are pumped at a constant rate determined in Scenario 2.

6 Model Simulation Results

6.1 Projection Baseline: No Growth

Under the baseline scenario with no projected growth, all wells remain above the April 1978 WTL throughout the projection period, which assumes 2024 conditions are repeated. Existing Well 1 was selected to illustrate the WTL through time in a hydrograph (Figure 40). Other existing wells exhibited similar trends and can be found in the appendix (A-2A-2). The median WTL across all well locations is more than 9 feet above the April 1978 trigger level, indicating strong aquifer stability under current extraction rates. Furthermore, the lowest WTL observed at any well remains at least 2.1 feet above its respective trigger, confirming that no wells approach critical thresholds under this scenario. The total change in study area GW storage during the full simulation period (1940 through 2074) was -1,602,601 ac-ft. Areas within the study area do fall below the modeled April 1978 WTL (see Figure 41 and Figure 42); however, it can be safely assumed that Aurora's municipal pumping is not likely directly responsible. It is much more likely that this occurs due to the other model boundary conditions and forcing data due to the relative magnitude of the GW fluxes. This is illustrated in Figure 43, which is an annual water budget plot for the full study area.

Table 2. No Growth Projection Baseline Simulated April Water-Table Level at Study Well Locations

Well ID	1978 WTL (ft)	Lowest Projected WTL (ft)	Difference[1] (ft)	Number of Years Below	Median WTL (ft)	Difference[2] (ft)
Existing Well 1	1699.0	1702.4	3.4	0.0	1709.0	10.0
Existing Well 2	1695.4	1699.4	4.0	0.0	1705.6	10.2
Existing Well 3	1697.1	1700.5	3.4	0.0	1707.2	10.1
Existing Well 4	1692.9	1696.4	3.5	0.0	1703.9	11.0
Existing Well 5	1701.3	1703.6	2.3	0.0	1711.0	9.7
Existing Well 6	1694.7	1697.2	2.5	0.0	1705.2	10.5
Existing Well 7	1699.1	1701.2	2.1	0.0	1709.0	9.9

[1] Indicates the lowest simulated projection period April WTL minus the April 1978 WTL

[2] Indicates the median simulated projection period April WTL minus the April 1978 WTL

6.2 Projection Baseline: Linear Growth

When extraction rates increase linearly over the projection period, wells 5, 6, and 7 briefly reach the 1978 WTL for one year each. In these instances, the projected April WTL falls less than 0.5 feet below the trigger level, suggesting only minor exceedances (Table 3). As can be seen in the selected hydrograph (Figure 44), the results suggest that water levels in Aurora are sensitive to dry periods and can both fall below trigger levels and recover over a time period of just a few years. The trigger is hit during a recurrence of an historic dry period (2001–2007), then quickly recovers.

The wells having hit the trigger are located northwest of downtown Aurora, where drawdown impacts appear most pronounced. This can be seen in Figure 45 and in Figure 46. Increasing municipal GW use at Aurora's well locations pulled a larger area below the April 1978 WTL than the "No Growth" projection baseline, suggesting that Aurora has an impact on the local WTLs.

Despite these localized impacts, the median WTL remains more than 7 feet above the trigger across all wells, indicating overall system resilience under moderate growth conditions. The total change in study area GW storage during the full simulation period was -1,634,515 ac-ft. The simulation water budget can be seen in Figure 47. The year in which the trigger was hit is also indicated in Figure 47 with a small black arrow on the x-axis.

Table 3. Linear Growth Projection Baseline Simulated Water-Table Level at Study Well Locations

Well ID	1978 WTL (ft)	Lowest Projected WTL (ft)	Difference[1] (ft)	Number of Years Below	Median WTL (ft)	Difference[2] (ft)
Existing Well 1	1699.0	1699.7	0.7	0	1706.7	7.7
Existing Well 2	1695.4	1696.8	1.4	0	1703.4	8.0
Existing Well 3	1697.1	1697.8	0.7	0	1704.9	7.8
Existing Well 4	1692.9	1693.8	0.9	0	1701.8	8.9
Existing Well 5	1701.3	1701.3	0.0	1	1709.1	7.8
Existing Well 6	1694.7	1694.6	-0.1	1	1703.1	8.4
Existing Well 7	1699.1	1698.7	-0.4	1	1707.0	7.9

[1] Indicates the lowest simulated projection period April WTL minus the April 1978 WTL

[2] Indicates the median simulated projection period April WTL minus the April 1978 WTL

6.3 Scenario 1: Maximum Development in the Aurora Area

Figure 48 shows three selected hydrographs for the well locations in the Aurora area. The three wells locations were selected to represent the highest, the lowest, and Existing Well 1 for a middle-ground value, WTL of the Aurora area well locations, for comparison with the baselines. The hydrographs of all study wells can be seen in the appendix (A-4). Similarity can be seen between the two projection baselines, and Scenario 1. The main difference to note is that there is a slightly greater downward trend throughout the projection period and that the trigger is hit in multiple years.

Under maximum GW development within Aurora, nine of the 15 wells in the area fall below the trigger level during the projection period, including six of the seven existing wells (see Table 4, Figure 49, and Figure 50). Of these, New Well 2 is the only location to remain below the April 1978 WTL for more than four consecutive years, falling as much as 1.5 feet below its trigger. Spatially, a similar trend can be seen between Scenario 1 and the two projection baselines. The area to the northwest of Aurora is predominantly below the trigger, and the simulated pumping increase enlarges that area that falls below the trigger further to the southeast.

The median WTL across all wells remains 6.6 feet above the 1978 trigger, but localized impacts are significant, particularly in the northwest portion of Aurora. Evidence of well interference is observed, as some wells fall below their trigger while others remain unaffected. The total change in study area GW storage during the full simulation period was -1,658,741 ac-ft, which can be seen in Figure 51.

The simulation pumping rate of each study well is shown in Table 4 with the WTL summary. Across all wells, the average pumping rate is 165 gpm for a total production rate of 3,996 ac-ft/yr. These pumping rates were determined through the method described in Section 5.2. This method treated each well individually when approximating a maximum pumping rate. However, it can be seen in the WTL map (Figure 49) that the wells do have an impact on the WTL of other nearby wells. This phenomena can also be seen in the wells that fell below the trigger or remain well above it during the simulation. If a similar regression method were performed, wherein the lowest WTL in all wells were plotted against a uniform pumping rate in all fifteen wells, and a linear regression were performed to find the level at which no wells hit the trigger, the calculated uniform constant pumping rate would be close to 150 gpm. An intermediate Scenario 1 simulation, wherein wells were uniformly pumped at a constant rate of 100 gpm, resulted in none of fifteen wells hitting the trigger.

Table 4. Scenario 1 Simulated April Water-Table Levels at Study Well Locations and their Projection Period Pumping Rates

Well ID	1978 WTL (ft)	Lowest Projected WTL (ft)	Difference[1] (ft)	Number of Years Below	Median Projected WTL (ft)	Difference[2] (ft)	Rate (gpm)
Existing Well 1	1699.0	1698.6	-0.4	2	1706.0	7.0	146
Existing Well 2	1695.4	1695.7	0.3	0	1702.5	7.1	182
Existing Well 3	1697.1	1696.7	-0.4	2	1704.0	6.9	145
Existing Well 4	1692.9	1692.4	-0.5	2	1700.6	7.7	148
Existing Well 5	1701.3	1700.1	-1.2	4	1708.3	7.0	101
Existing Well 6	1694.7	1693.7	-1.0	2	1702.4	7.7	114
Existing Well 7	1699.1	1697.9	-1.2	4	1706.3	7.2	97
New Well 1	1703.2	1702.6	-0.6	2	1710.0	6.8	133
New Well 2	1706.1	1704.6	-1.5	5	1712.7	6.6	63
New Well 3	1686.1	1686.9	0.8	0	1694.2	8.1	239
New Well 4	1690.6	1691.9	1.3	0	1698.3	7.7	287
New Well 5	1674.5	1675.7	1.2	0	1684.0	9.5	302
New Well 6	1684.8	1684.9	0.1	0	1693.9	9.1	189
New Well 7	1735.6	1735.8	0.2	0	1742.2	6.6	188
New Well 8	1719.4	1719.2	-0.2	1	1726.1	6.7	142

[1] Indicates the lowest simulated projection period April WTL minus the April 1978 WTL

[2] Indicates the median simulated projection period April WTL minus the April 1978 WTL

6.4 Scenario 2: Maximum Development in the Aurora Area and Development in the Townships

The hydrograph for Scenario 2 resembles the hydrographs of Scenario 1 and the projection baselines. Hydrographs for representative wells can be seen in Figure 52. The difference in WTL at the three selected locations is hard to see with the naked eye; however, Table 5 clearly reports that WTLs are lower in Scenario 2. The hydrographs of all study wells can be seen in the appendix (A-5A-5).

Expanding development to include nearby townships intensifies drawdown effects. In this scenario, 11 of the 15 Aurora wells hit the 1978 trigger, including six of the seven existing wells. Figure 53 presents the WTL difference map for Scenario 2 where this can be seen. Four of the new township well locations produced zero water above the April 1978 WT (i.e., the WTL in those locations fell below the trigger without any pumping)—see Figure 54. Added pumping from the township wells does appear to have some, although limited, impact on the WTL in the Aurora area.

New Well 2 again falls the furthest below its trigger, by 1.5 feet. Among township wells, four locations cannot produce water without falling below the trigger, while the remaining three stay above their respective triggers. Interference between wells is evident, and areas northwest of Aurora consistently fall below the April 1978 WTL, indicating regional stress under this development pattern. The total change in study area GW storage during the full simulation period was -1,670,526 ac-ft, which can be seen in the scenario water balance (Figure 55).

Table 5. Scenario 2 Simulated April Water-Table Levels at Study Well Locations and their Projection Period Pumping Rates

Well ID	1978 WTL (ft)	Lowest Projected WTL (ft)	Difference [1] (ft)	Number of Years Below	Median Projected WTL (ft)	Difference[2] (ft)	Rate (gpm)
Existing Well 1	1699.0	1698.1	-0.9	2.0	1705.5	6.5	155
Existing Well 2	1695.4	1695.2	-0.2	2.0	1702.1	6.7	171
Existing Well 3	1697.1	1696.1	-1.0	2.0	1703.6	6.5	157
Existing Well 4	1692.9	1691.9	-1.0	2.0	1700.1	7.2	156
Existing Well 5	1701.3	1699.4	-1.9	6.0	1707.7	6.4	133
Existing Well 6	1694.7	1693.2	-1.5	5.0	1701.8	7.1	142
Existing Well 7	1699.1	1697.2	-1.9	6.0	1705.8	6.7	132
New Well 1	1703.2	1702.0	-1.2	5.0	1709.5	6.3	144
New Well 2	1706.1	1704.0	-2.1	8.0	1712.2	6.1	101
New Well 3	1686.1	1686.6	0.5	0.0	1694.0	7.9	186
New Well 4	1690.6	1691.6	1.0	0.0	1698.0	7.4	200
New Well 5	1674.5	1675.7	1.2	0.0	1684.0	9.5	212
New Well 6	1684.8	1684.6	-0.2	1.0	1693.6	8.8	167
New Well 7	1735.6	1735.5	-0.1	1.0	1742.0	6.4	165
New Well 8	1719.4	1718.9	-0.5	3.0	1725.8	6.4	139
Township Well 1	1664.7	1662.6	-2.1	6.0	1671.6	6.9	0
Township Well 2	1692.4	1690.6	-1.8	6.0	1700.1	7.7	0
Township Well 3	1749.9	1749.5	-0.4	2.0	1755.2	5.3	0
Township Well 4	1661.4	1663.5	2.1	0.0	1667.7	6.3	144
Township Well 5	1693.2	1693.5	0.3	0.0	1700.1	6.9	161
Township Well 6	1739.4	1739.4	0.0	0.0	1745.1	5.7	119
Township Well 7	1794.9	1792.7	-2.2	11.0	1797.2	2.3	0

[1] Indicates the lowest simulated projection period April WTL minus the April 1978 WTL

[2] Indicates the median simulated projection period April WTL minus the April 1978 WTL

6.5 Scenario 3: Projected Development in the Aurora Area and Development in the Townships

When projected Aurora growth is combined with maximum development in both Aurora and surrounding townships, results mirror those of Scenario 2. The selected hydrographs display similar trends as in other simulations (Figure 56). The hydrographs of all study wells can be seen in the appendix (A-6). Eleven of the fifteen Aurora-area wells fall below the trigger, including six existing wells, and New Well 2 again falls 1.5 feet below its trigger. Four township wells cannot operate without falling below the trigger, while three remain above their triggers (Table 6).

The northwest region of Aurora continues to experience the greatest drawdown, and well interference remains a notable concern under this combined development scenario. The lowest projected April WTL minus the modeled April 1978 WTL can be found in Figure 57. The scenario pumping rates and locations can be seen in Figure 58. The total change in study area GW storage during the full simulation period was -1,655,212 ac-ft. The years in which any study well fell below the trigger is indicated in the scenario water budget (Figure 59). This excludes the four new township wells with zero production capacity.

Table 6. Scenario 3 Simulated April Water-Table Levels at Study Well Locations and their Projection Period Pumping Rates

Well ID	1978 WTL (ft)	Lowest Projected WTL (ft)	Difference[1] (ft)	Number of Years Below	Median Projected WTL (ft)	Difference[2] (ft)	Rate (gpm)
Existing Well 1	1699.0	1698.7	-0.3	2	1706.2	7.2	162
Existing Well 2	1695.4	1695.7	0.3	0	1702.7	7.3	202
Existing Well 3	1697.1	1696.7	-0.4	2	1704.2	7.1	161
Existing Well 4	1692.9	1692.4	-0.5	2	1700.8	7.9	164
Existing Well 5	1701.3	1700.1	-1.2	3	1708.4	7.1	112
Existing Well 6	1694.7	1693.8	-0.9	2	1702.6	7.9	126
Existing Well 7	1699.1	1697.9	-1.2	3	1706.6	7.5	107
New Well 1	1703.2	1702.5	-0.7	2	1710.1	6.9	133
New Well 2	1706.1	1704.6	-1.5	5	1712.7	6.6	63
New Well 3	1686.1	1686.6	0.5	0	1694.1	8	239
New Well 4	1690.6	1691.5	0.9	0	1698.5	7.9	287
New Well 5	1674.5	1675.4	0.9	0	1683.9	9.4	302
New Well 6	1684.8	1684.8	0	1	1694.0	9.2	189
New Well 7	1735.6	1735.6	0	1	1742.1	6.5	188
New Well 8	1719.4	1719.1	-0.3	2	1726.1	6.7	142
Township Well 1	1664.7	1662.7	-2	5	1671.9	7.2	0
Township Well 2	1692.4	1690.7	-1.7	5	1700.4	8	0
Township Well 3	1749.9	1749.6	-0.3	2	1755.4	5.5	0
Township Well 4	1661.4	1663.6	2.2	0	1668.0	6.6	144
Township Well 5	1693.2	1694.0	0.8	0	1701.0	7.8	161
Township Well 6	1739.4	1739.5	0.1	0	1745.3	5.9	119

Well ID	1978 WTL (ft)	Lowest Projected WTL (ft)	Difference[1] (ft)	Number of Years Below	Median Projected WTL (ft)	Difference[2] (ft)	Rate (gpm)
Township Well 7	1794.9	1792.7	-2.2	11	1797.3	2.4	0

[1] Indicates the lowest simulated projection period April WTL minus the April 1978 WTL
[2] Indicates the median simulated projection period April WTL minus the April 1978 WTL

6.6 New Groundwater Development Considerations Related to Nitrate Pollution

UBBNRD provides nitrate concentration observations and the location of those observations (UBBNRD 2025). It also provides maps of the Ground Water Quality Management Zones within the NRD (UBBNRD 2025). Aurora and all study wells lie within Groundwater Quality Management Zone 2, which is designated a Phase II Ground Water Quality Management Zone. This designation means that the median nitrate concentration is between 7 ppm and 10 ppm, where 10 ppm is the EPA's drinking water limit. Zone 2 had a median nitrate concentration of 7.1 ppm in UBBNRD's 2024 Management Area Rules and Regulations (UBBNRD 2024). UBBNRD data suggests that nitrate pollution is present both upgradient and downgradient of study well locations including Aurora's seven existing wells.

Olsson (2023) reports that Aurora's existing wells have not hit the EPA drinking water limit for nitrate since 2013. Data from this report shows concentrations of nitrate in Aurora's wells are close to the Zone 2 management area median of 7.1 ppm. The development of new GW wells in the Aurora area should expect similar nitrate concentrations, but further investigation should be performed before definitive conclusions can be made.

Based on production rates, new well locations to the southeast of Aurora are favorable for GW development. UBBNRD data suggests that there is at least one site with known nitrate contamination above the EPA's drinking water limit near this area with many other sites further away both upgradient and downgradient. This should be considered when developing new GW wells in the area. However, GW flow gradients may serve to mitigate the issue caused by this site, because the known contamination is downgradient of proposed Aurora-area wells and all other study wells with the possible exception of Township Well 4.

7 Summary and Recommendations

7.1 Summary

The GW sustainability study was conducted to (1) understand how Aurora's potential municipal growth could affect the local water budget and GW availability in the Aurora area, and (2) quantify the availability of GW for new large industry water users. A distributed numerical GW model was developed for the study area and run to assess the effects of stresses on the local GW system in transient simulations over the future projection period from 2024 to 2075. In total, three baselines and three scenarios were modeled using the local model developed for the study. The first baseline was used to compare local model performance to regional model performance during the historical period from 1940 through 2017. The second two baselines serve to test the AOI's sensitivity to Aurora's municipal pumping and potential growth in the projection period. Scenario 1 was used to assess the maximum amount of GW development that could be sustained by the Aurora area. Scenario 2 was used to assess the maximum amount of GW that could be developed in the Aurora Aea and surrounding townships. Scenario 3 was used to assess how large new GW users would affect GW availability to Aurora under continued growth. Modeled GW levels from the projection period were compared with the modeled April 1978 WTL (management trigger) to determine the sustainability of the existing and new pumping simulated.

The following primary tasks for the GW sustainability study have been completed:

1) Collected and reviewed recent hydrogeological data,
2) Constructed a new (local) GW flow model with an improved model grid from the existing (regional) BRBGWM,
3) Quantified the performance of the newly created local GW model using head targets and compared performance with the existing regional model,
4) Developed scenarios and performed model simulations of municipal and industrial GW use in the Aurora area under current and projected conditions,
5) Provide recommendations on maximum monthly pumping rates by location as well as provide recommendations on an overall average pumping rate,
6) Identified priority locations for possible new GW extraction wells based on model simulation results, and
7) Discussed water quality considerations to be made for known existing nitrate pollution at priority locations for new GW development.

The baseline projection with no growth in municipal or industrial demand modeled WTLs above the 1978 trigger in all of Aurora's municipal well locations. The baseline projection with linear growth in municipal demand showed that 3 of Aurora's existing wells hit the 1978 trigger for a single year in each case. Median WTLs at Aurora's existing well locations remained above the 1978 trigger by more than 7 feet.

Scenario 1 results in nine out of 15 wells falling below the April 1978 WTL. This partly to do with the interaction between the cone of depression of each simulated well (i.e., drawdown interference). Largely, it appears that the instances where the trigger is reached are isolated in time, marked by a few short (~3 year) drought periods. Spatially, simulated wells southeast of Aurora are able to produce more water than wells northwest of Aurora and had fewer instances of falling below the April 1978 WTL owing to a higher water table available above the trigger. Hydrographs from Scenario 1 indicate a slight downward trend for the study wells. However, the calculated and simulated maximum sustainable pumping rates are much higher than Aurora's projected municipal demand.

Scenario 2 results in three of the selected township wells being able to produce water without hitting the 1978 WTL. The producing township wells are located south and east of Aurora. The other four township well locations fall below the 1978 WTL with zero additional pumping.

Scenario 3 results in Aurora's existing wells falling below the 1978 WTL in a lesser number of years compared to Scenarios 1 and 2. This is due to the gradual increase from baseline pumping throughout the projection period simulation, as opposed to the constant maximum pumping in Scenarios 1 and 2 for the projection period. New well locations perform similarly to Scenario 2, as they are extracting the same amount of water. Of the 22 new well locations,15 fall below the 1978 WTL, with four of those being township wells that hit the trigger without any pumping.

These findings suggest the following:

1) Aurora will likely be able to meet its municipal water demand with local GW to 2075 and beyond,
2) There will be available GW in the Aurora area for the development of new industrial users, and
3) There is available GW in the areas outside of Aurora for future GW development.

Groundwater nitrate concentrations indicate that the Aurora area and its surrounding townships have a mean of 7.1 ppm and that they are in a Phase II Ground Water Quality Management Zone. The measurements of nitrate in GW indicate that nitrate pollution is present both upgradient and downgradient of study well locations.

7.2 Recommendations

7.2.1 Pumping Rates for Existing Wells

The existing Aurora-area wells appear to perform adequately under current stress conditions and are capable of producing volumes that exceed present demand. Baseline simulations and Scenario 1 indicate that average monthly extraction rates could be increased if necessary. Simulation results suggest that average pumping rates of approximately 150 gpm could be applied across the 7 existing municipal wells without causing WTL to fall below the 1978 trigger for extended periods of time during the projection period.

7.2.2 Additional Wells

To meet increased demands, it is likely that Aurora will need to develop new municipal wells between now and 2075. Simulation results suggest that average pumping rates of approximately 150 gpm could be applied across the eight new Aurora-area wells without causing GW levels to fall below the April 1978 trigger WTL for extended periods of time.

Aurora may avoid hitting the 1978 WTL by developing less total GW than was simulated in Scenario 1, or by distributing GW development over a larger area with wells spaced further apart from each other. Note, Scenario 1 simulated 8 new well locations representing future municipal or industrial growth, and not all these locations will necessarily be required to bring in new industry. Additionally, it is recommended that new wells located in the southeast be operated below their calculated maximum pumping rates to maintain sustainable water levels and avoid reaching the 1978 WTL in the northwest region, thereby balancing system-wide drawdown.

Scenario 2 results suggest that water outside the Aurora area is available to a new industrial user. Retiring agricultural wells would allow more water for a new user. Scenario 3 results in drawdown below the 1978 trigger in many of the Aurora-area wells. The city may choose to avoid this by utilizing one or more of the new well locations to meet municipal demand. Interference between wells should be anticipated and incorporated into the overall design and operational planning to ensure efficient resource management.

Preliminary assessments indicate that the southeastern portion of the AOI has greater water availability compared to other areas, making it a favorable location for additional development. For new wells, an average pumping rate of approximately 150 gpm is recommended to optimize performance while maintaining aquifer stability.

7.2.3 Future Evaluations

To utilize the local model as an effective tool for identifying new GW well locations more precisely, recalibration is recommended. This process should include the update of parameters and more rigorous alignment of specific parameter values against those expected from an update to the conceptual model, and local hydrogeological investigations, to improve model accuracy and ensure that predictions reflect responses controlled by in-situ hydrogeologic conditions. Site-specific modeling should be conducted for proposed GW development to ensure that well placement and pumping strategies are tailored to local hydrogeologic conditions. This will help optimize resource use while maintaining aquifer sustainability.

Underflows, which are currently excluded from the model, should be incorporated at the northern and southern boundaries. Including these flows will provide a more accurate representation of regional GW movement and improve the reliability of model outputs. This would require accurate quantification of underflows at those boundaries as well as additional model development. Estimates for the fluxes at these boundaries could be modeled with the (regional) Blue River Basin GW Model.

Although wells were initially placed in the model based on anticipated development patterns, future developers may prioritize different locations. Therefore, future work should include testing alternative well placements or relocating wells within the model to identify areas with optimal yield potential, with consideration of GW quality that includes (but should not be limited to) nitrate concentrations. Similarly, projection period pumping scenarios could be simulated with new wells in each model cell in the Aurora area, or even the AOI or study area, to create a continuous map of expected sustainable production rates.

8 Study Limitations

HDR used generally accepted engineering methods in preparation of the model and simulations reported herein. The content included in this report is correct to the best of our knowledge and has been developed in accordance with the standard of care that is customarily followed by a practitioner in this industry. Decisions that are made based on this report should consider the limitations documented herein. Some of the information provided in this report was developed or provided by others. Except as specifically identified in this report, HDR has not performed independent validation or verification of exploration data, modeling data, or other analysis on data provided by others. While HDR has used its best efforts in preparing this report, HDR has assumed that third-party data is accurate, complete, reliable, and current.

Groundwater flow models are generalizations of complex hydrogeologic flow systems. The complexity is captured in the model in a generalized manner, but local effects can influence outcomes that would be anticipated to differ from model-generated results in the real world. The model-generated results are from deterministic simulations with a numerical GW flow model built using a single representation of the system (and model structure). Some details cannot be reasonably simulated without extensive data, detailed inputs, refinements to the model grid, or model parameter refinements (calibration), and large computational requirements. Additional analysis or updates may be required in the future to provide more detailed and/or accurate simulation results.

Other known assumptions and limitations of the modeling presented in this report that should be considered are listed as follows:

- Hydrostratigraphy has been simplified to five model layers, whereas local variability in lithology, texture, degree of cementation, and sorting of sediments exists and may not conform to the five-layer conceptualization.
- Layer thicknesses and hydraulic property zone boundaries do not perfectly reflect reality, and the model results are nonunique. Therefore, model results that differ from those presented in this report could reasonably be expected to be generated from other similar versions of the model that also could be considered calibrated.
- The scale of irrigation pumping and recharge in the model outweigh industrial and municipal pumping, making results heavily dependent on the assumptions about those two water budget flow components.
- The parameter calibration zones in the regional model allowed for unnatural breaks in hydrologic conductivity and storativity, unrepresentative of local hydrogeology.
- The spatial resolution of the model averages drawdown across a 1/4-by-1/4-mile area, dampening the impact of the local cone of depression of each simulated well.
- This study has not considered the life cycle of infrastructure, so well replacements due to aging infrastructure are not captured or described.
- The locations of hypothetical “new” wells simulated during the projection period were assumed within the spatially-explicit numerical model based on the best available information available on future development plans and as a means of simplification were arbitrary in some cases (township wells); whereas real-world locations of future wells are likely to differ from those simulated.

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FIGURES

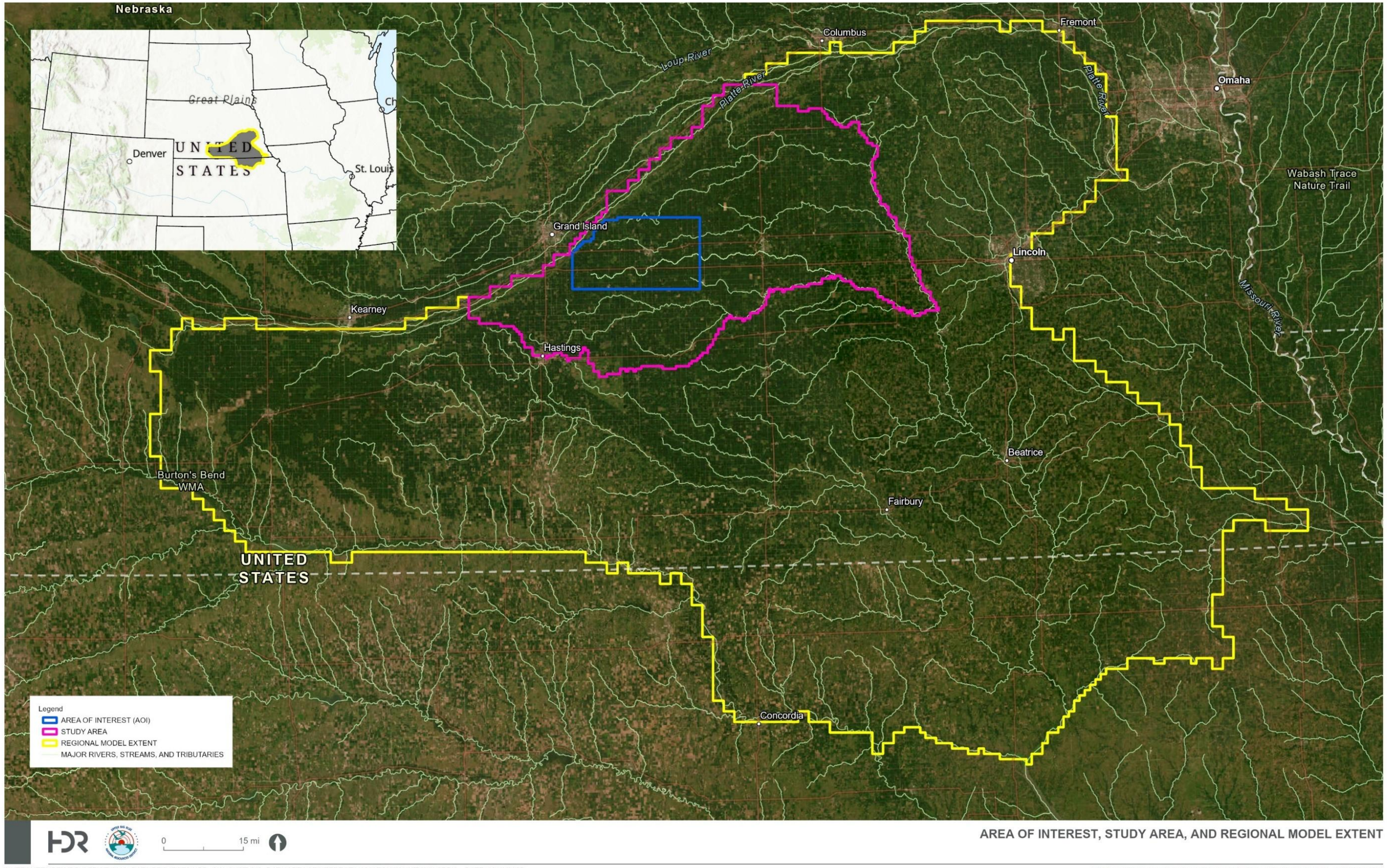


Figure 1. Study Area and Area of Interest Shown with the Regional Model Extent

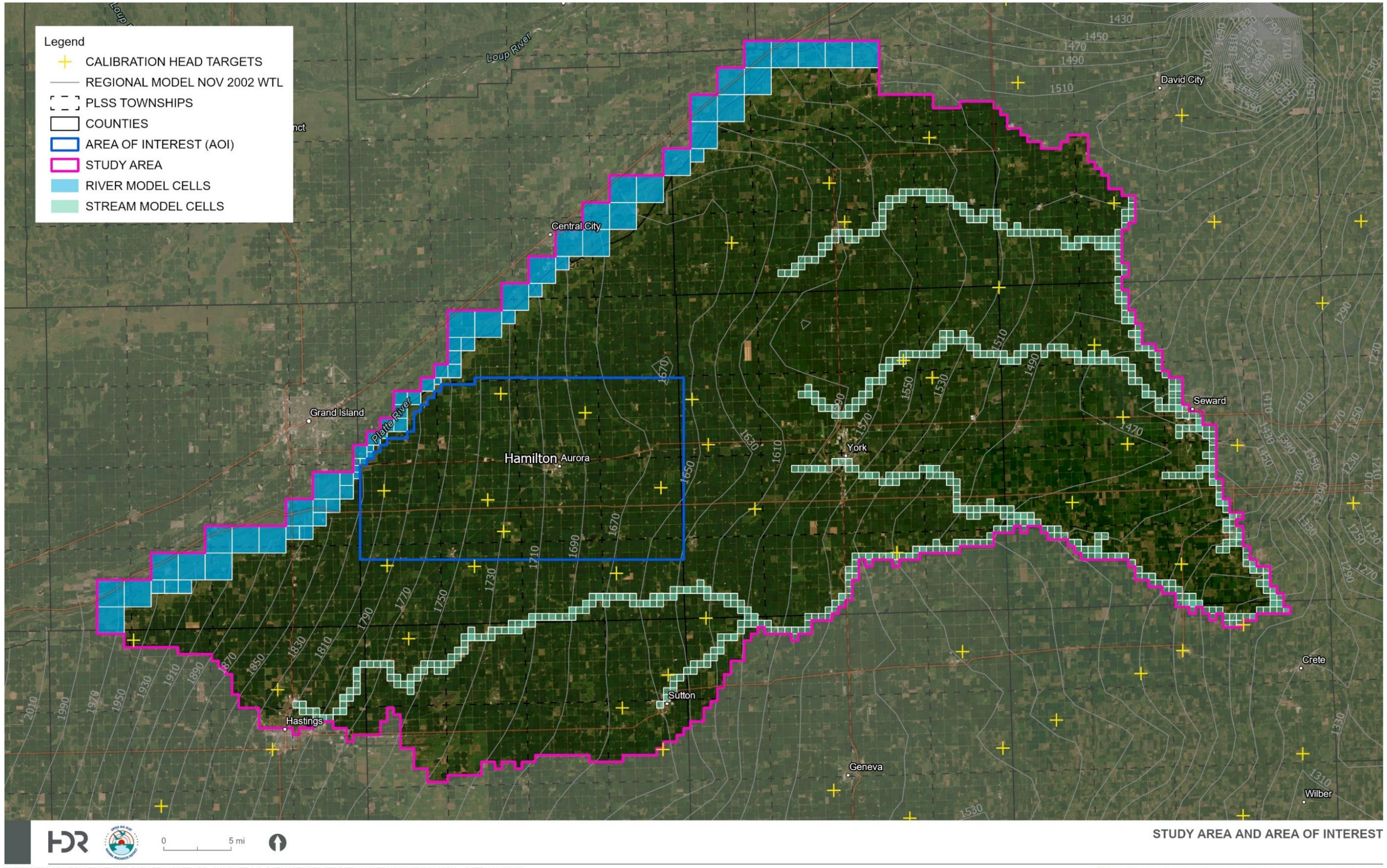


Figure 2. Local Model Boundary Conditions with Low-Recharge Period Head Contours from the Regional Model Simulation and Head Target Locations

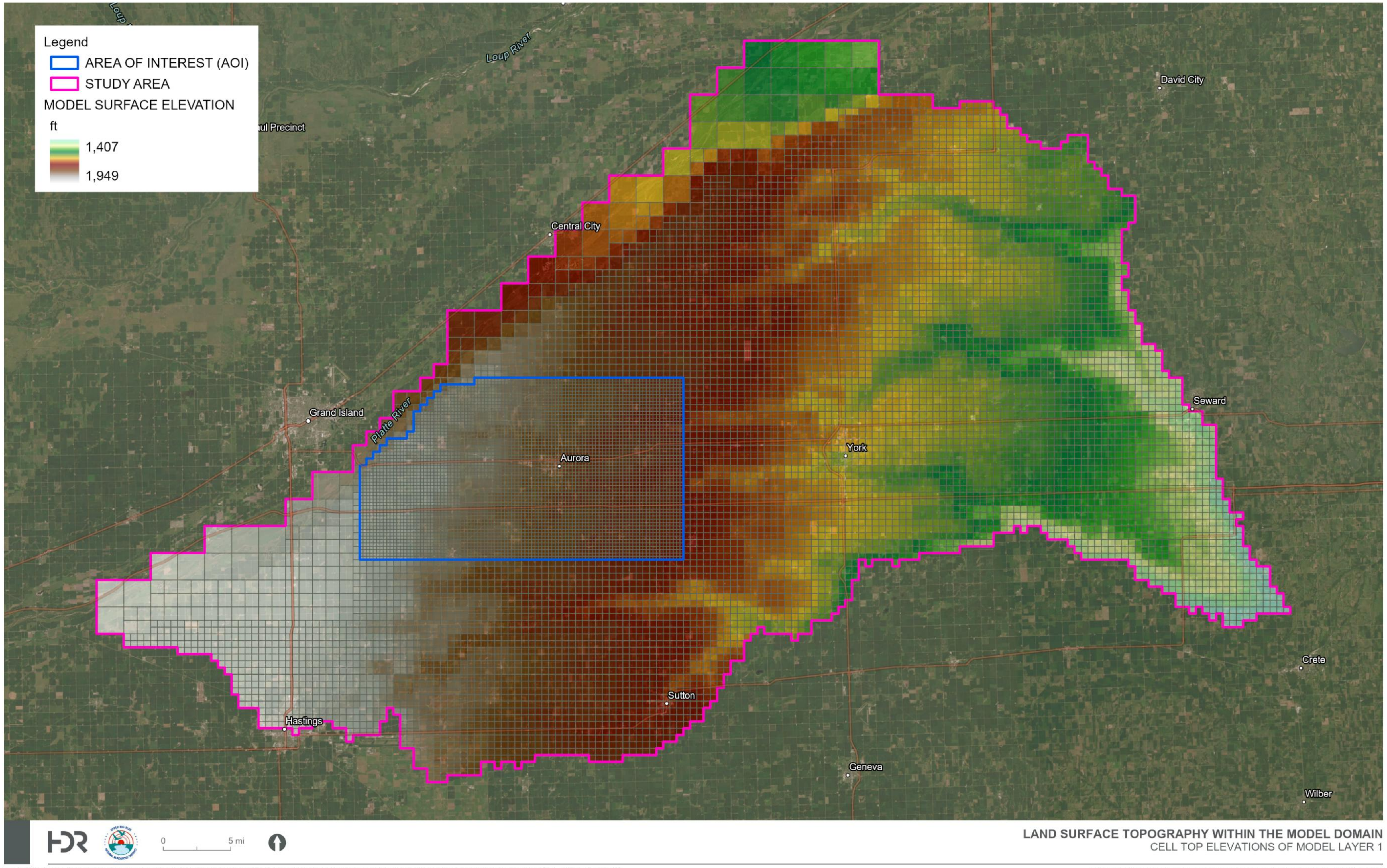


Figure 3. Land Surface Topography Within the Model Domain

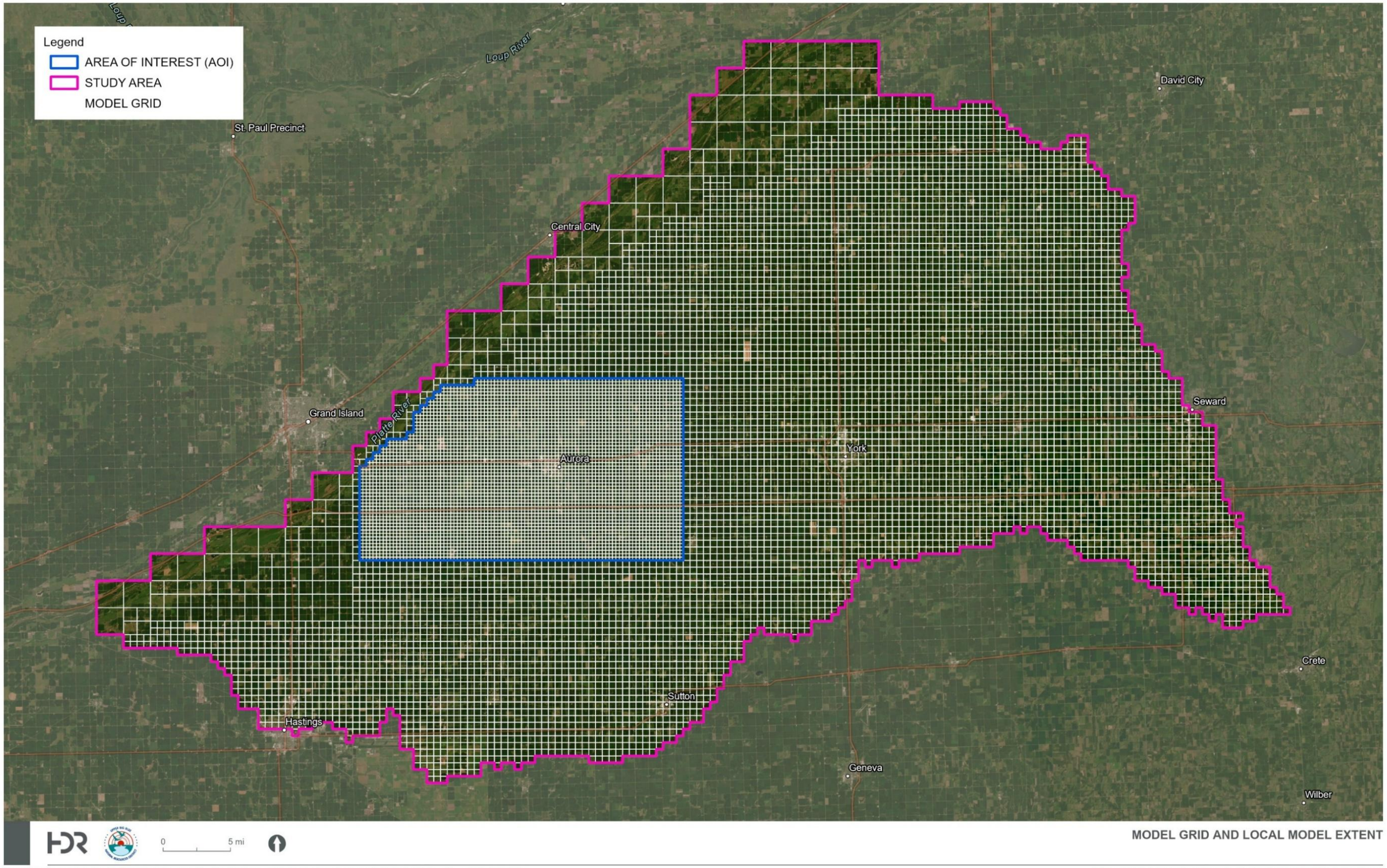


Figure 4. The Local Model Grid

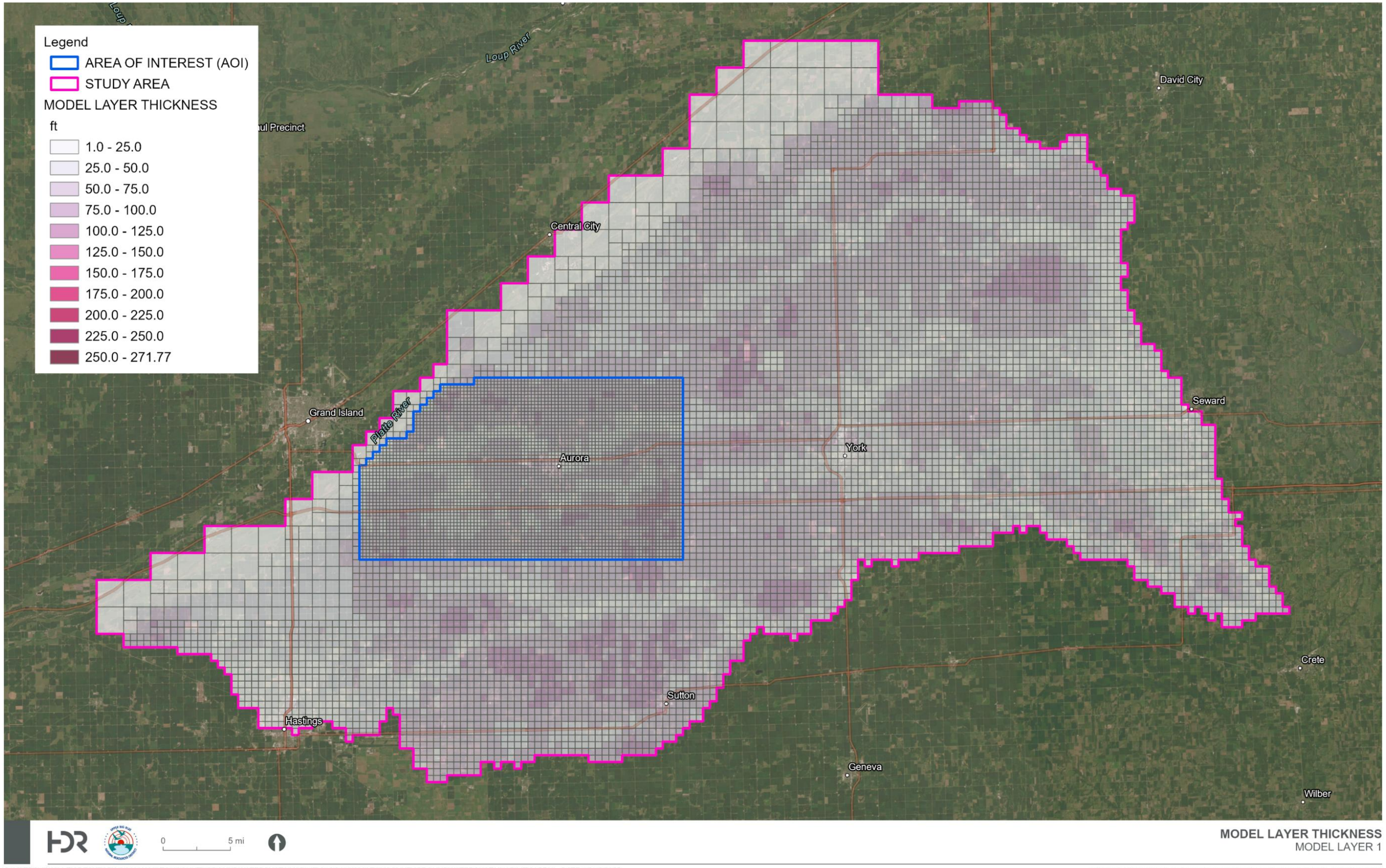


Figure 5. Thickness of Model Layer 1

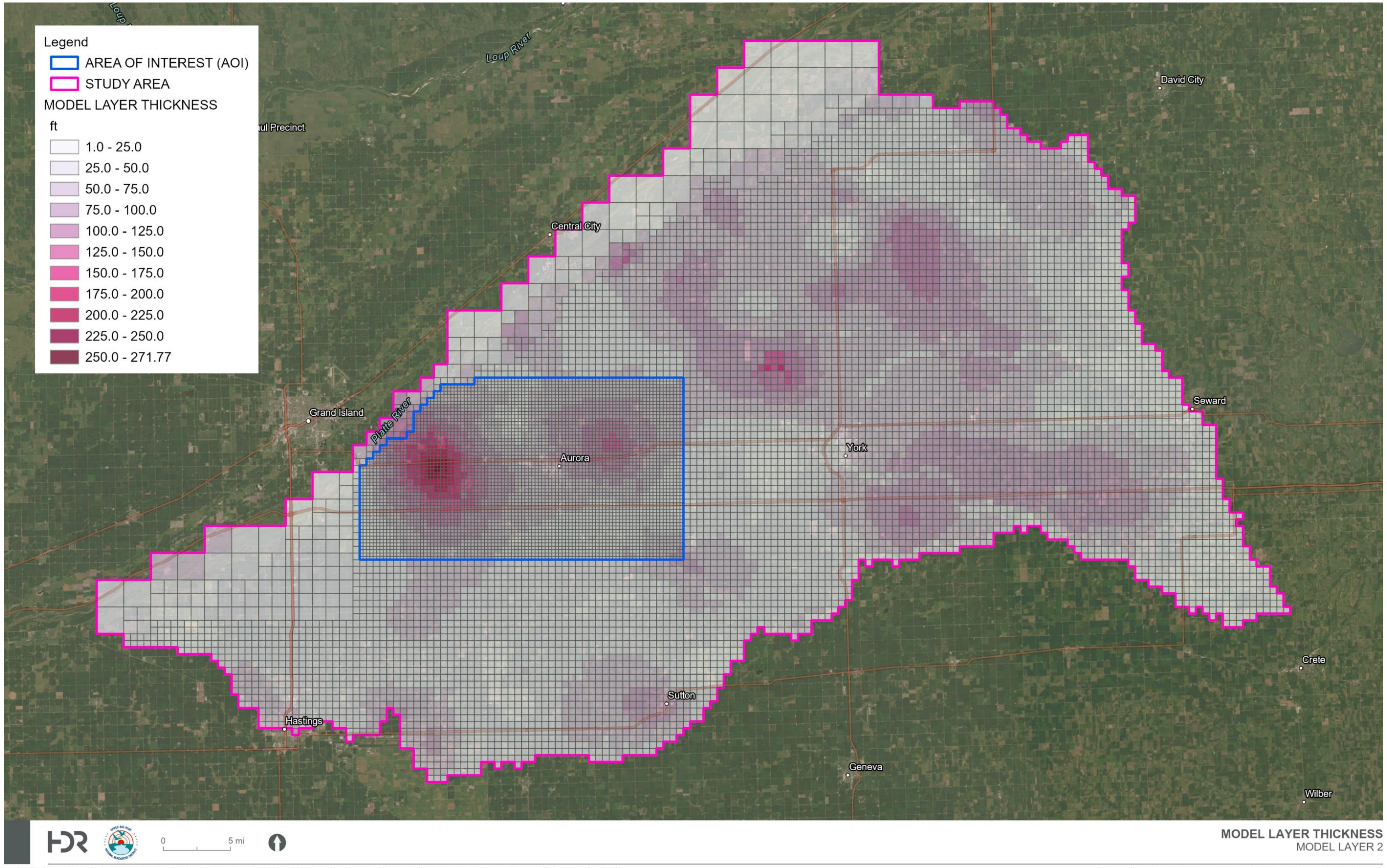


Figure 6. Thickness of Model Layer 2

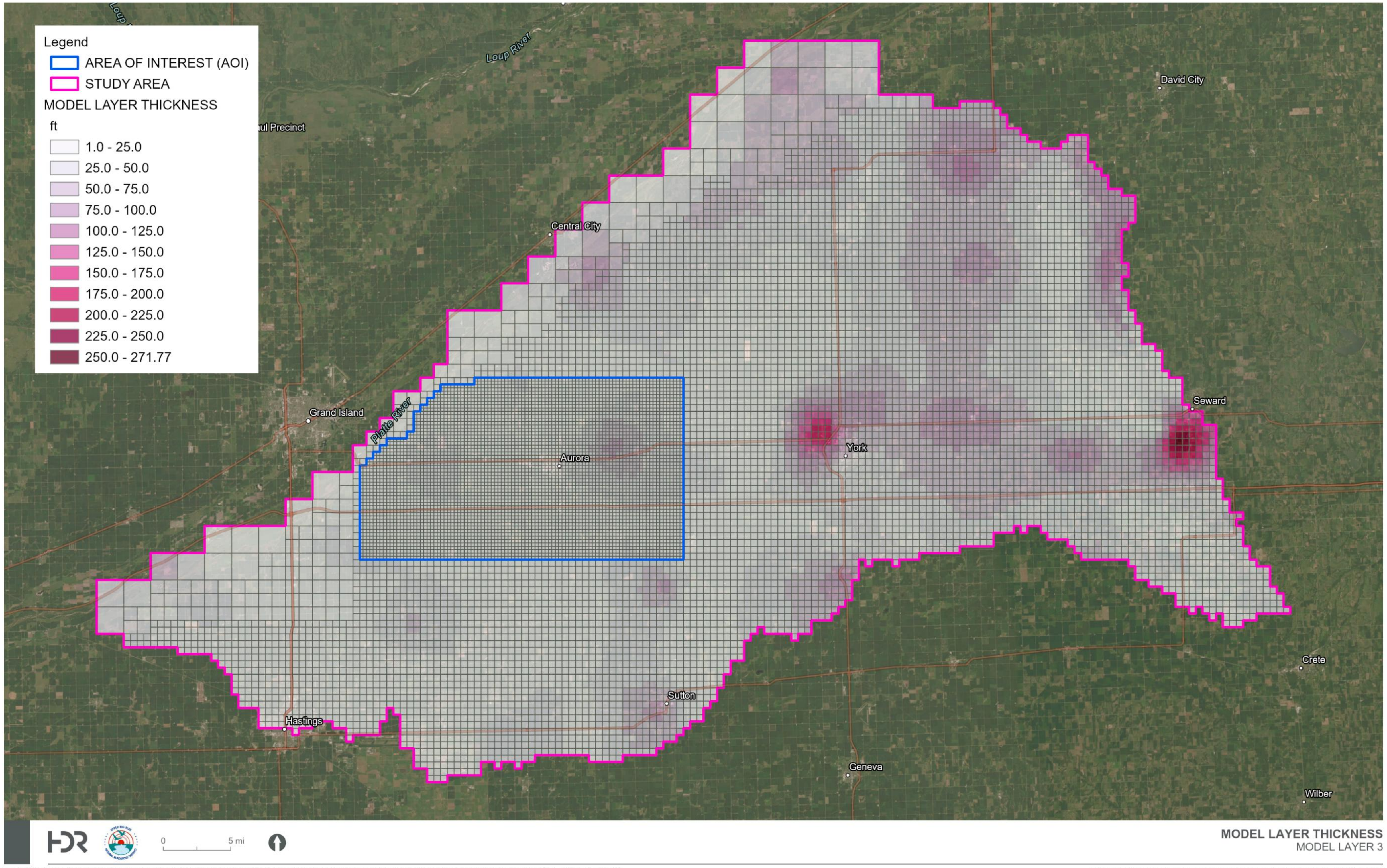


Figure 7. Thickness of Model Layer 3

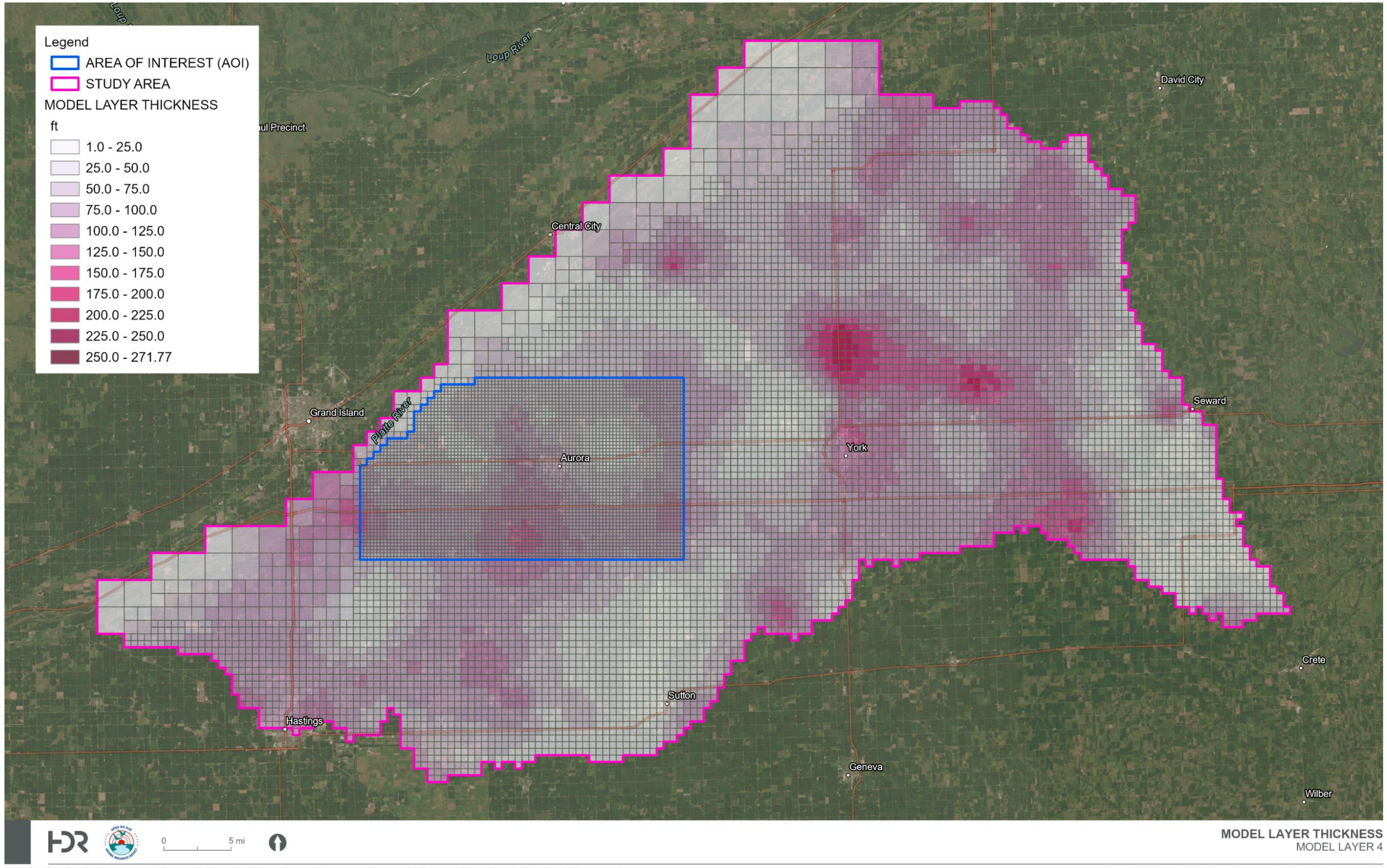


Figure 8. Thickness of Model Layer 4

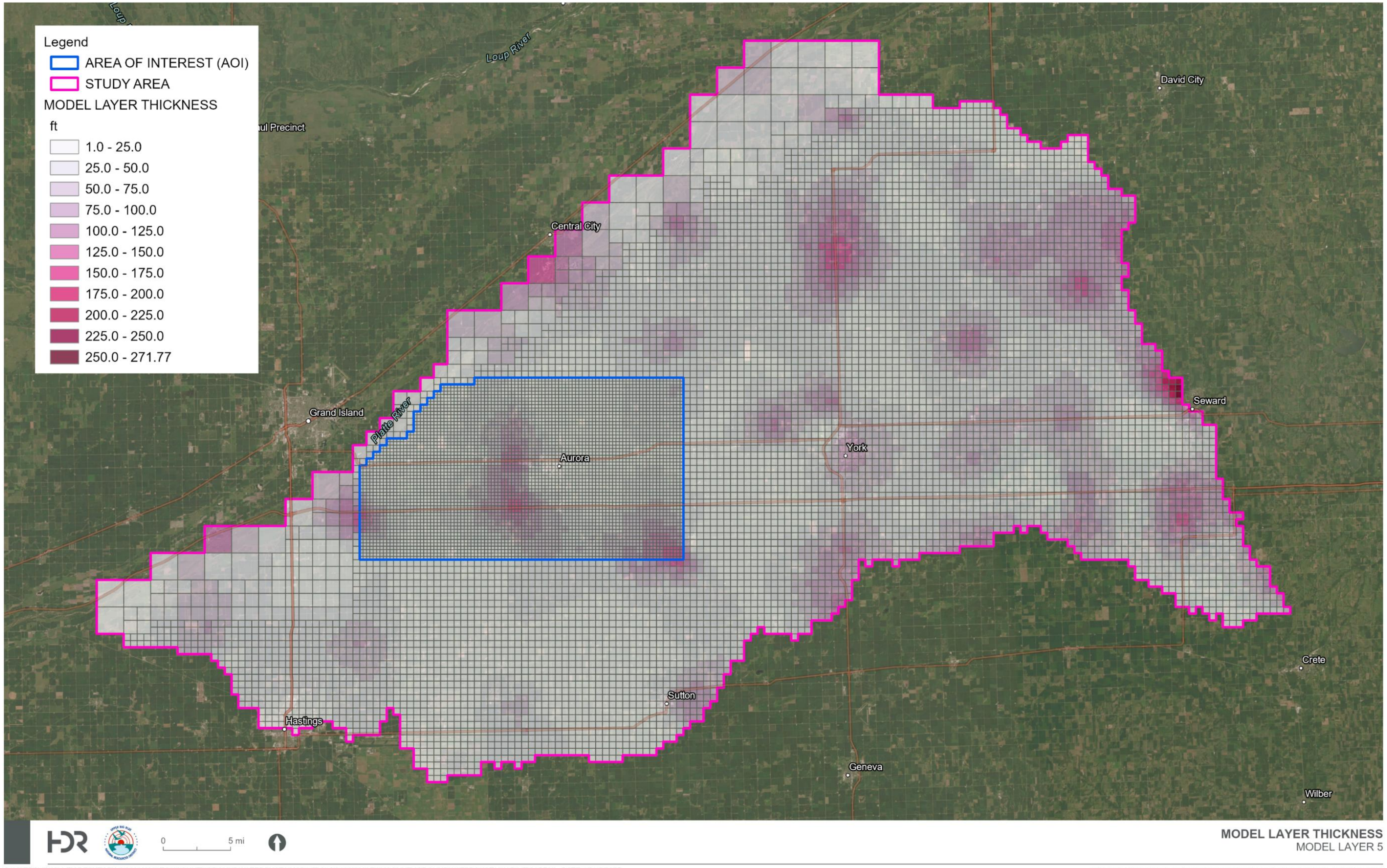


Figure 9. Thickness of Model Layer 5

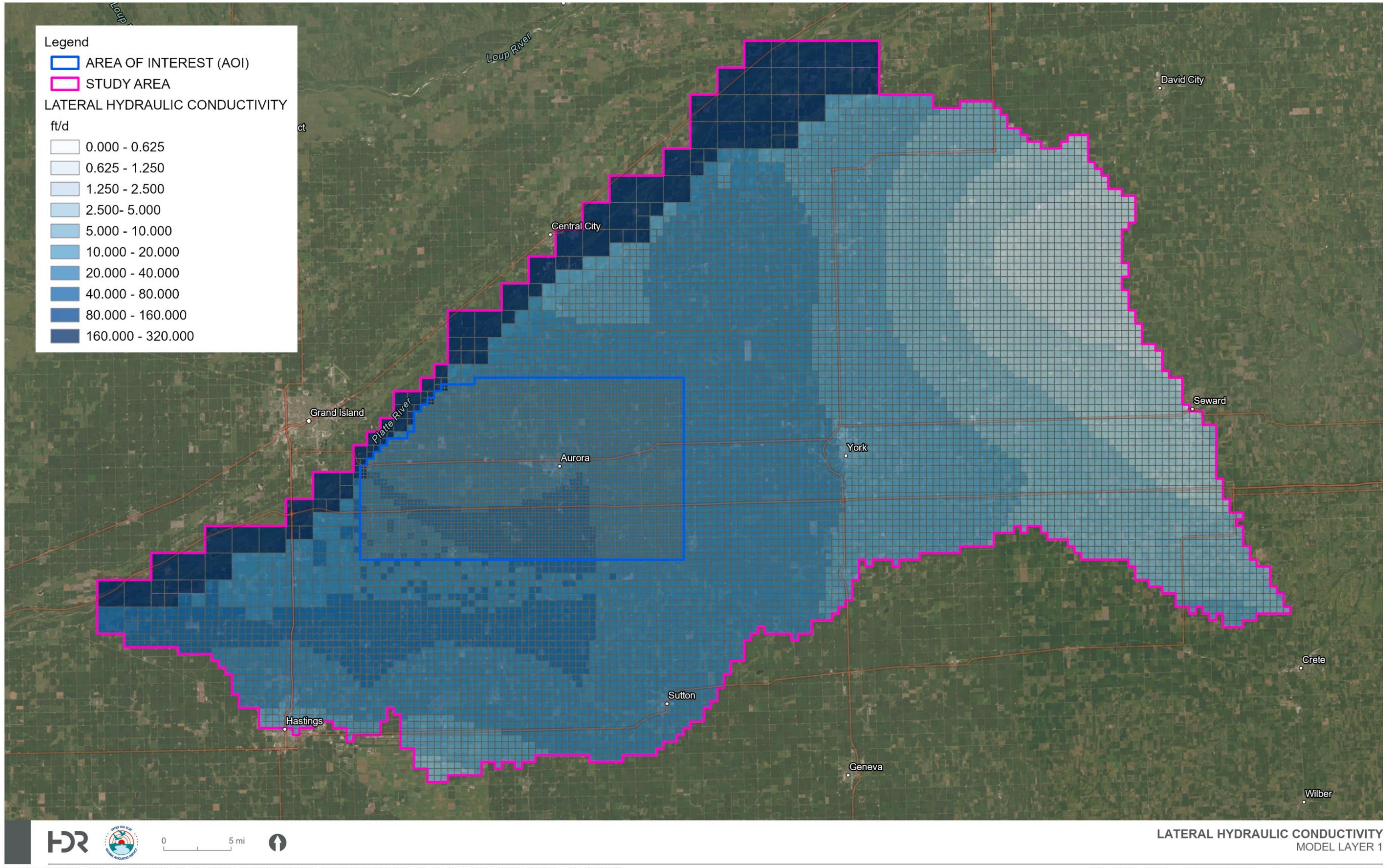


Figure 10. Lateral Hydraulic Conductivity in Model Layer 1

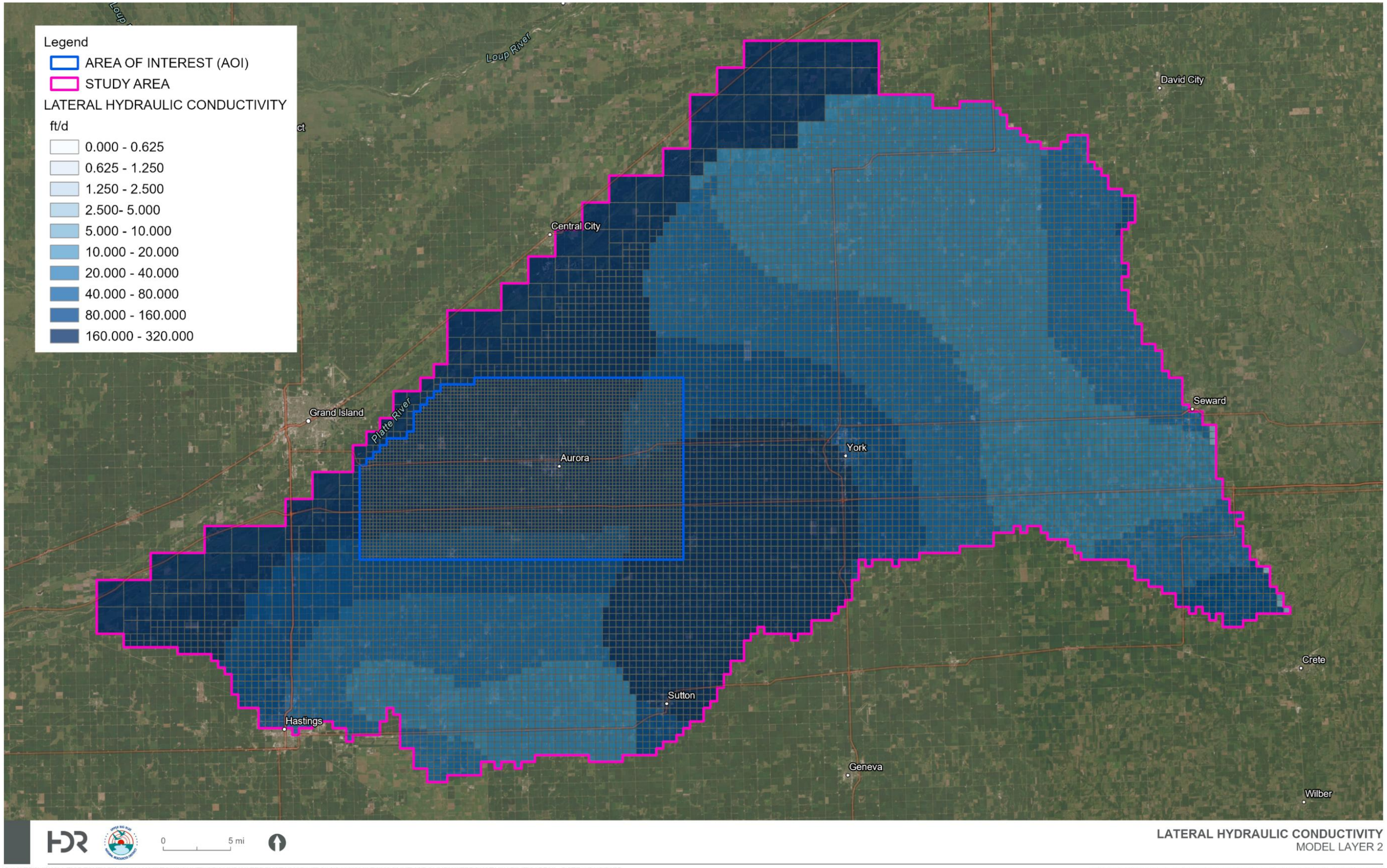


Figure 11. Lateral Hydraulic Conductivity in Model Layer 2

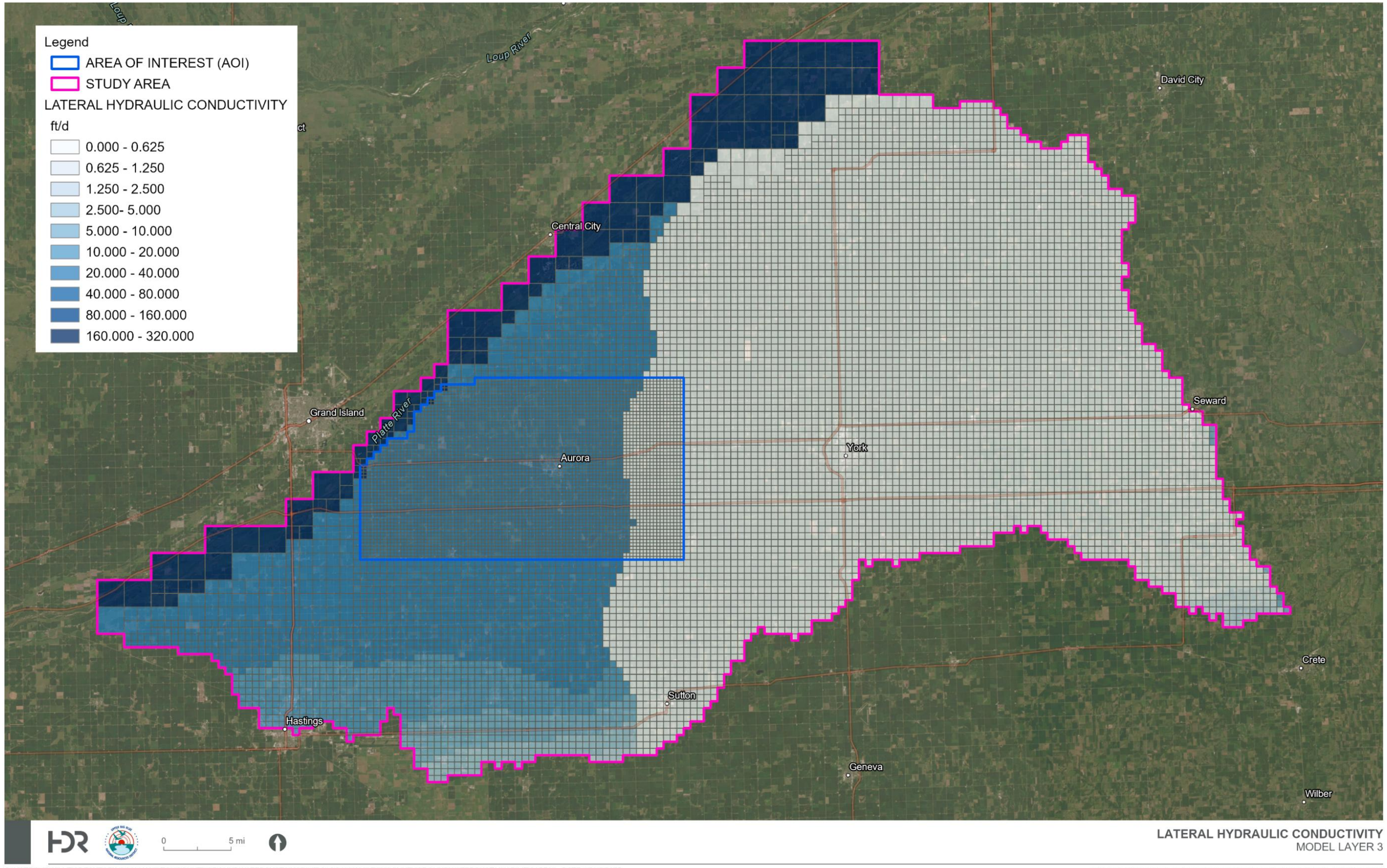


Figure 12. Lateral Hydraulic Conductivity in Model Layer 3

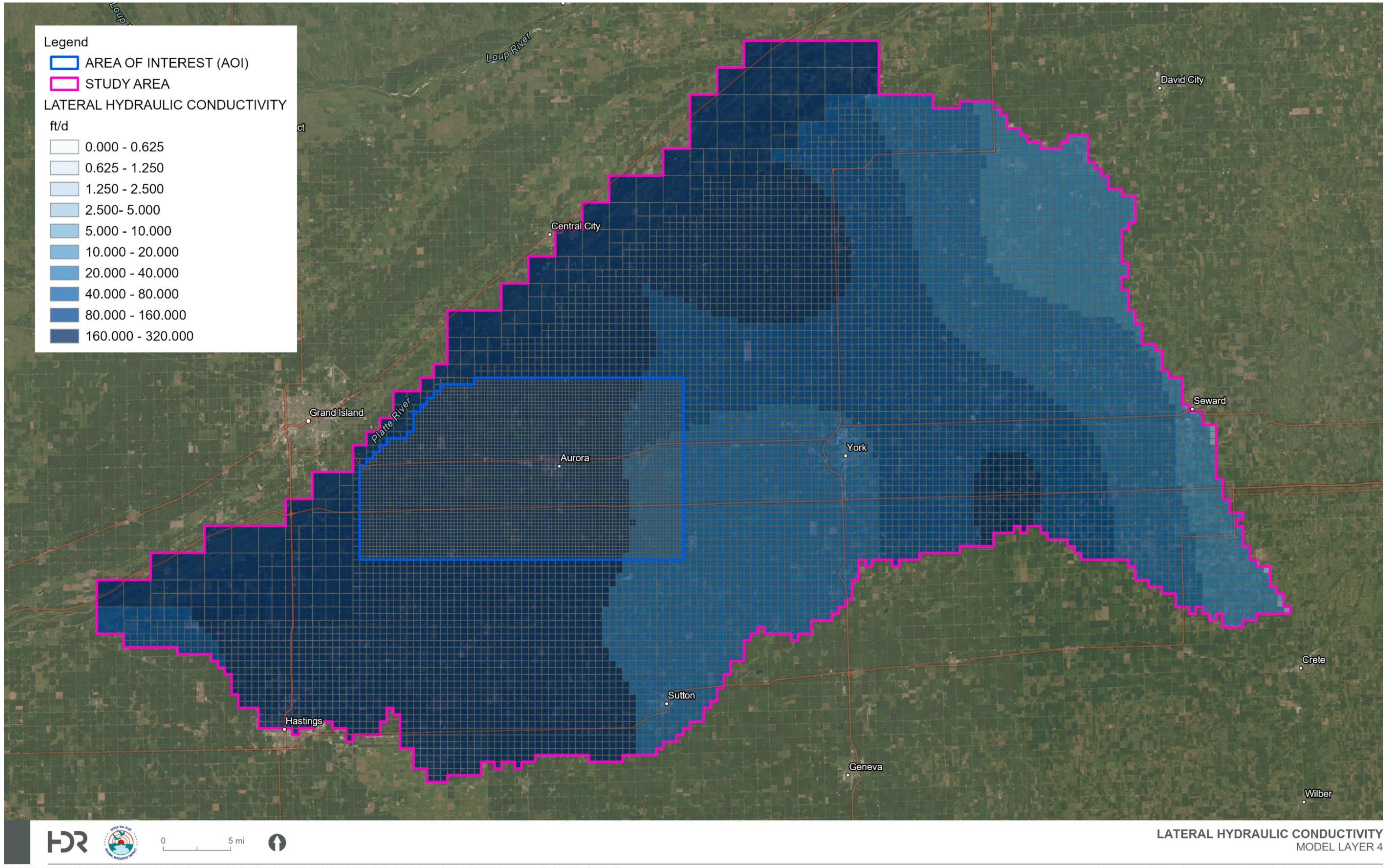


Figure 13. Lateral Hydraulic Conductivity in Model Layer 4

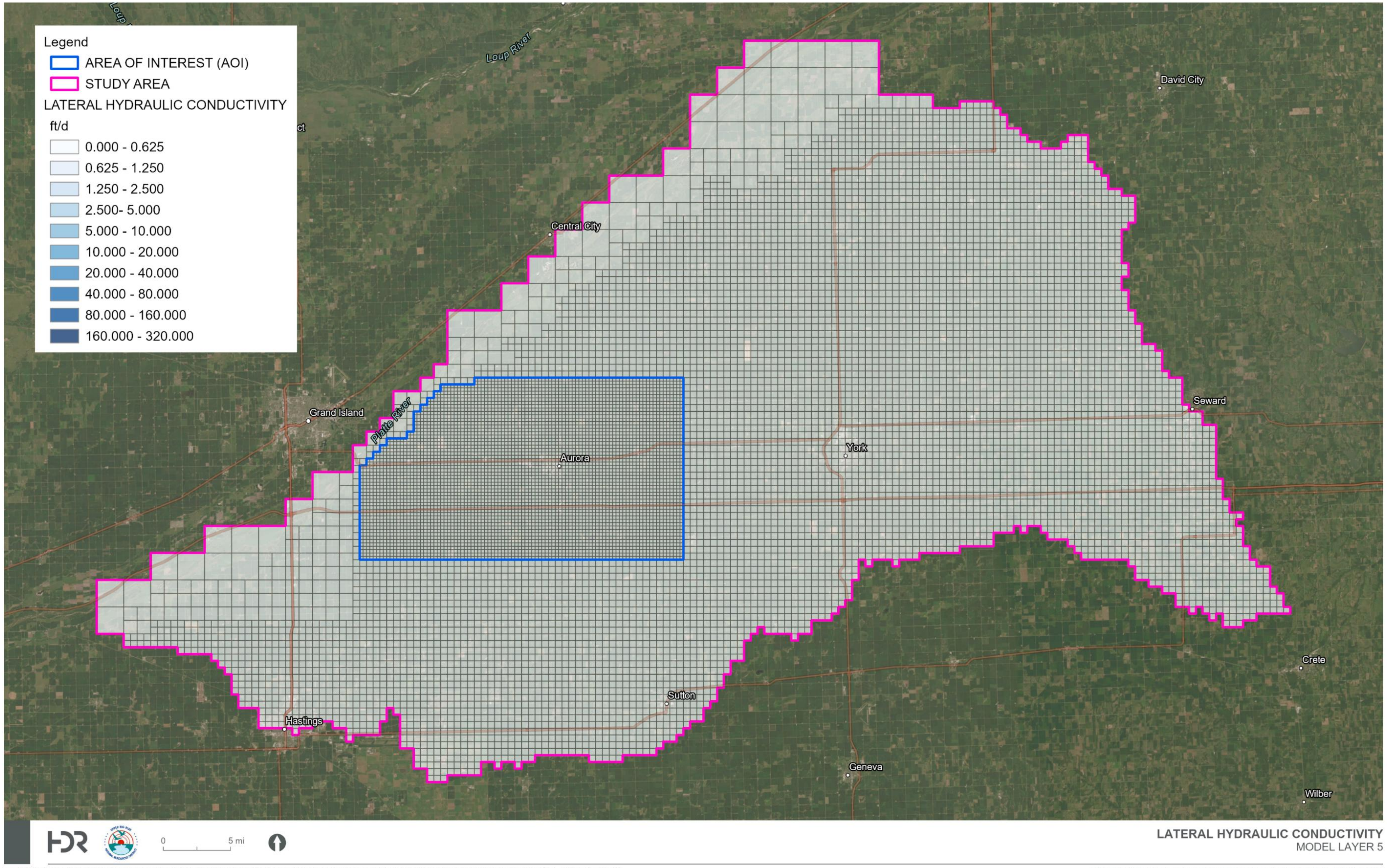


Figure 14. Lateral Hydraulic Conductivity in Model Layer 5

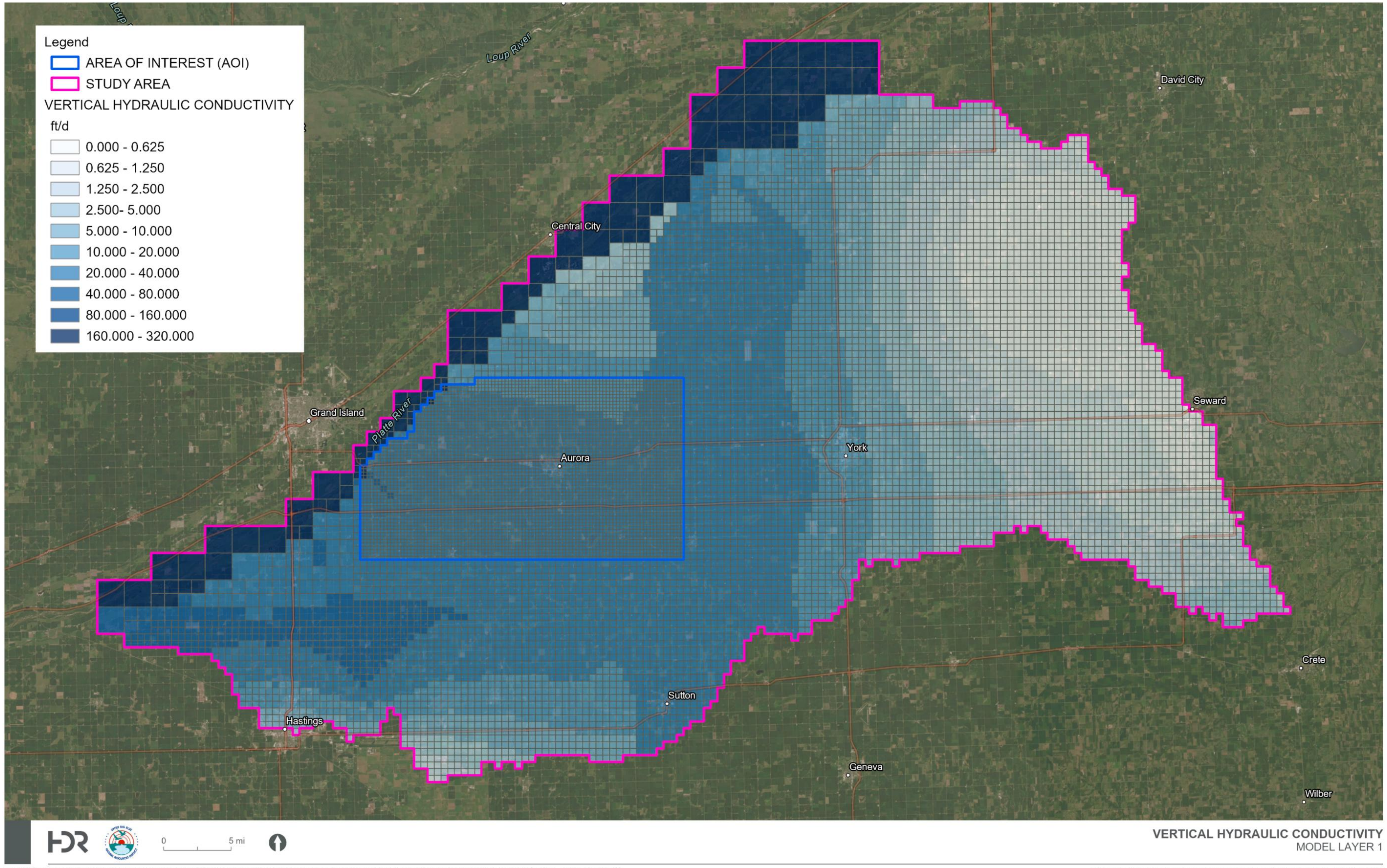


Figure 15. Vertical Hydraulic Conductivity in Model Layer 1

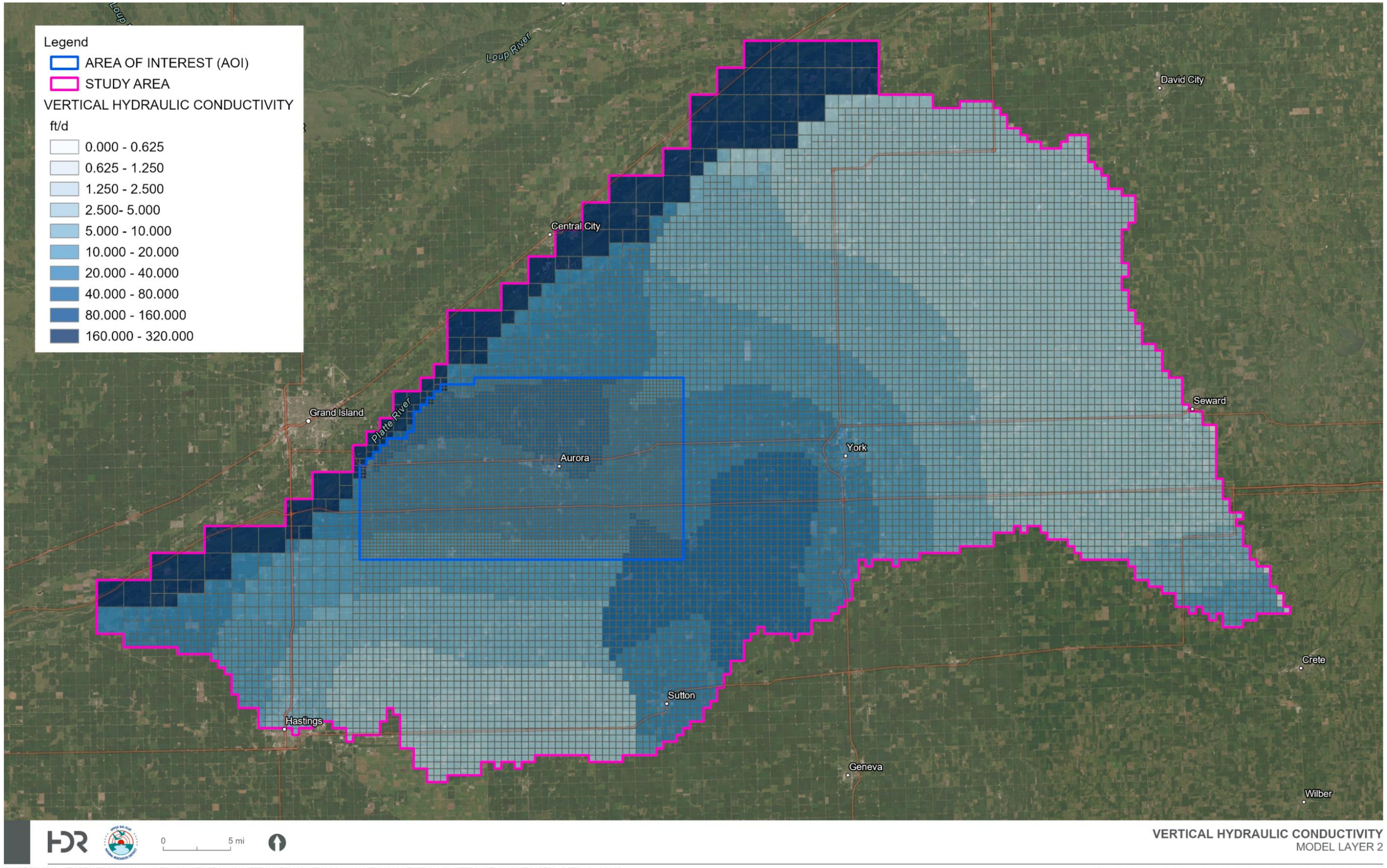


Figure 16. Vertical Hydraulic Conductivity in Model Layer 2

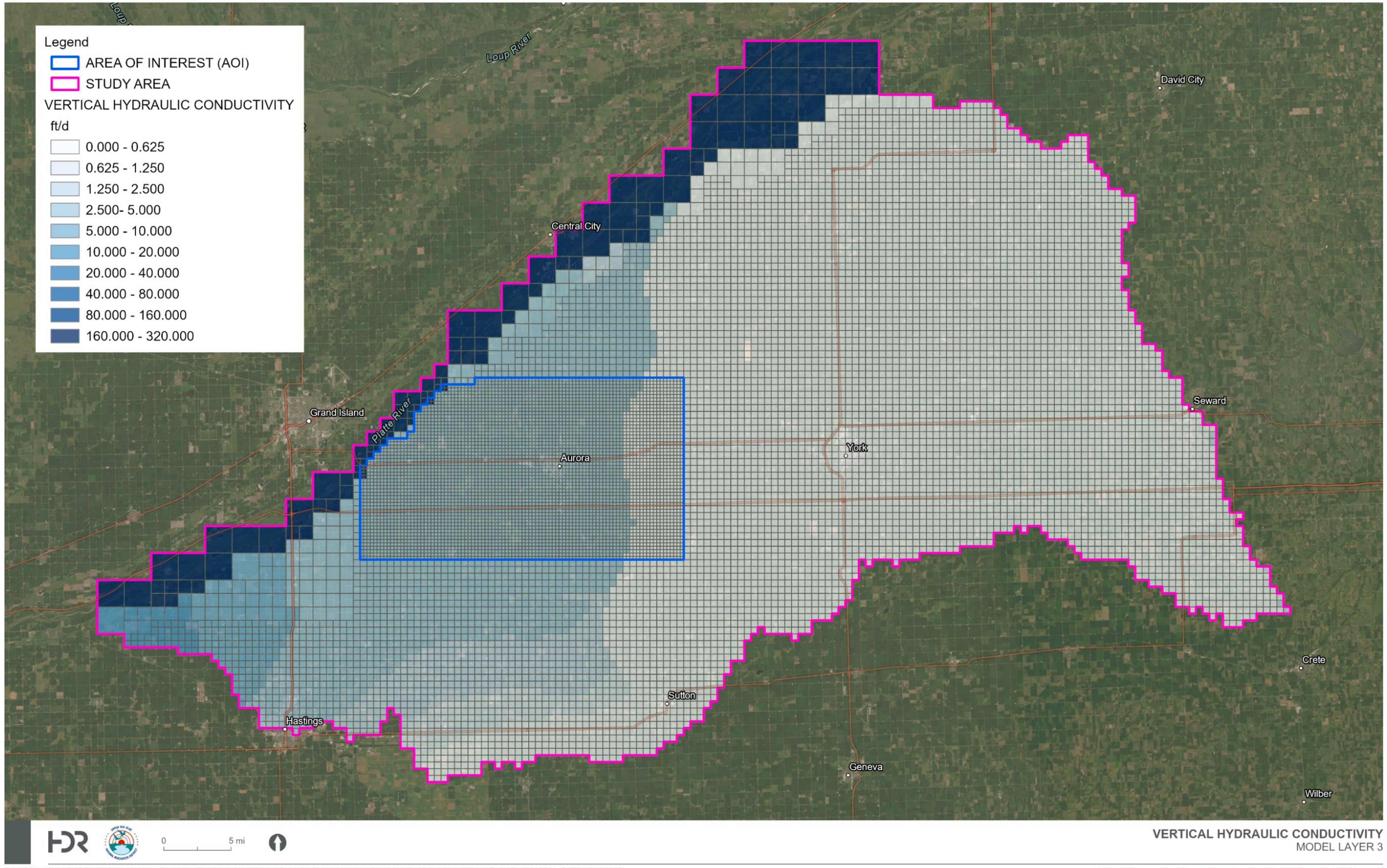


Figure 17. Vertical Hydraulic Conductivity in Model Layer 3

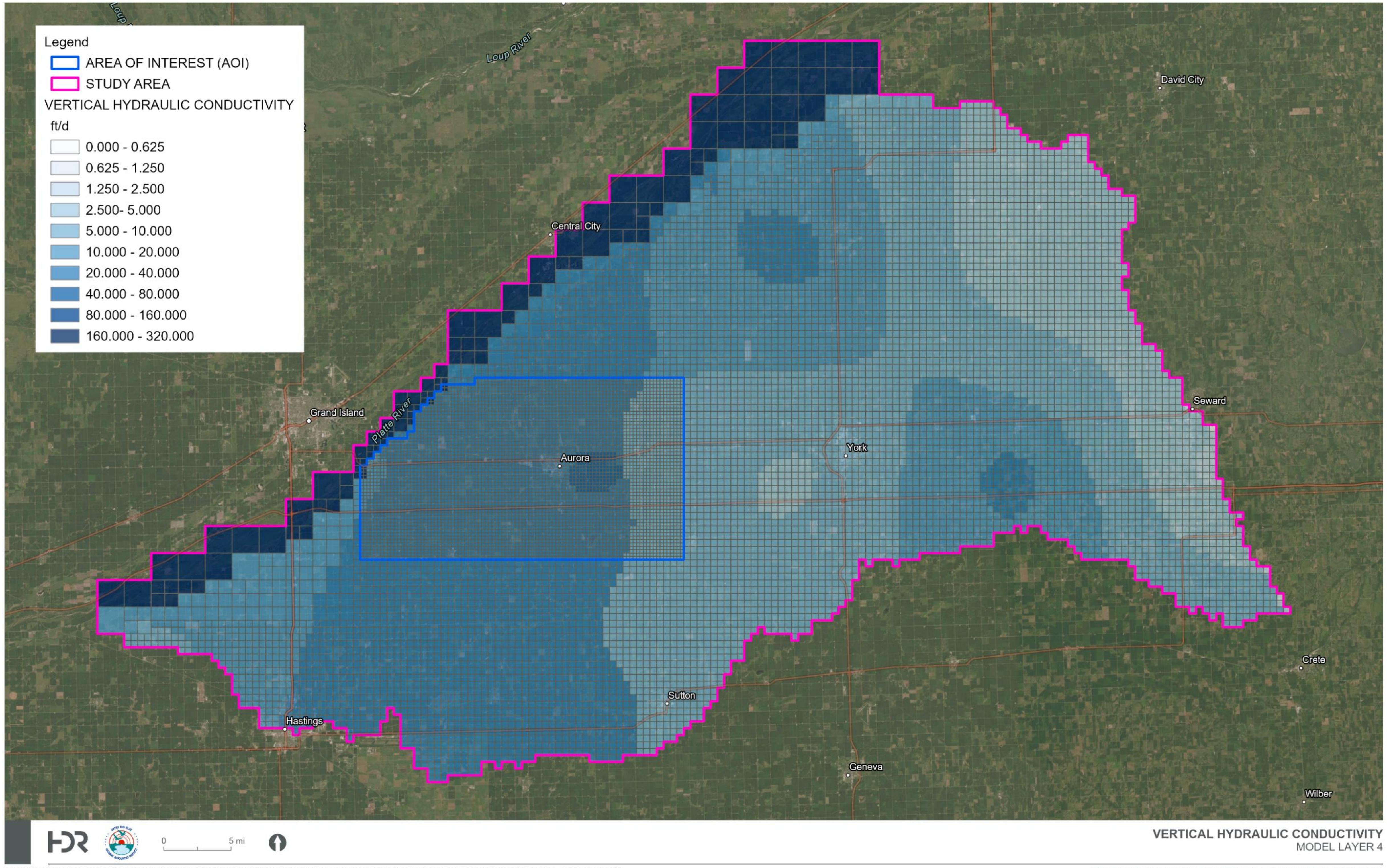


Figure 18. Vertical Hydraulic Conductivity in Model Layer 4

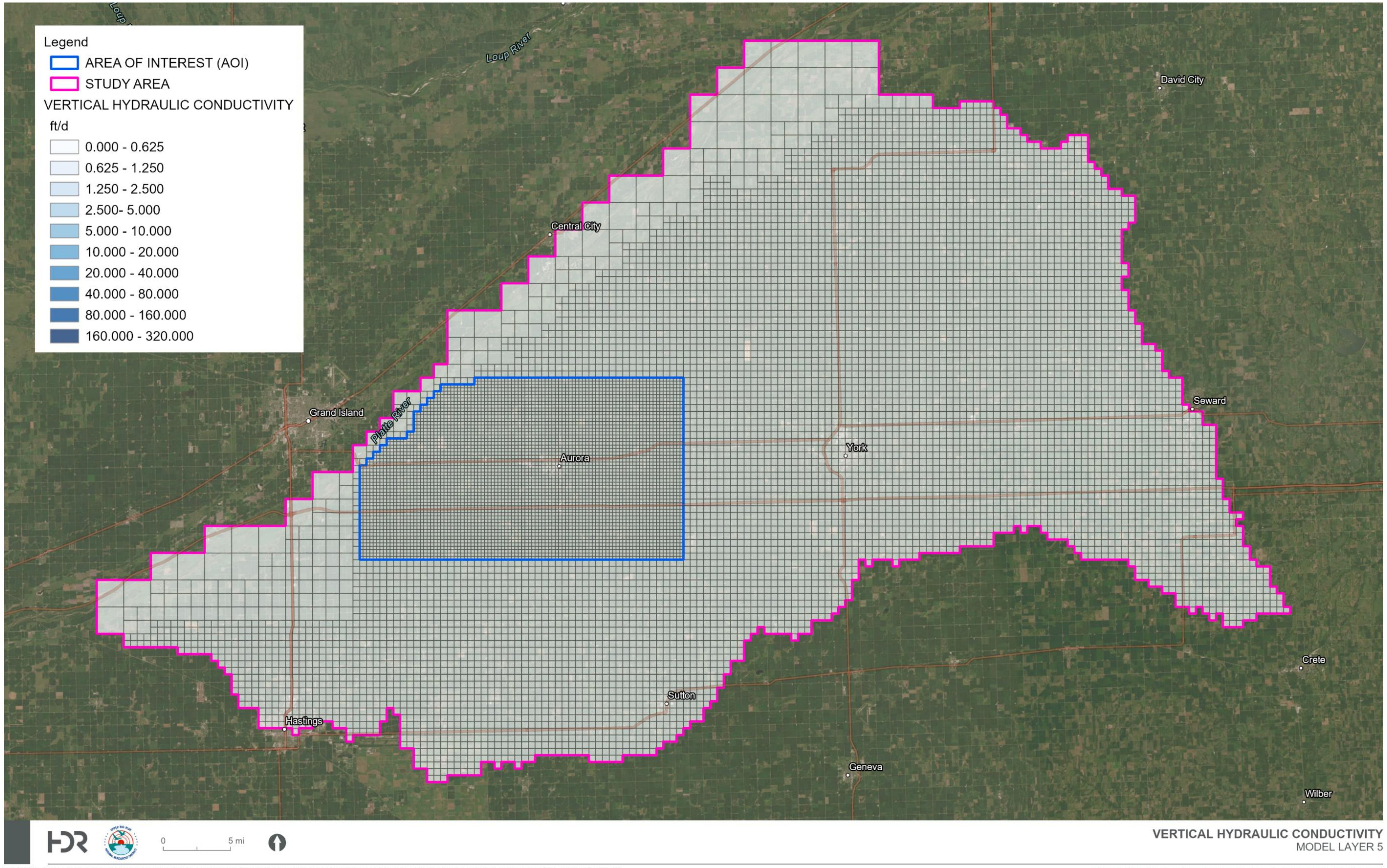


Figure 19. Vertical Hydraulic Conductivity in Model Layer 5

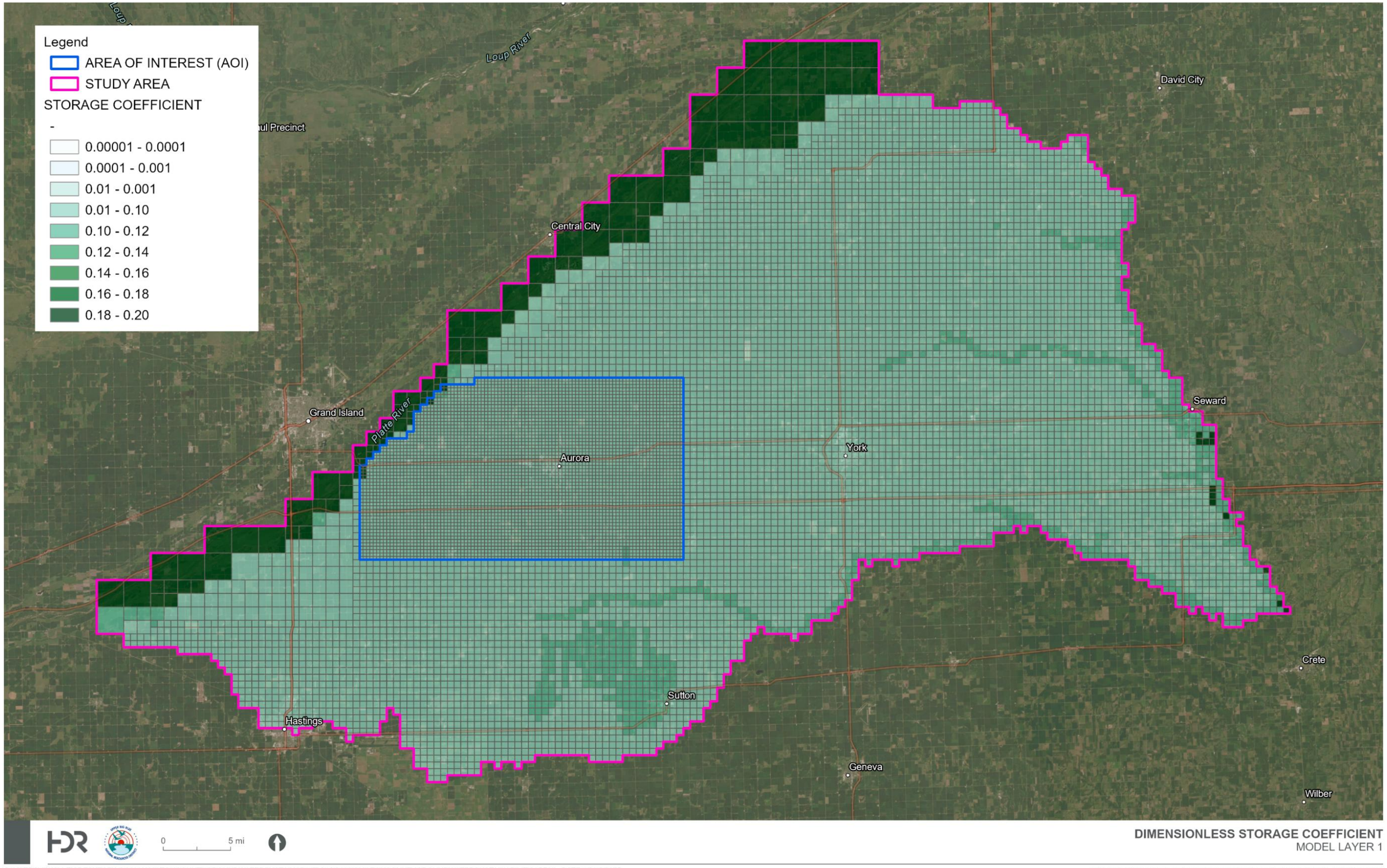


Figure 20. Dimensionless Storage Coefficient in Model Layer 1

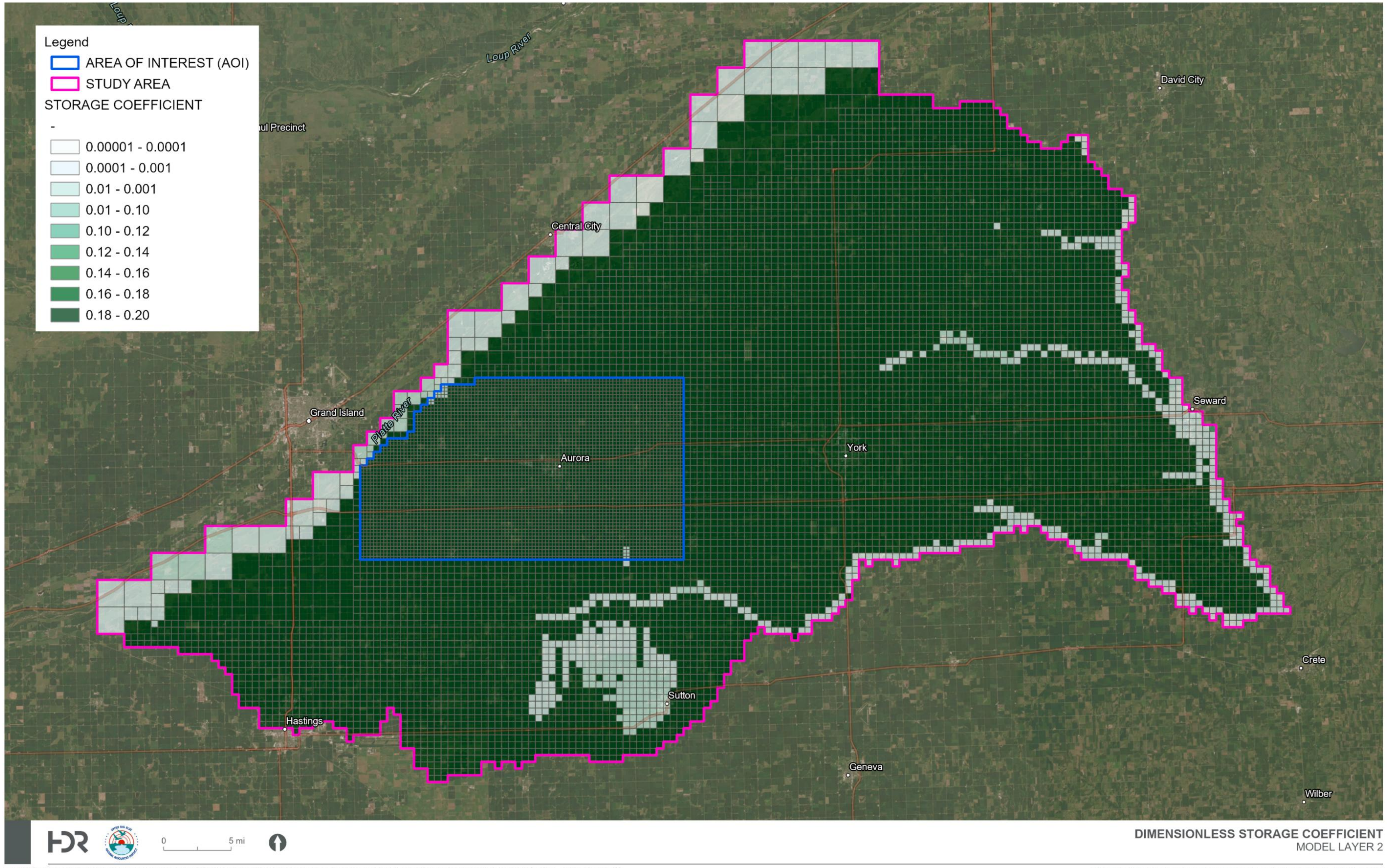


Figure 21. Dimensionless Storage Coefficient in Model Layer 1

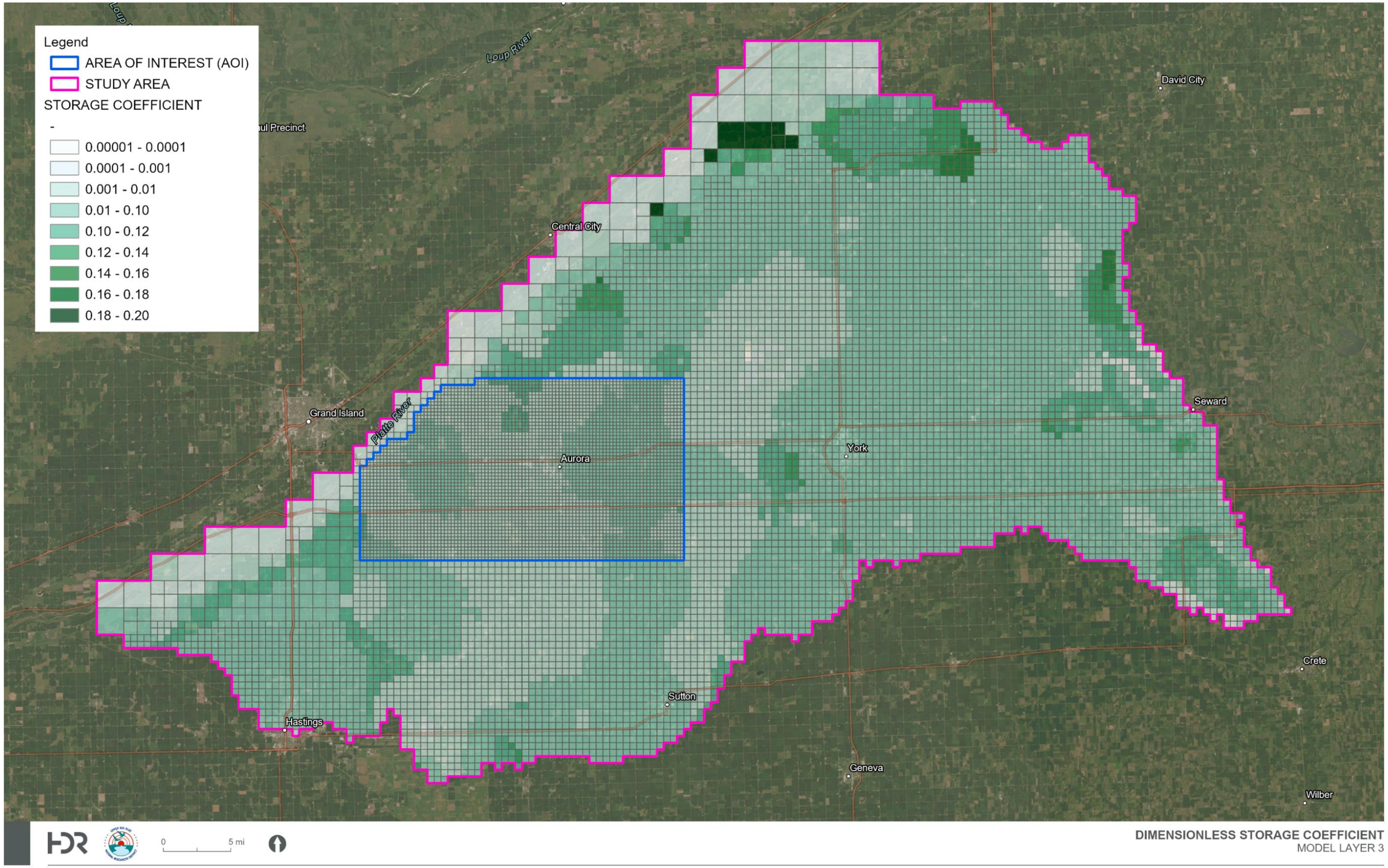


Figure 22. Dimensionless Storage Coefficient in Model Layer 3

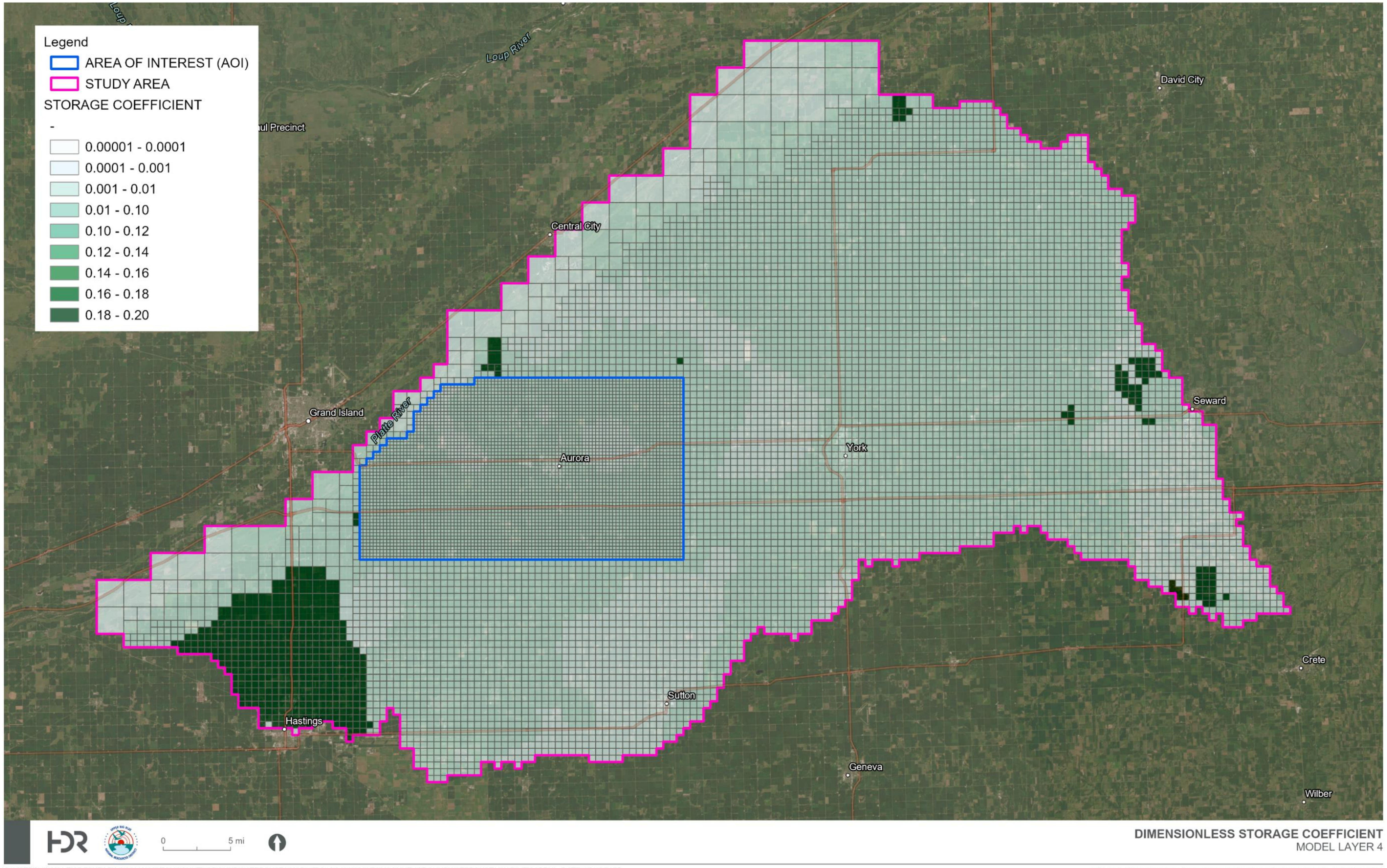


Figure 23. Dimensionless Storage Coefficient in Model Layer 4

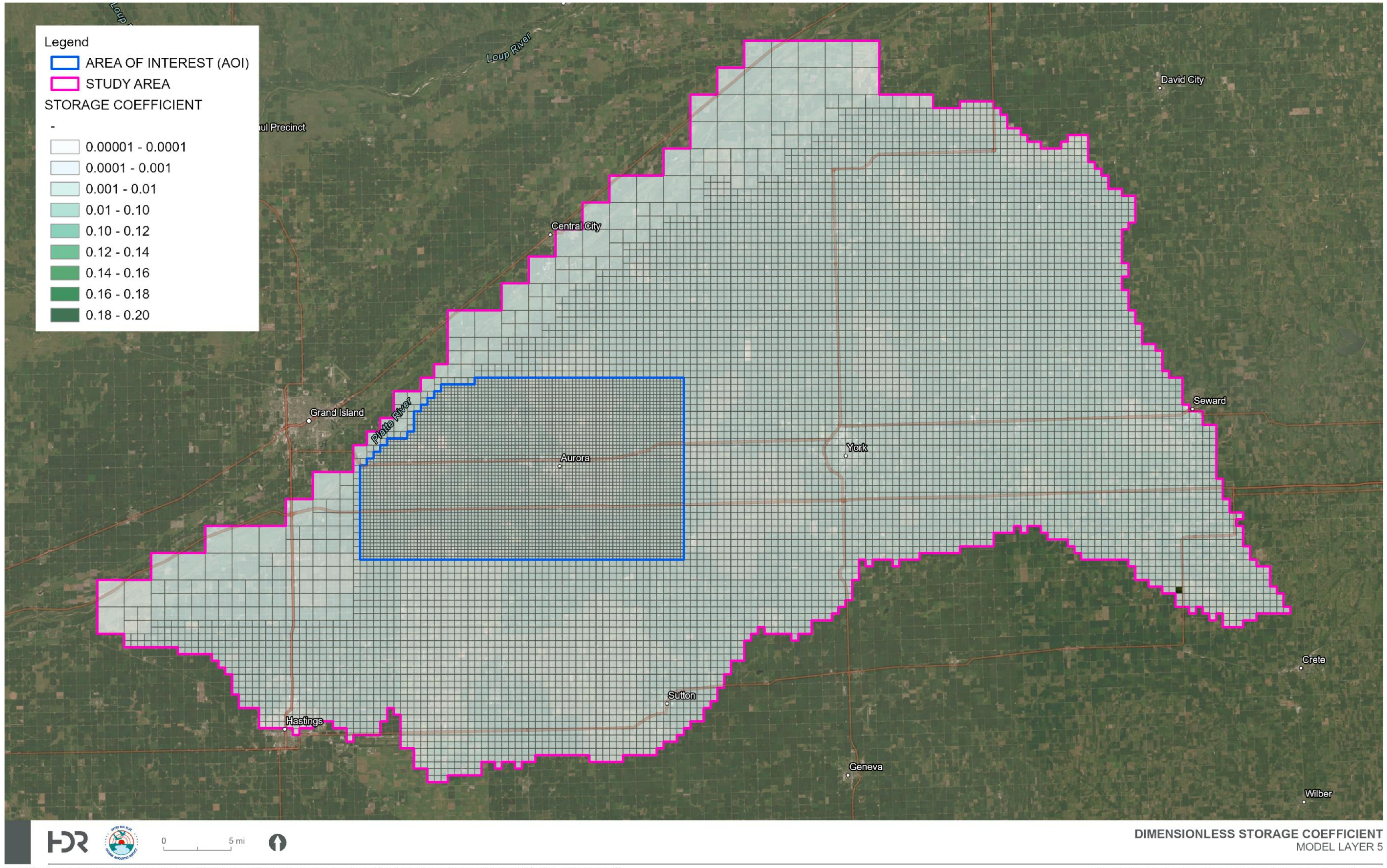


Figure 24. Dimensionless Storage Coefficient in Model Layer 5

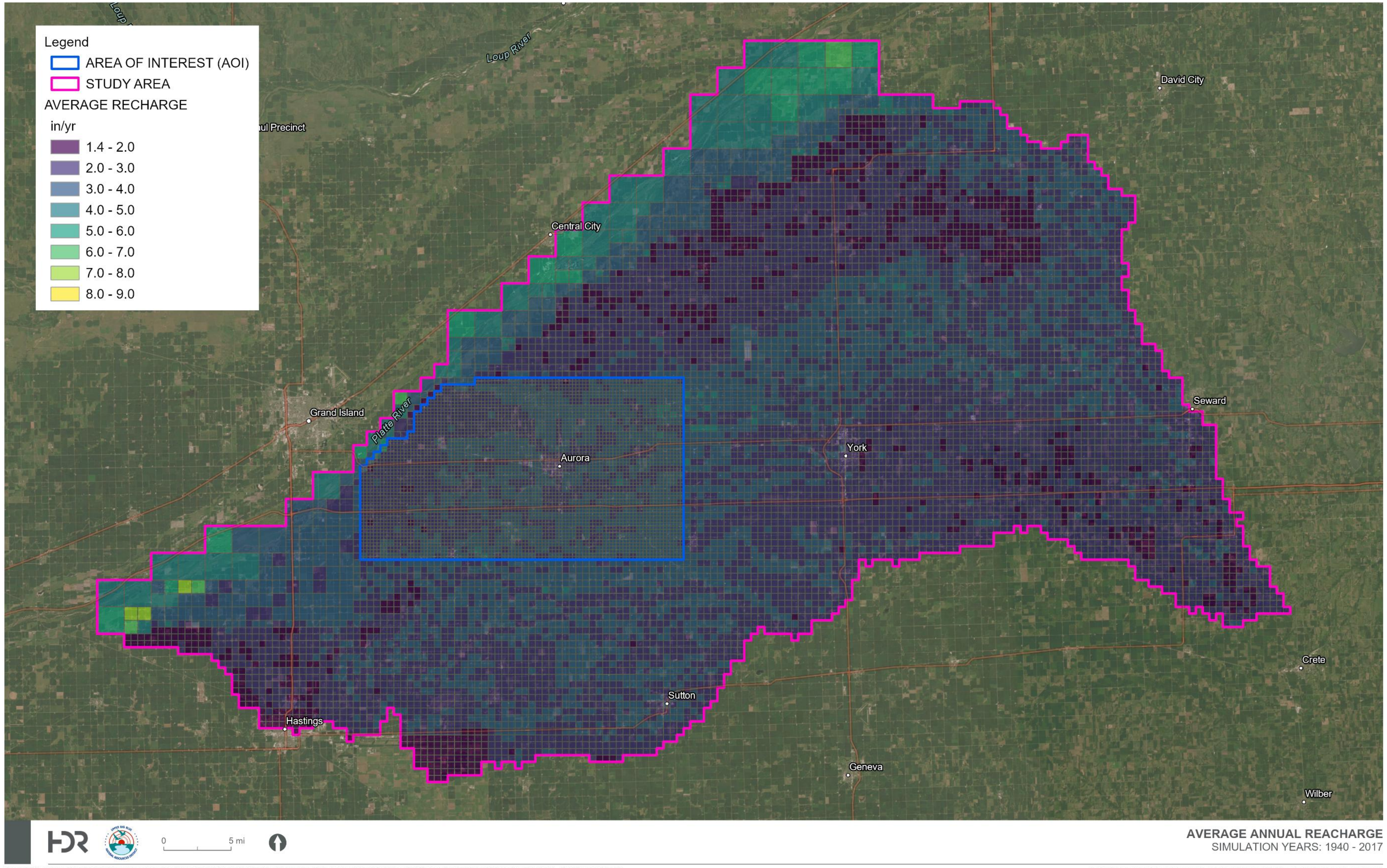


Figure 25. Average Annual Recharge During the Historical Period (1940–2017)

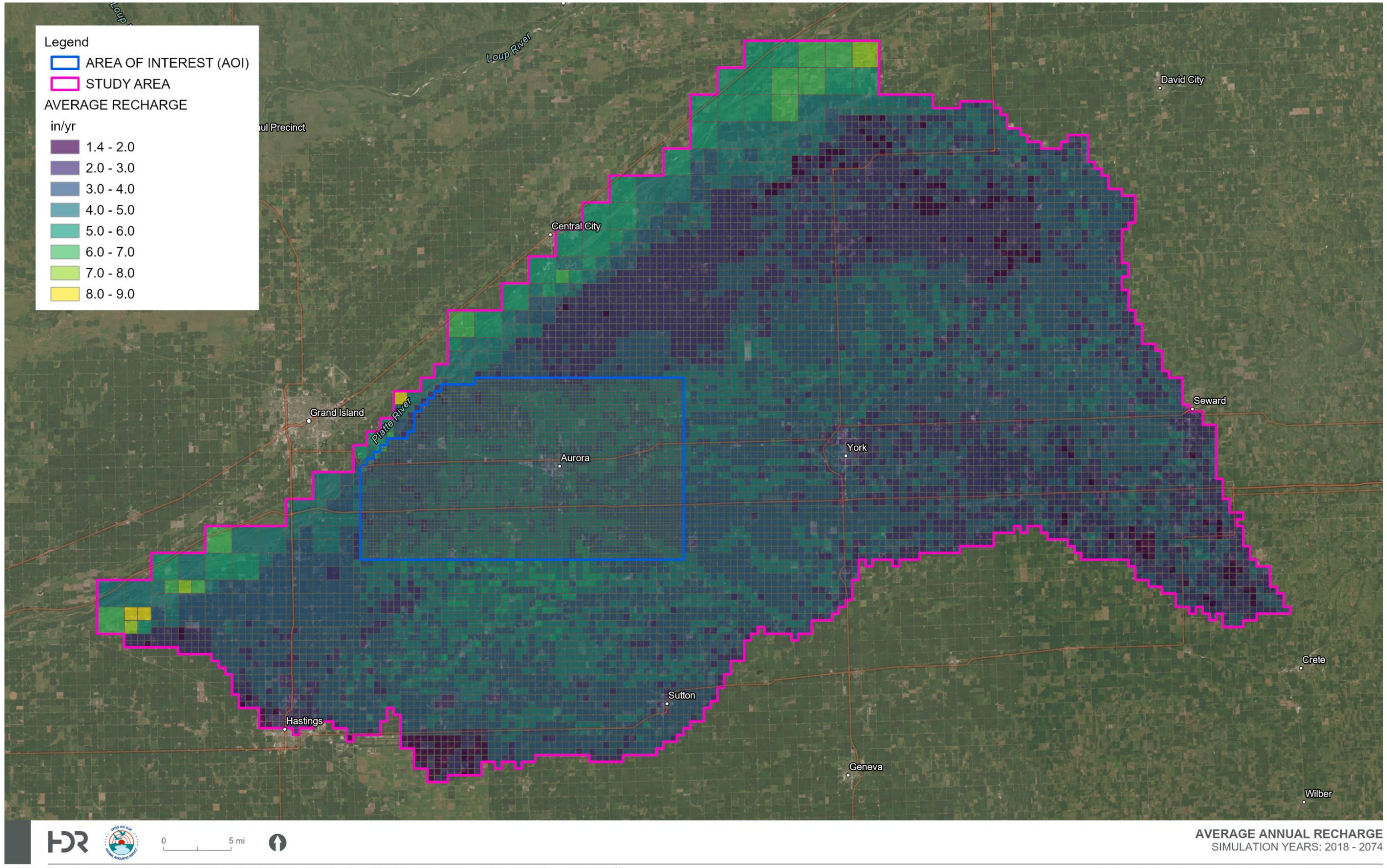


Figure 26. Average Annual Recharge During the Historical Period (2018–2024) and Projection Period (2025–2074)

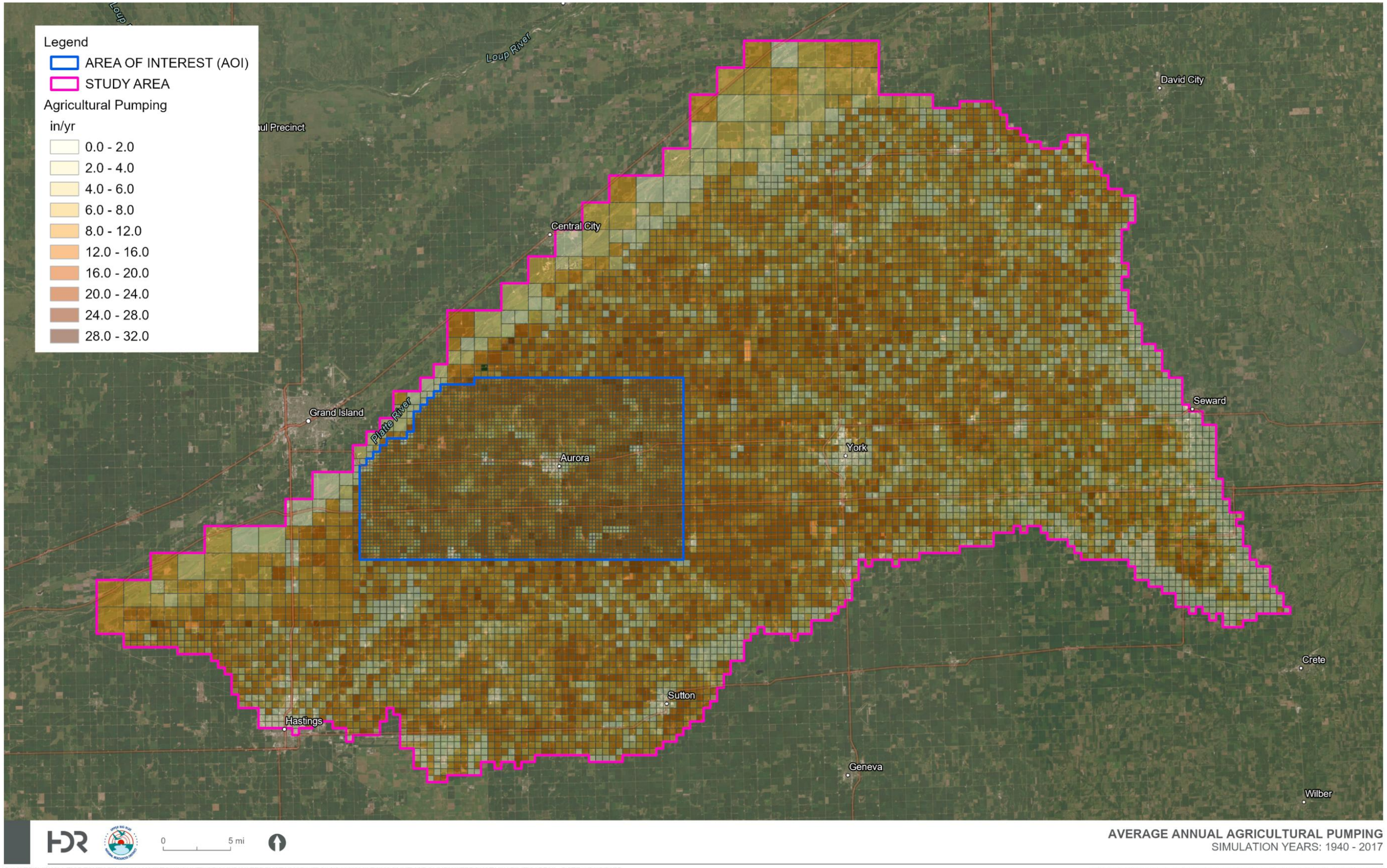


Figure 27. Average Annual Agricultural Pumping During the Historical Period (1940–2017)

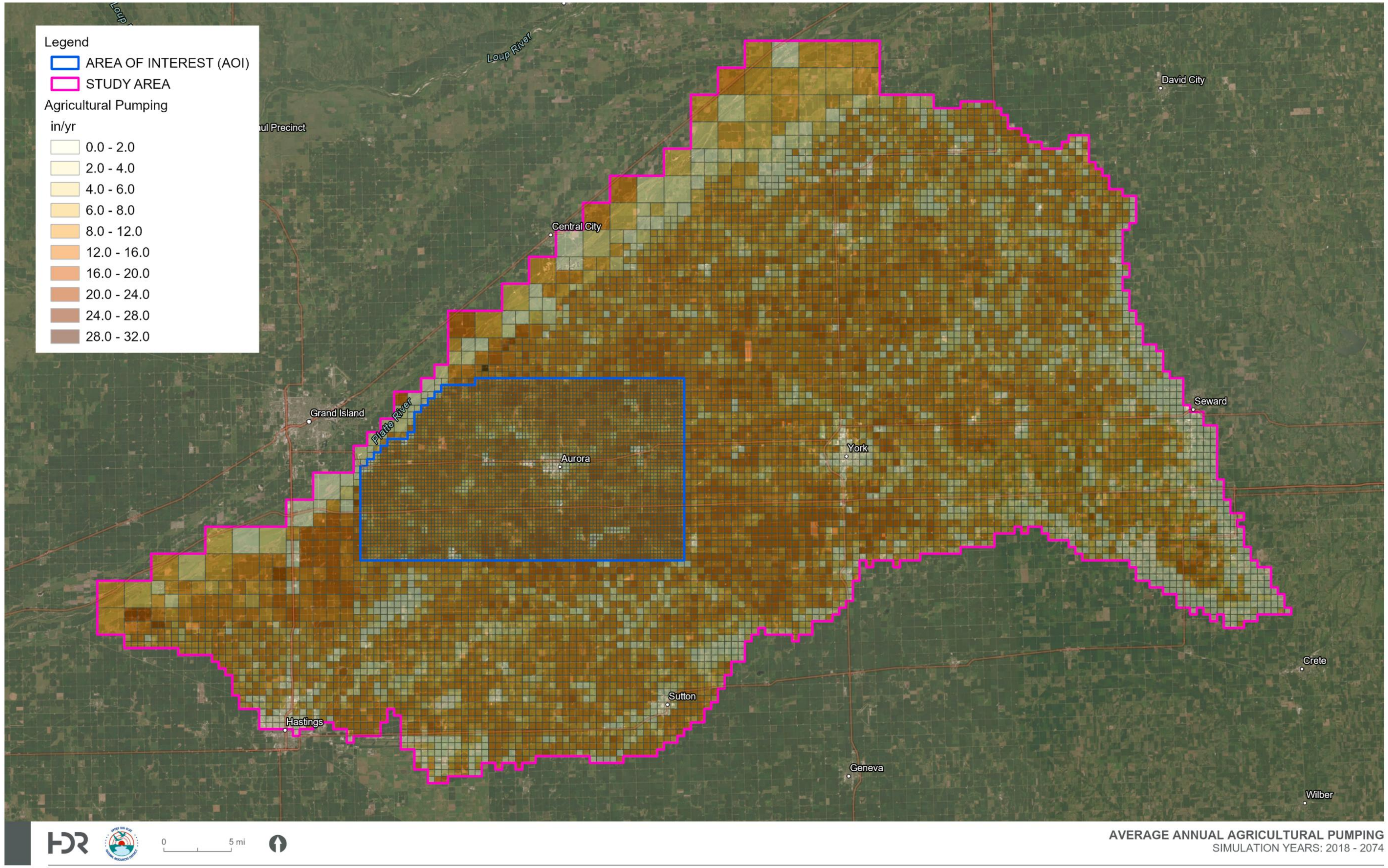


Figure 28. Average Annual Agricultural Pumping During the Historical Period (2018–2024) and Projection Period (2025–2074)

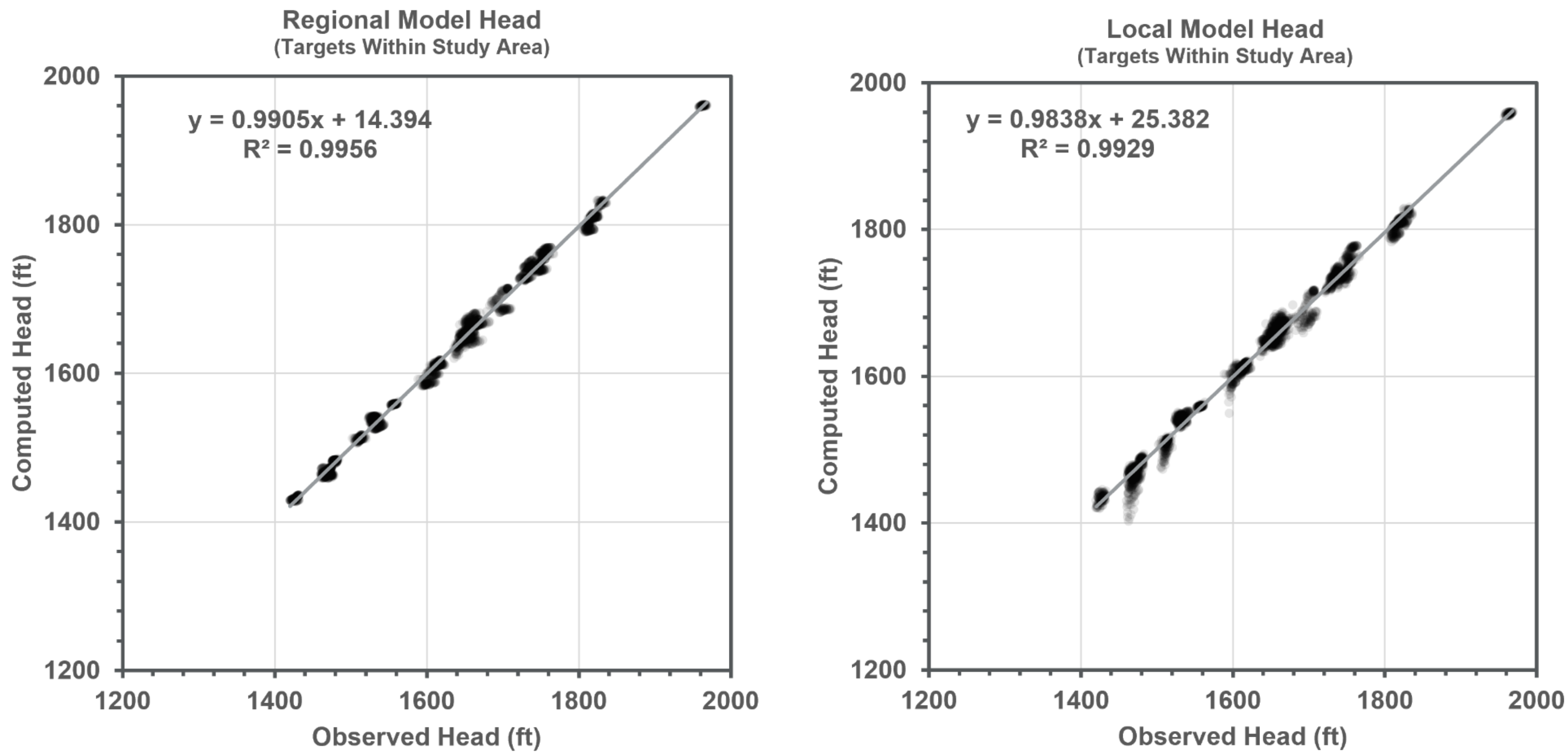


Figure 29. Comparison of Regional and Local Model Fit to Head Targets

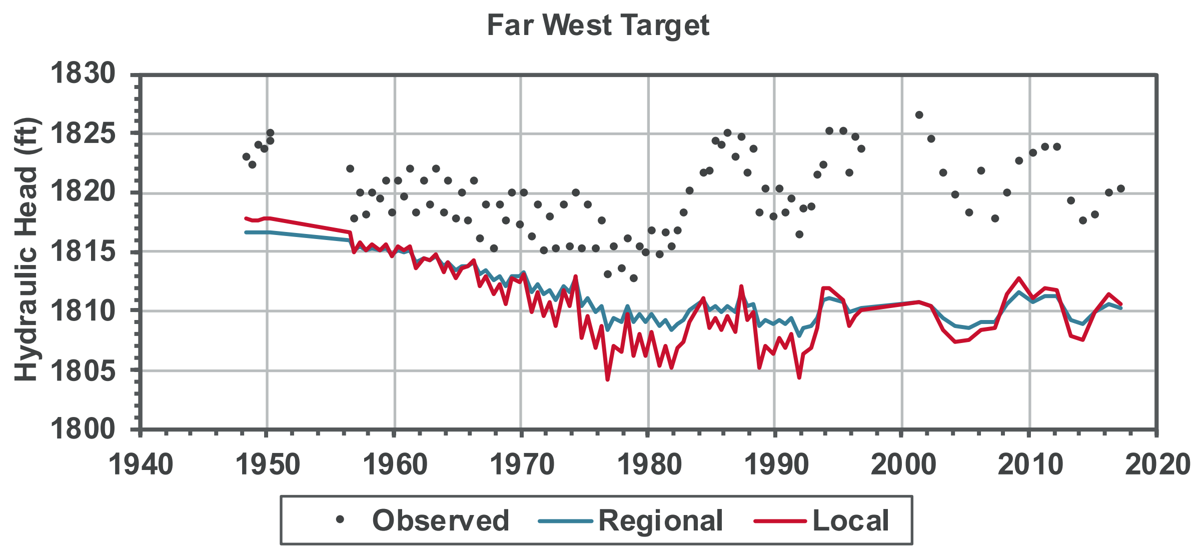


Figure 30. Head Target Performance in Area of Interest

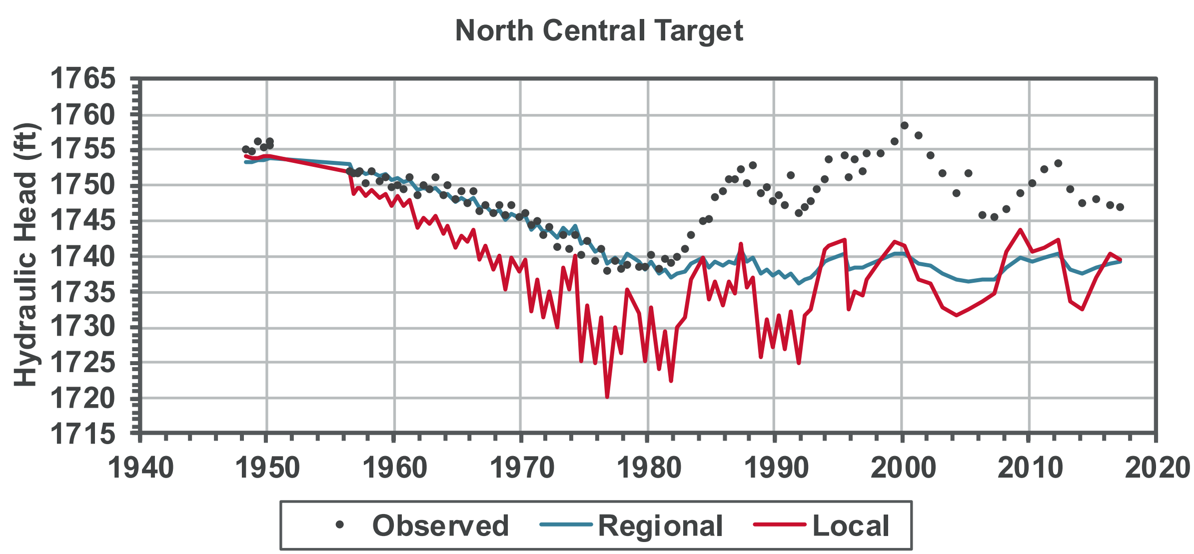


Figure 31. Head Target Performance in Area of Interest

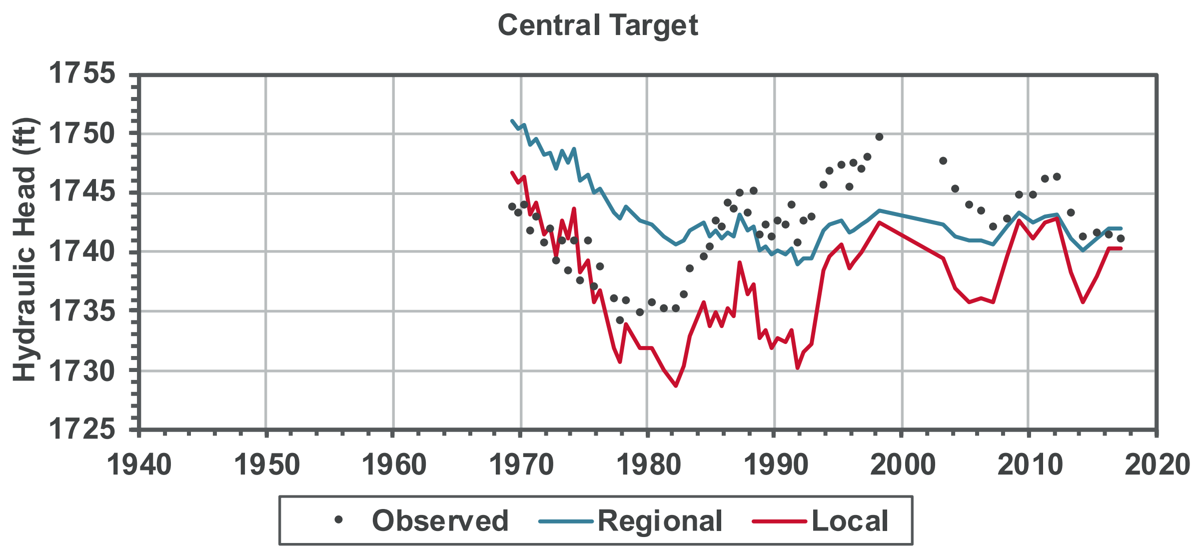


Figure 32. Head Target Performance in Area of Interest

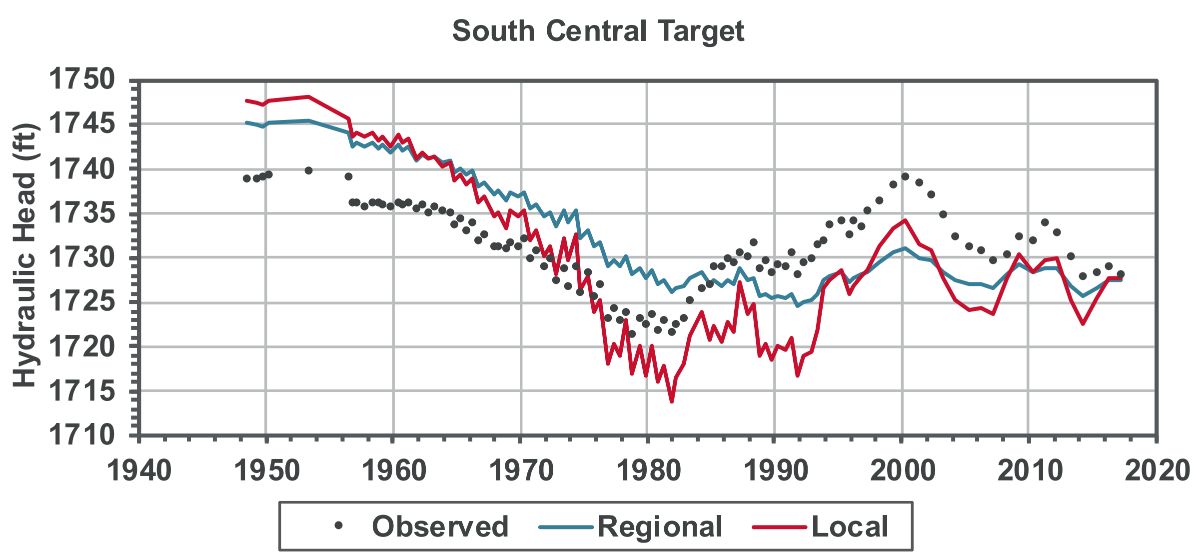


Figure 33. Head Target Performance in Area of Interest

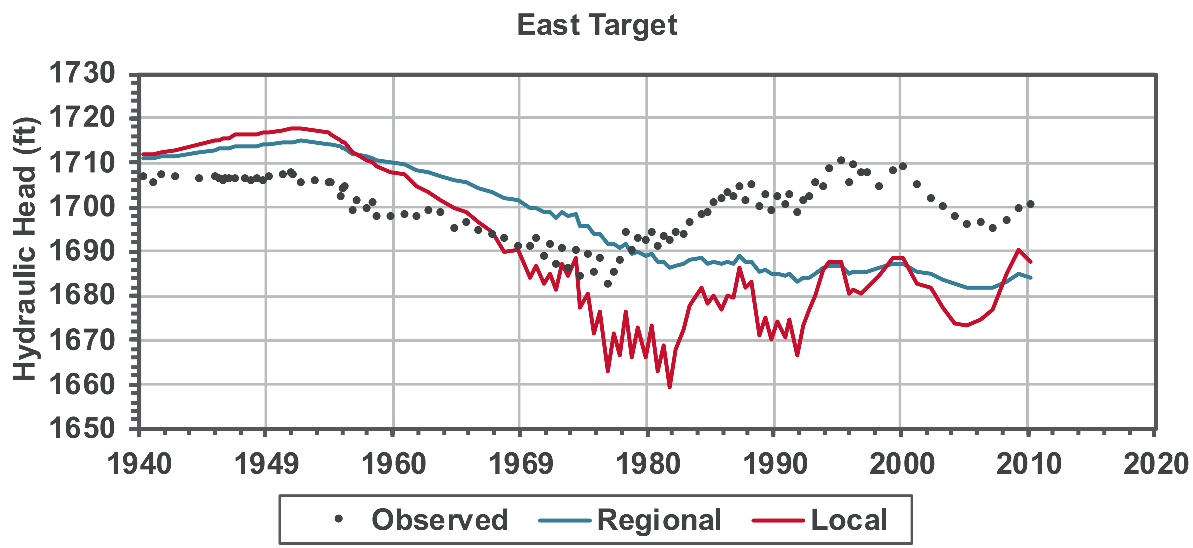


Figure 34. Head Target Performance in Area of Interest

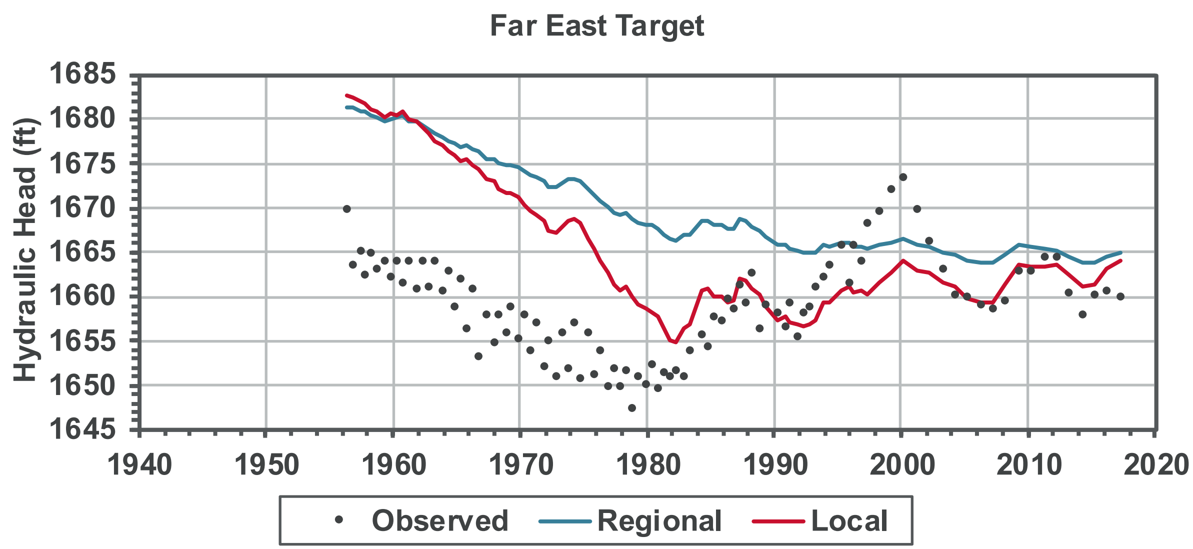


Figure 35. Head Target Performance in Area of Interest

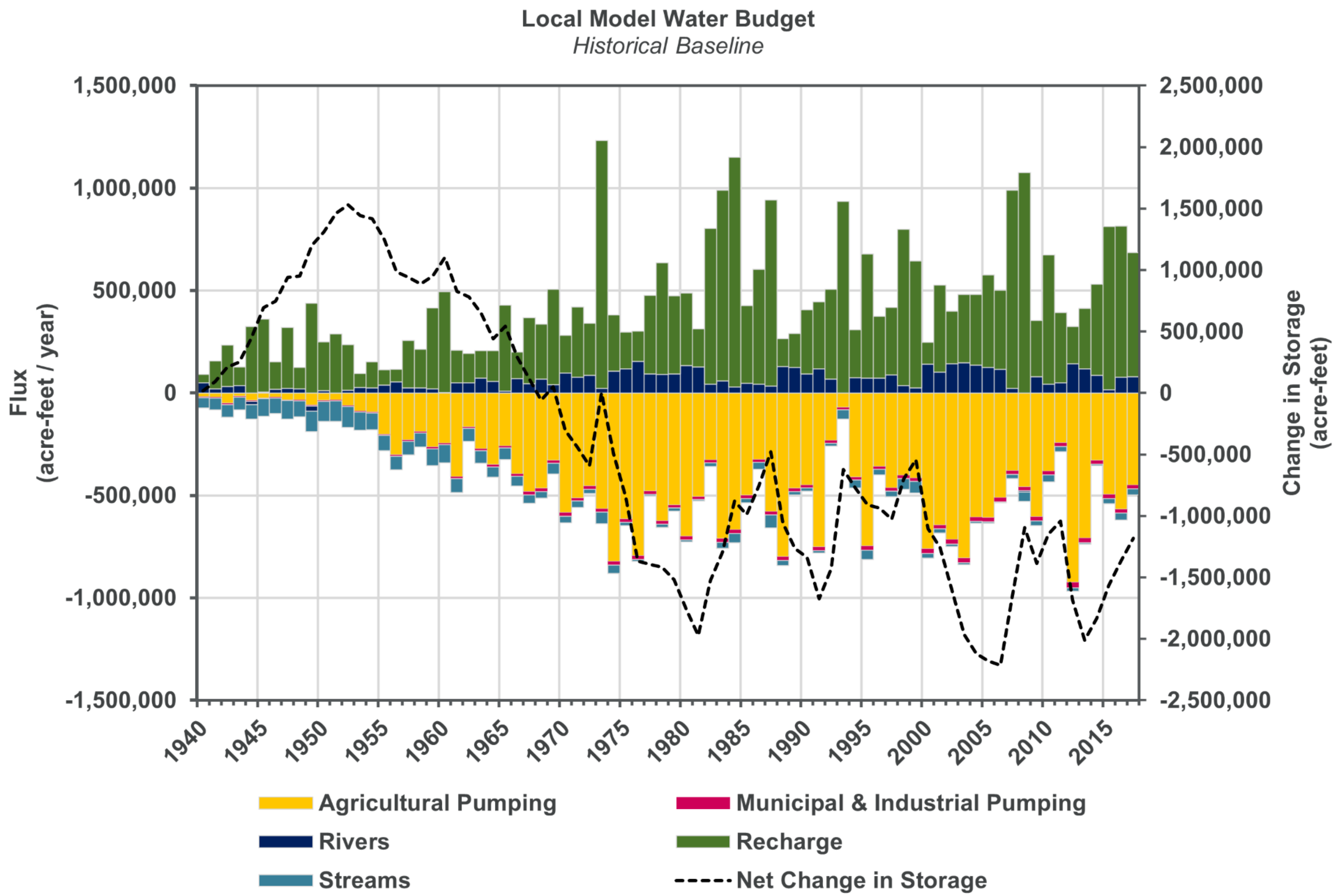


Figure 36. Historical Baseline Water Budget

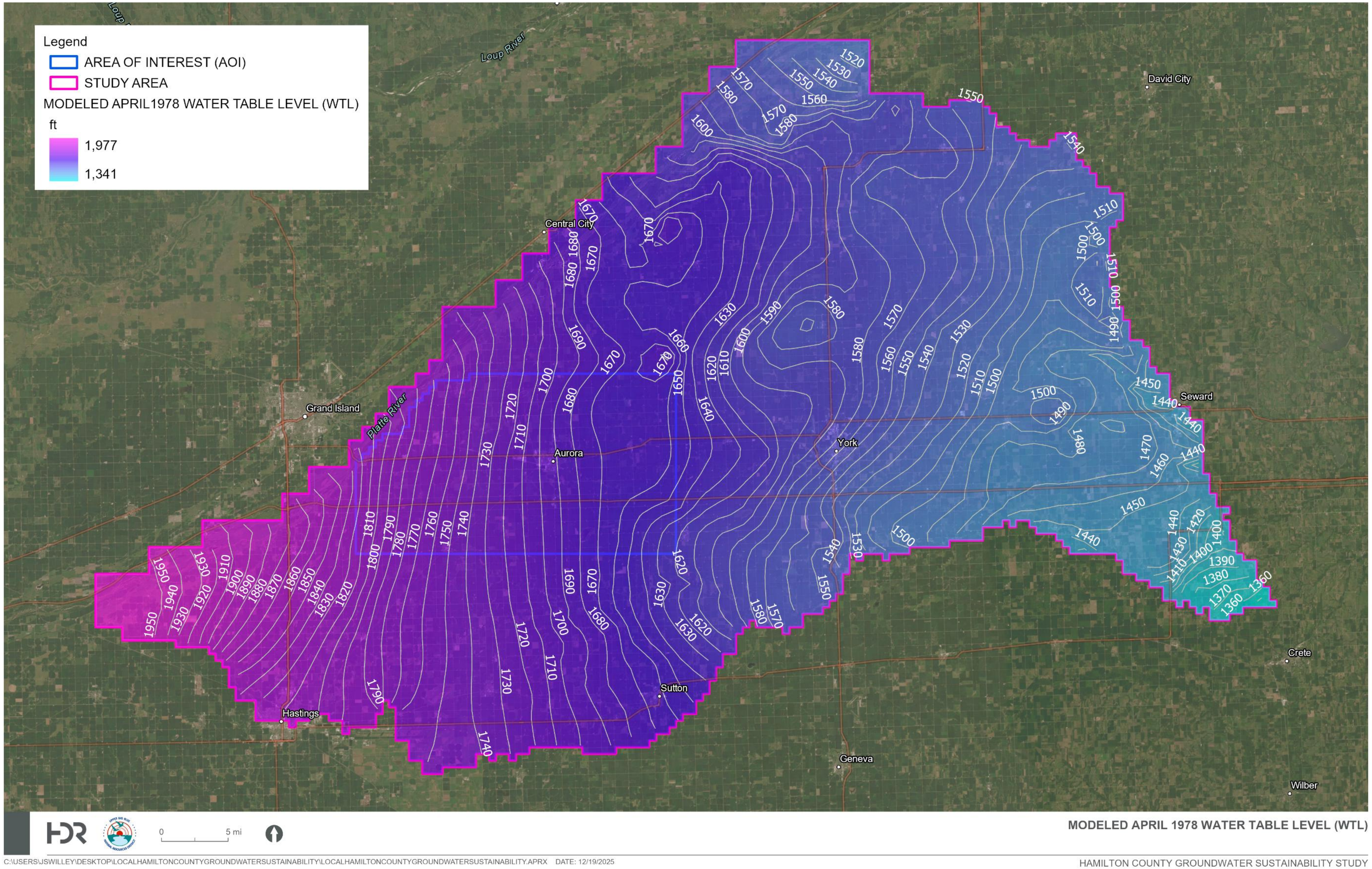


Figure 37. Modeled April 1978 Water-Table Level (WTL)

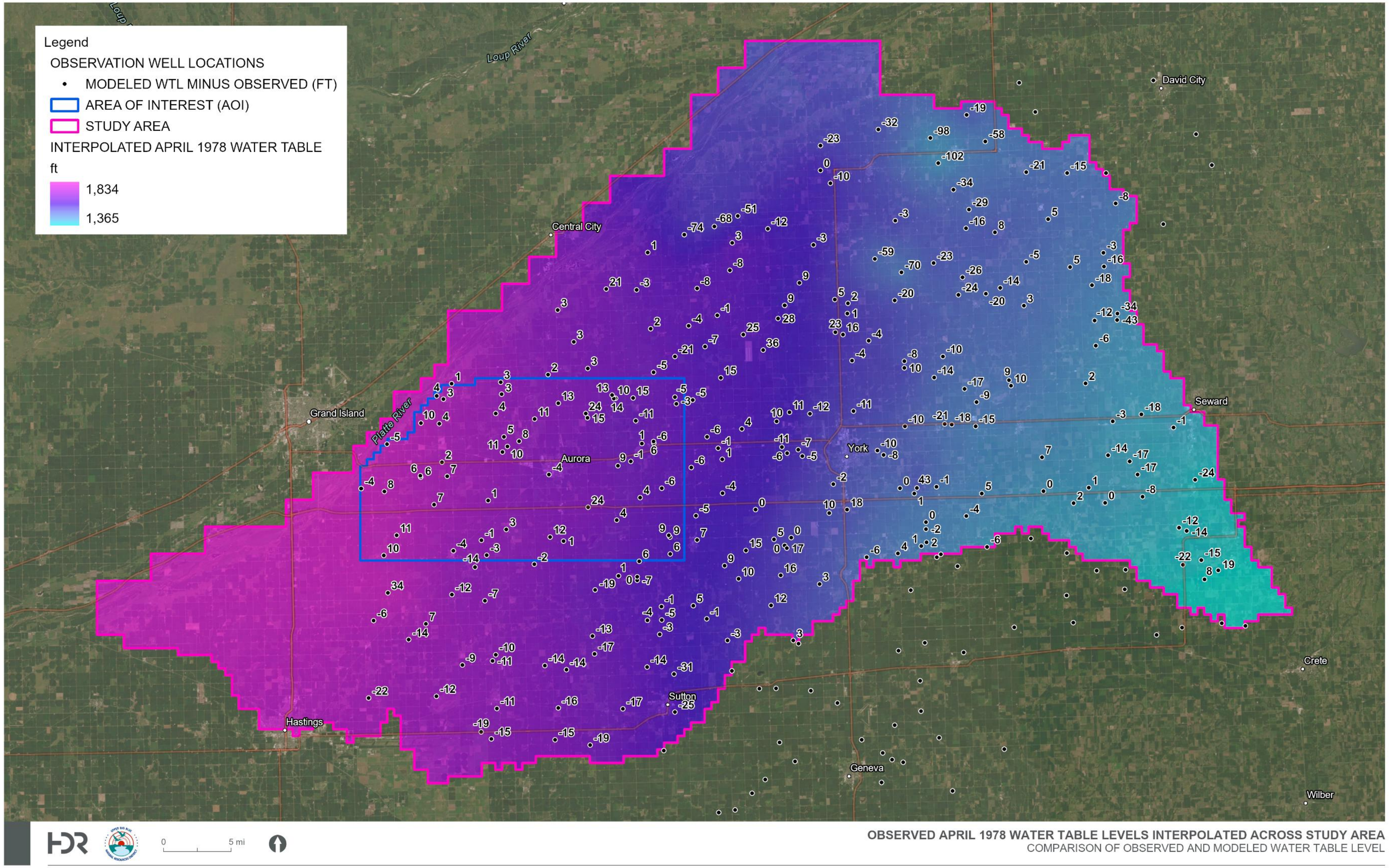


Figure 38. April 1978 Water-Table Level (WTL) Interpolated from Observations with Differences in Modeled WTL and Observed WTL at Observation Well Locations

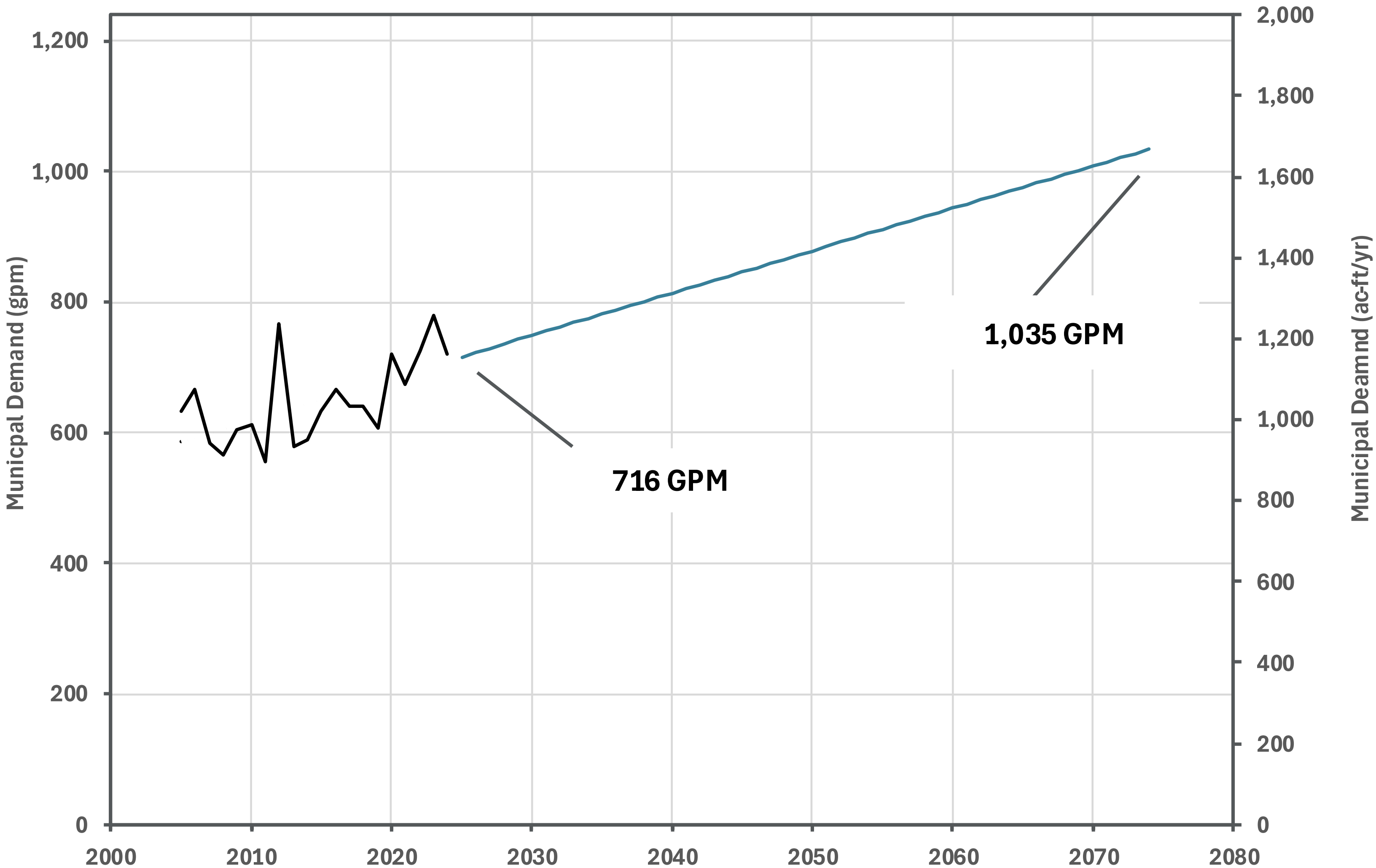


Figure 39. Aurora Historical Municipal Demand from 2005–2024 and Linear Projection of Municipal Demand

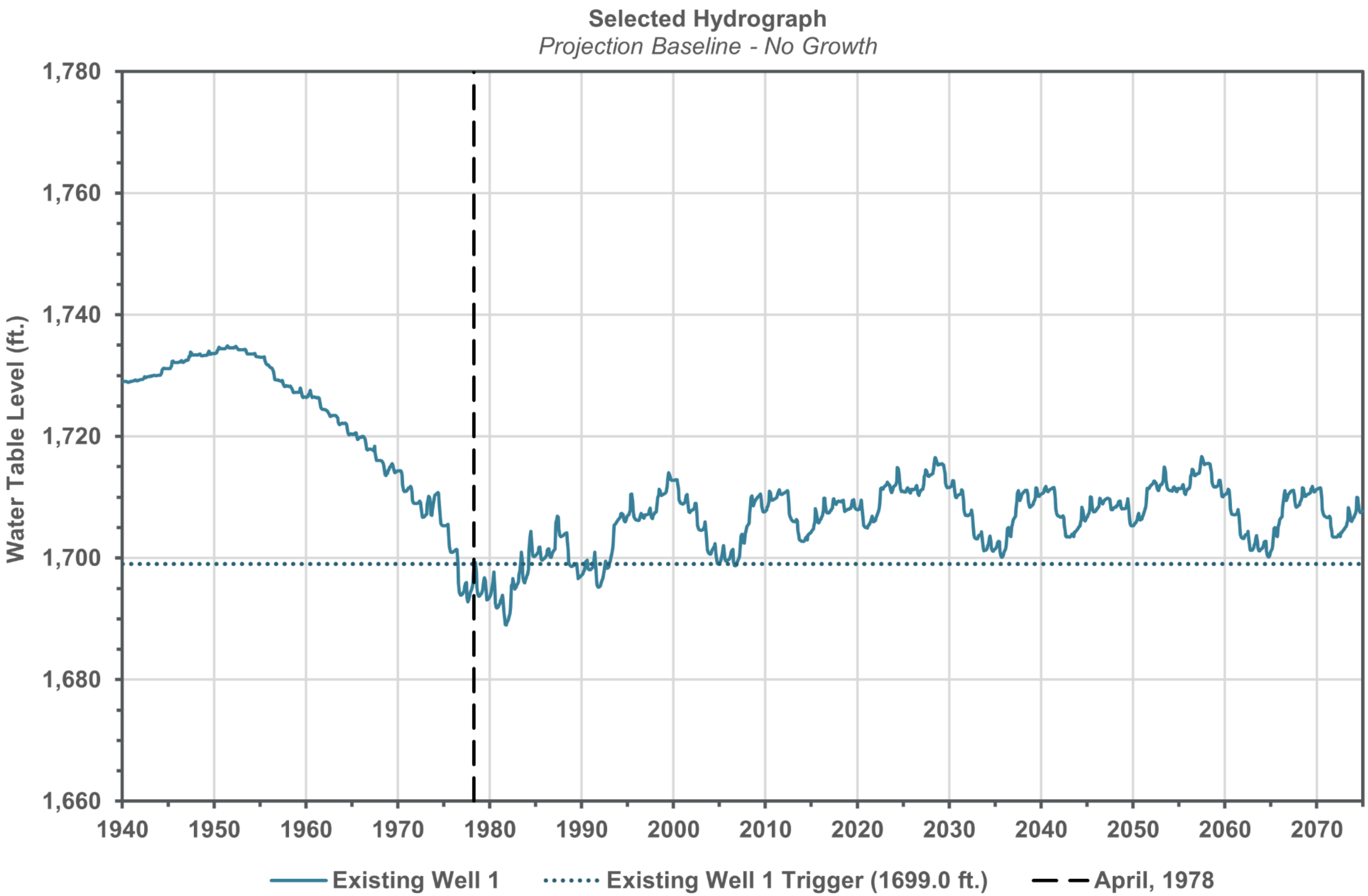


Figure 40. Selected Hydrograph for Aurora's Existing Well Locations During Projection Baseline: No Growth

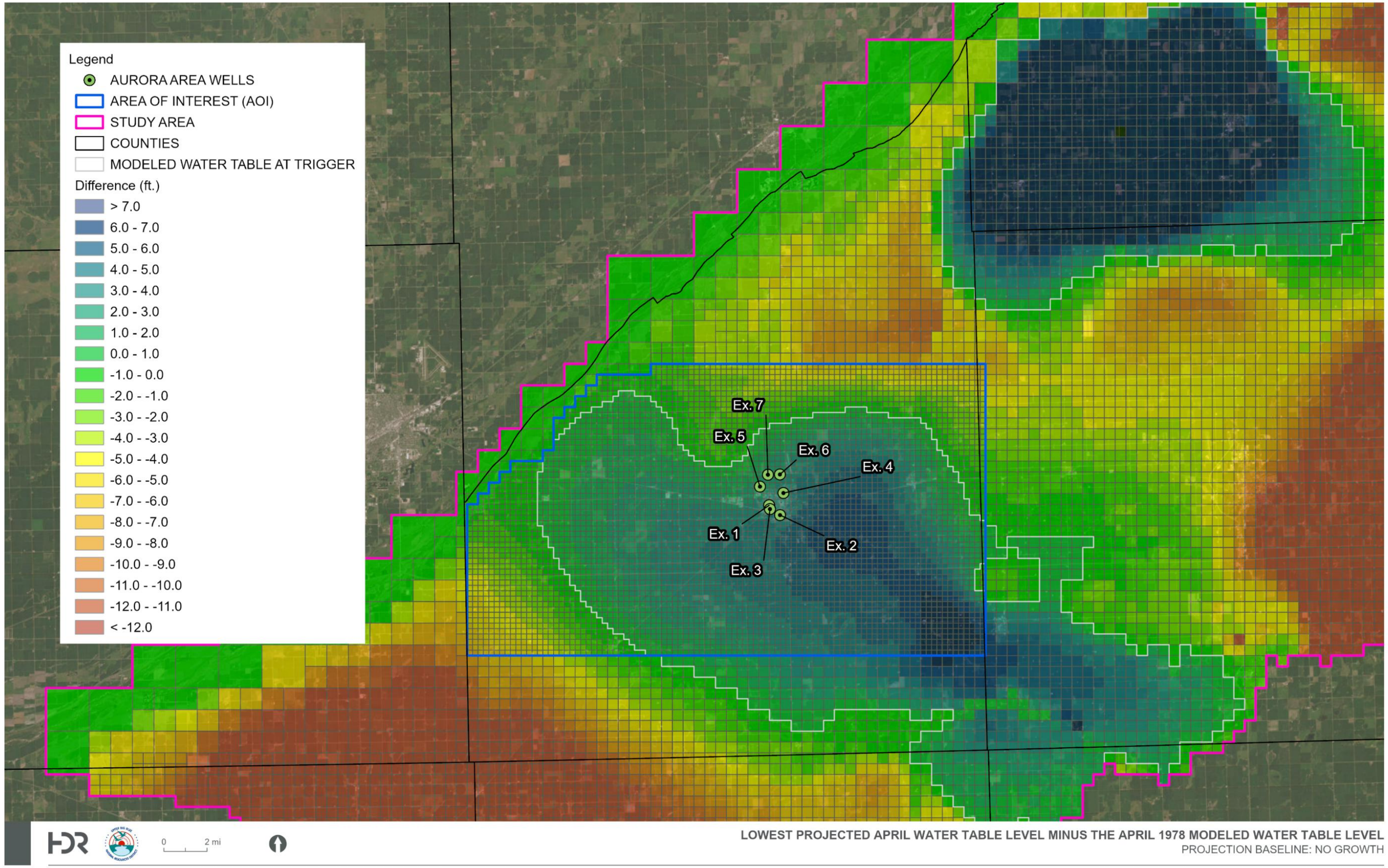


Figure 41. Lowest Modeled April Water-Table Level During Projection Period Minus 1978 Modeled Water Table: Projection Baseline No Growth

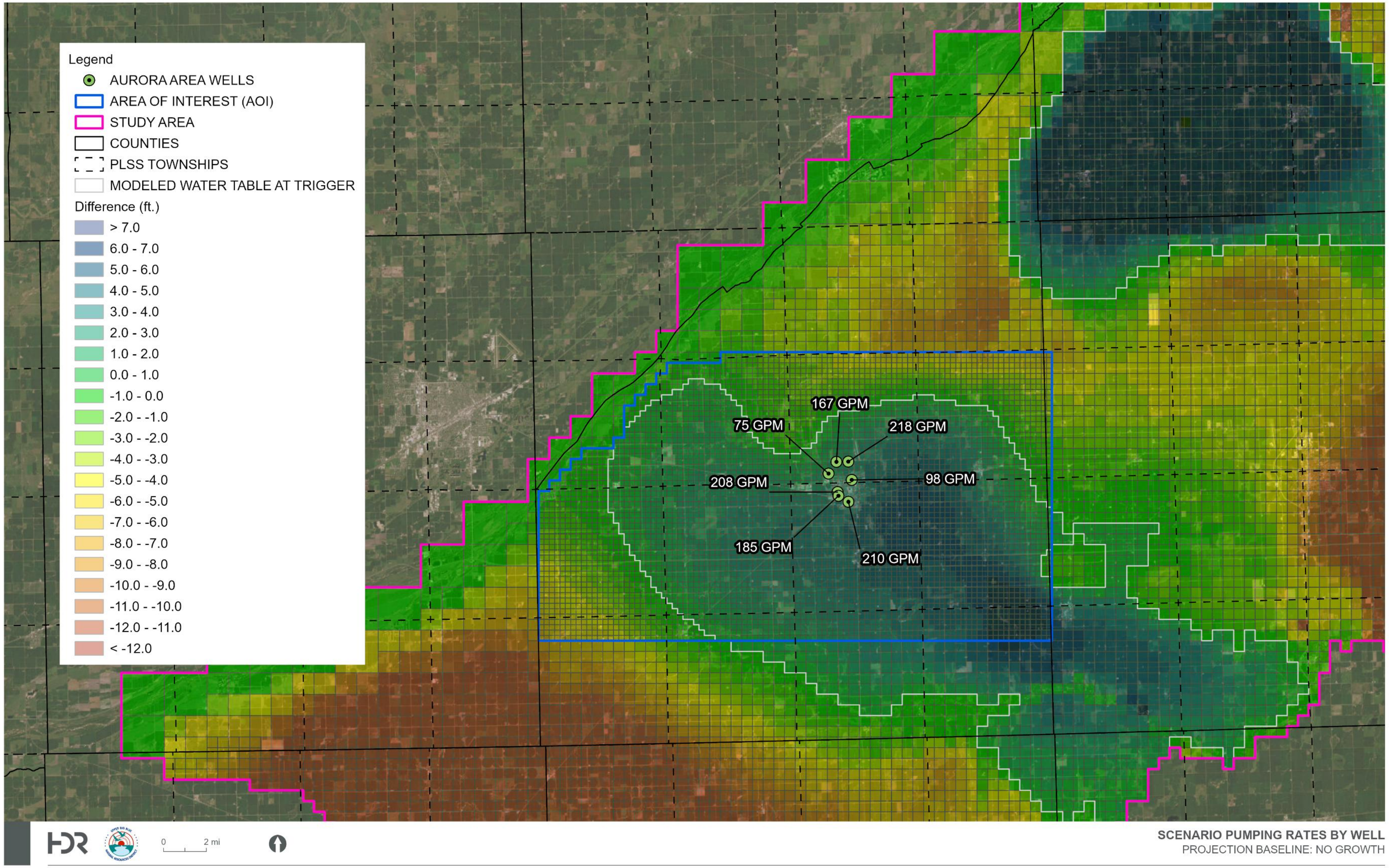


Figure 42. Pumping Rates by Well for Projection Baseline: No Growth

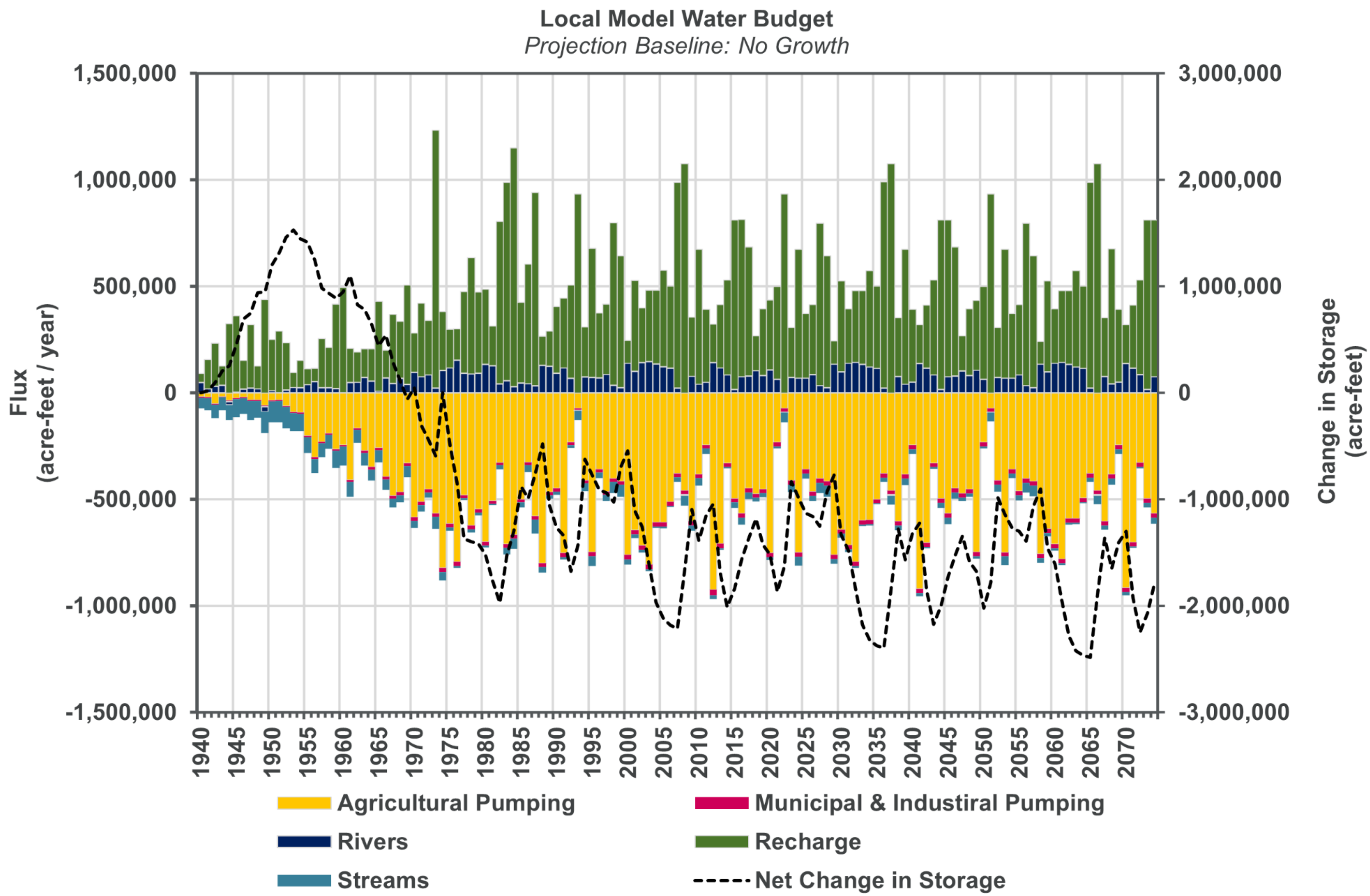


Figure 43. Water Balance of Projection Budget with No Growth in Aurora Municipal Demand after 2024

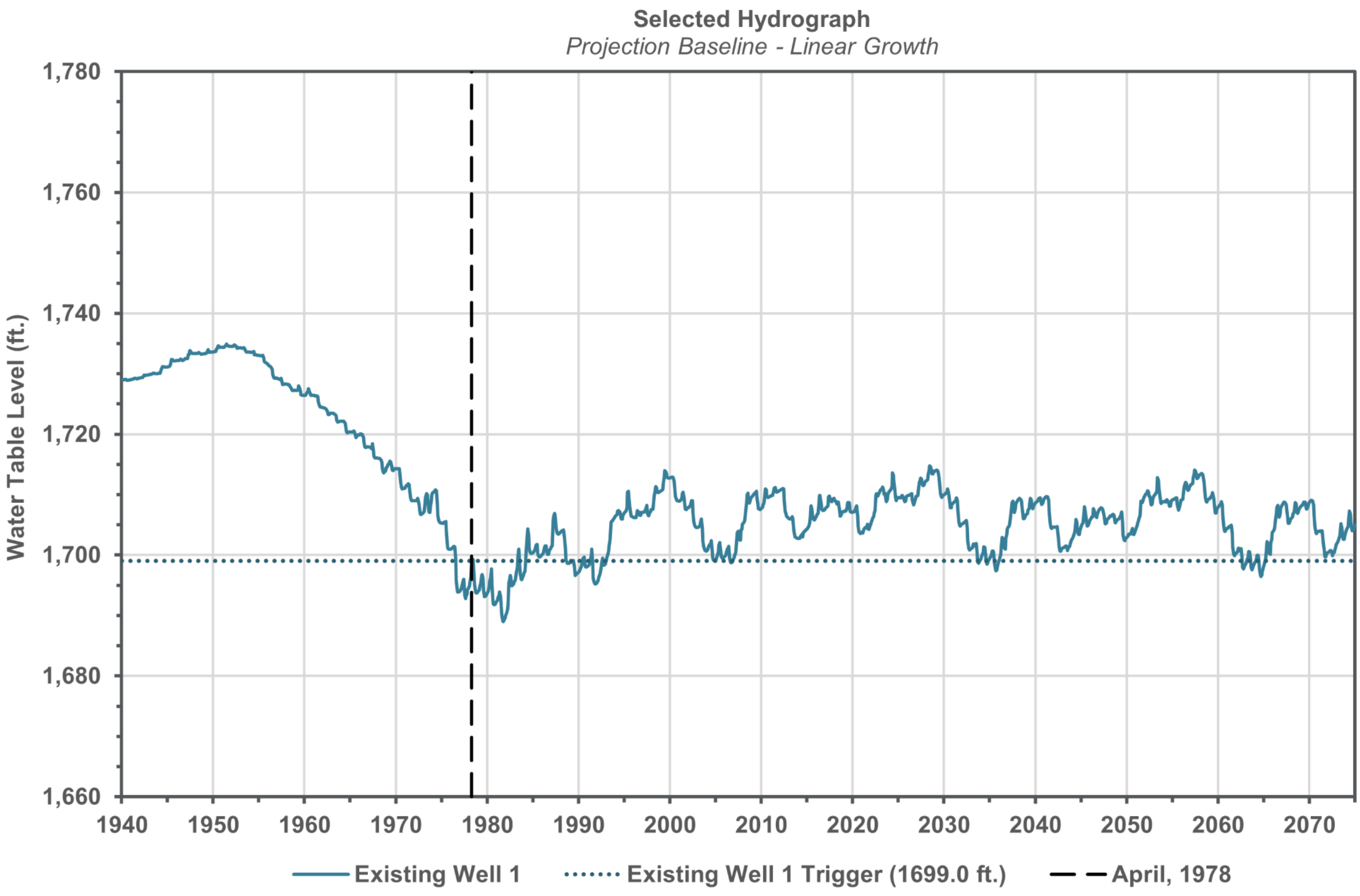


Figure 44. Selected Hydrograph for Aurora's Existing Well Locations During Projection Baseline: Linear Growth

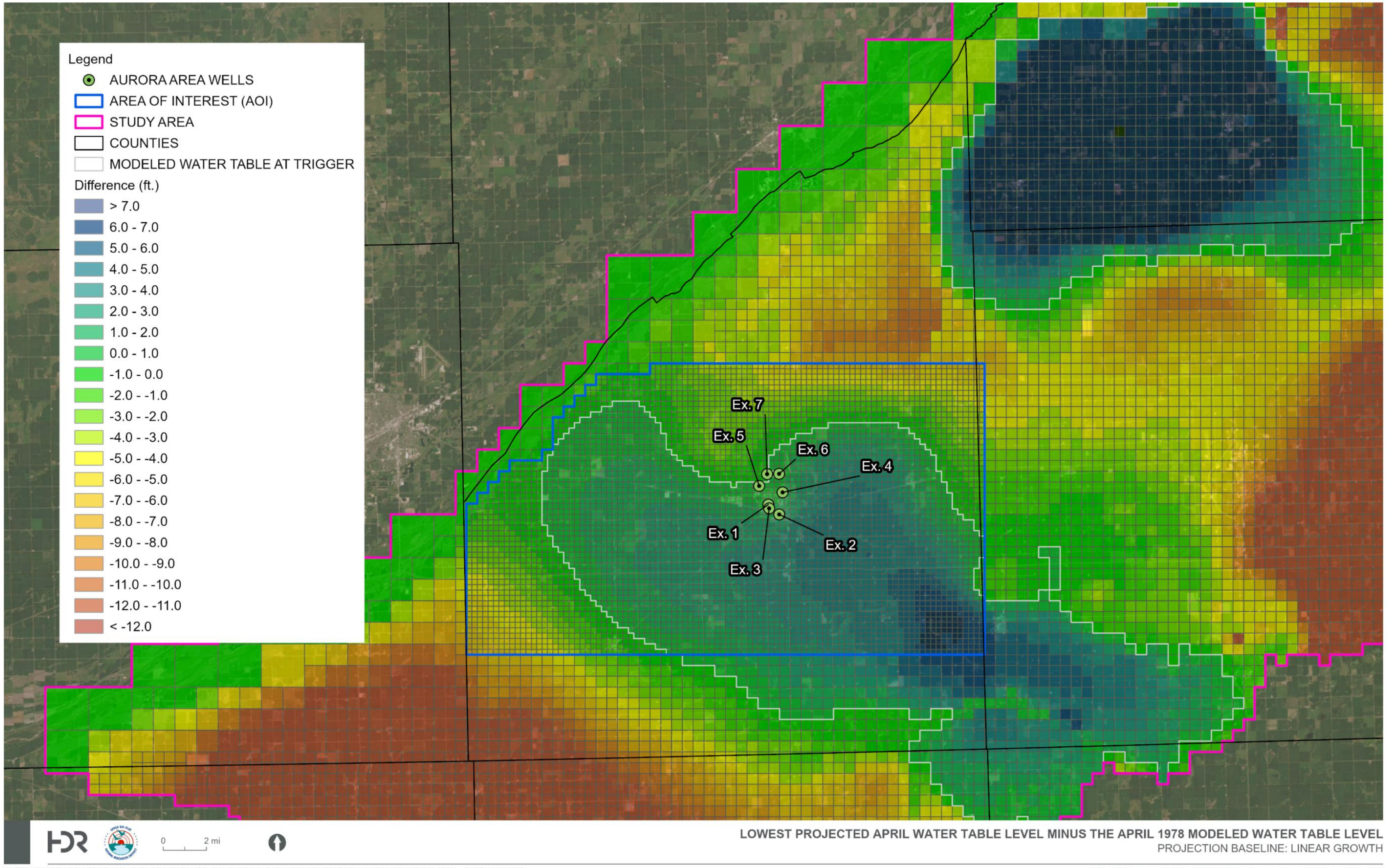


Figure 45. Lowest Modeled April Water-Table Level During Projection Period Minus 1978 Modeled Water Table: Projection Baseline Linear Growth

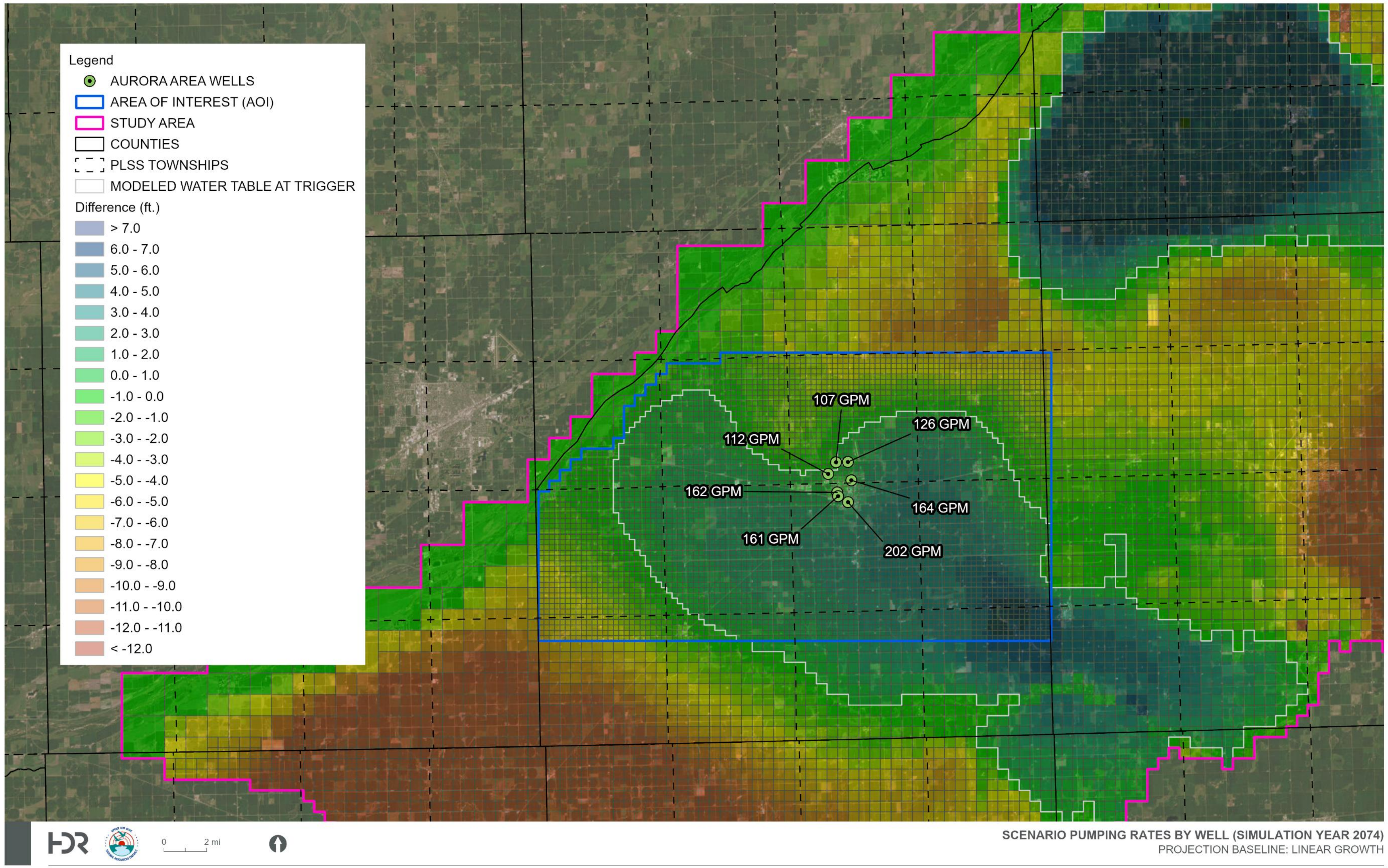


Figure 46. Pumping Rates by Well for Projection Baseline: Linear Growth

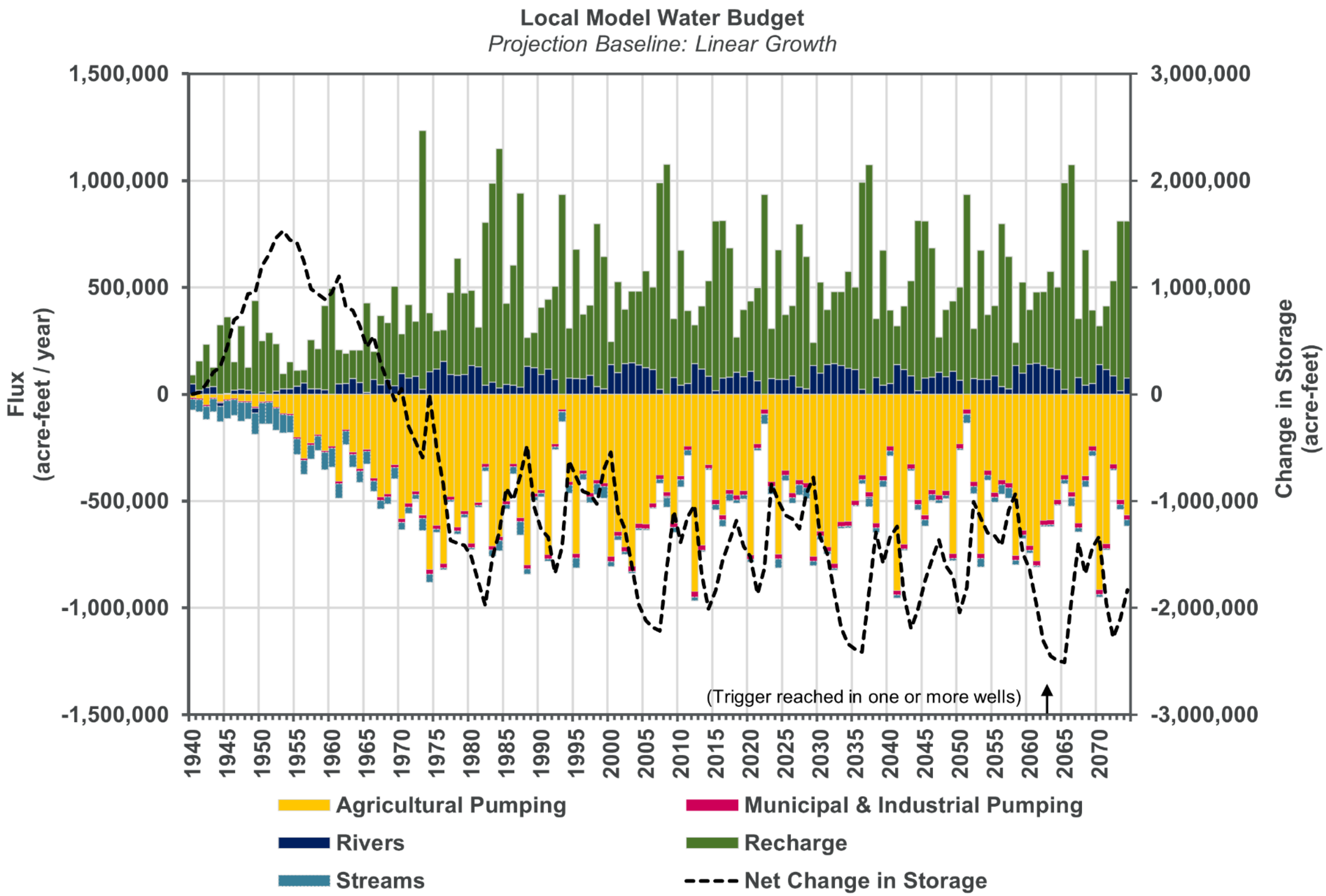


Figure 47. Water Budget of Projection Baseline with Linear Growth of Aurora Municipal Demand after 2024

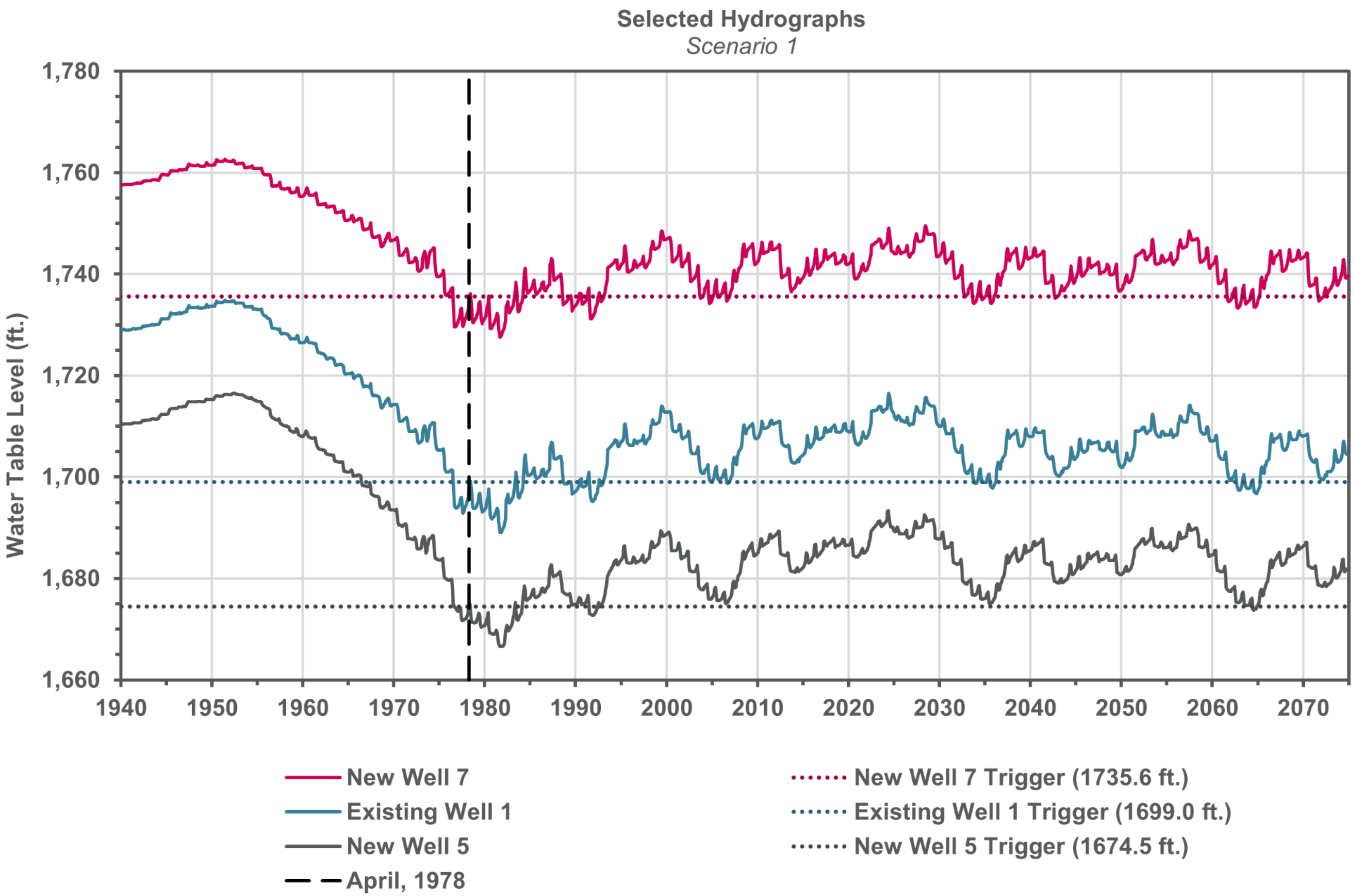


Figure 48. Selected Hydrographs for Aurora's Existing Well Locations During Scenario 1

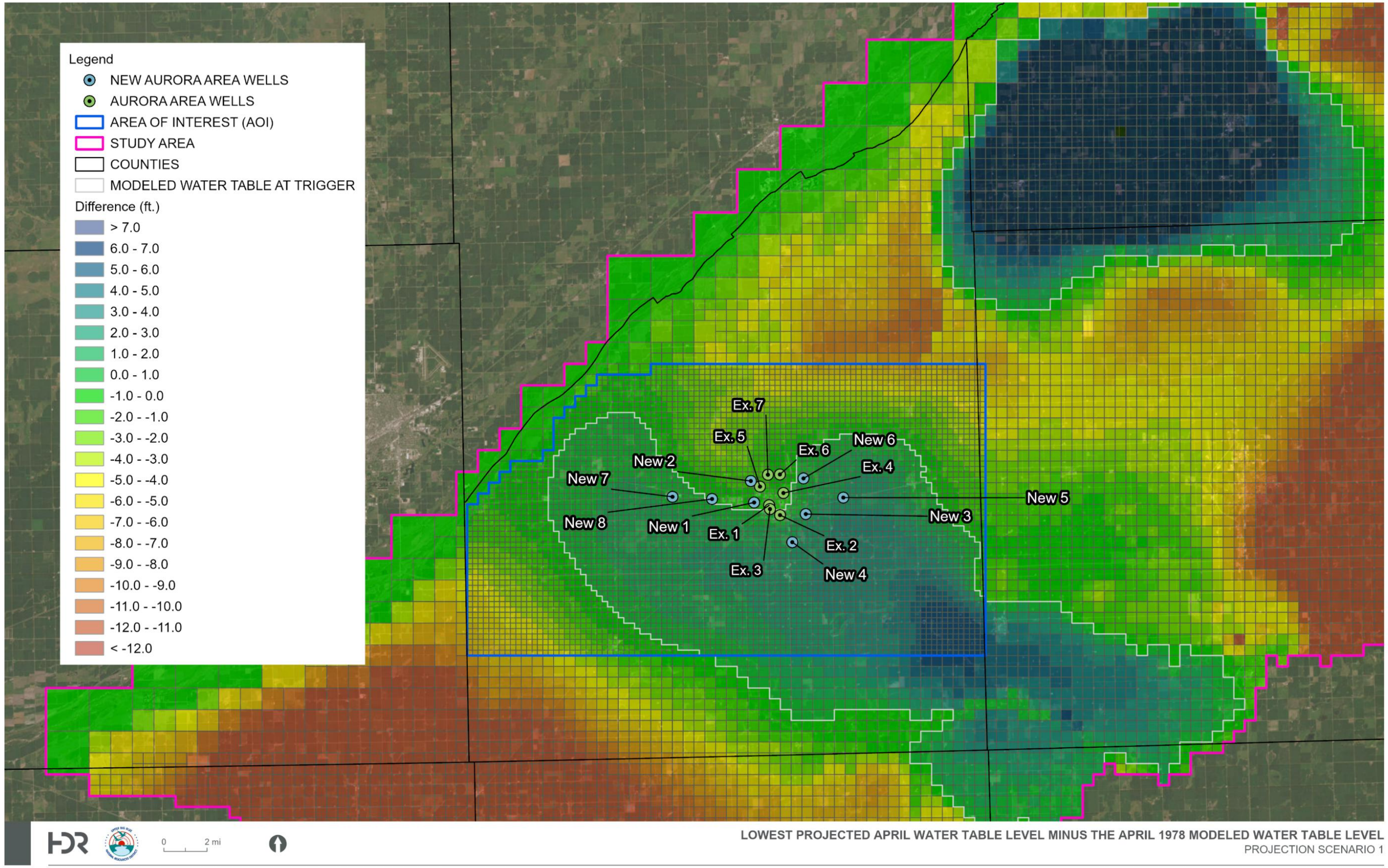


Figure 49. Lowest Modeled April Water-Table Level During Projection Period Minus 1978 Modeled Water Table: Scenario 1

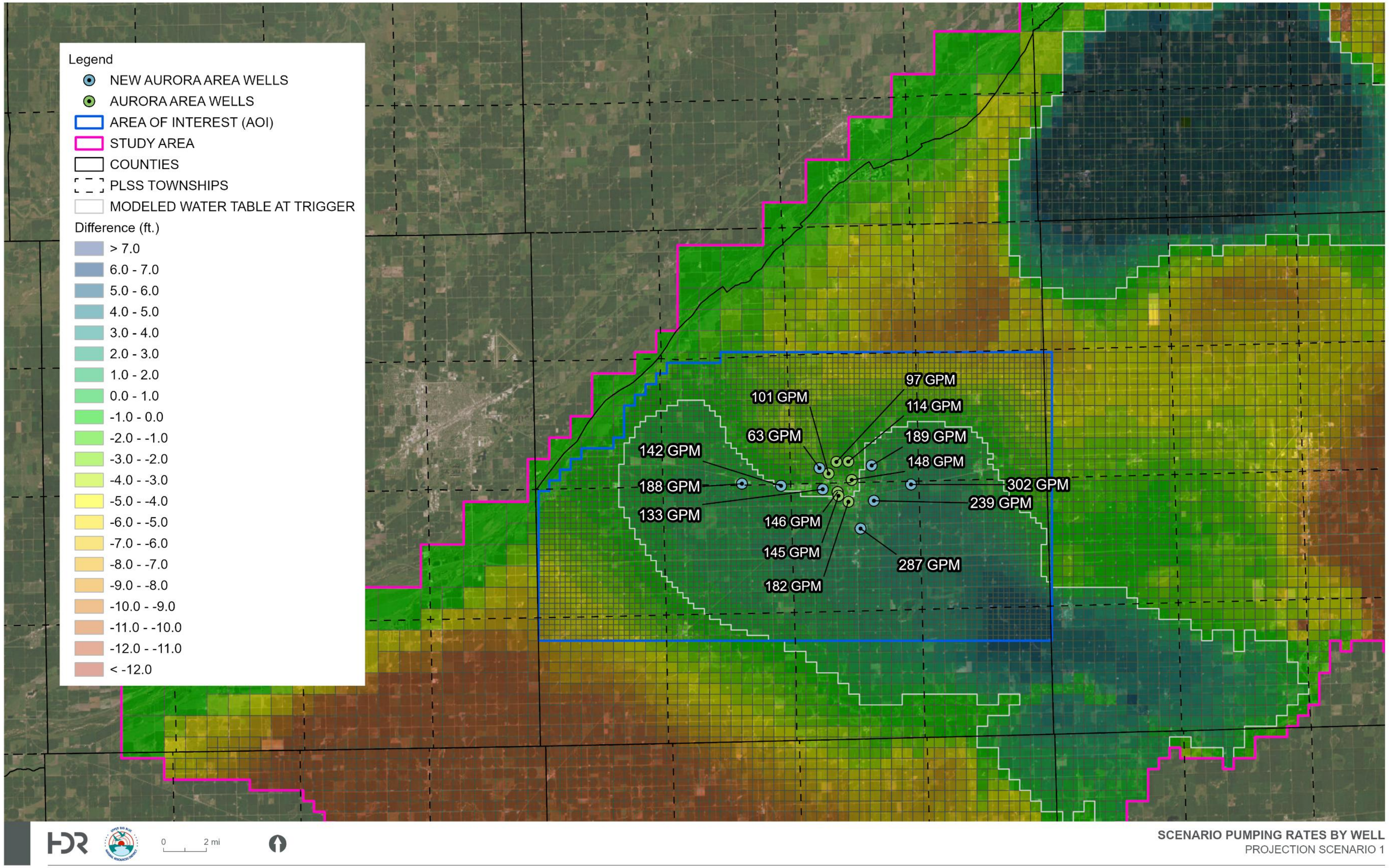


Figure 50. Pumping Rates by Well for Scenario 1

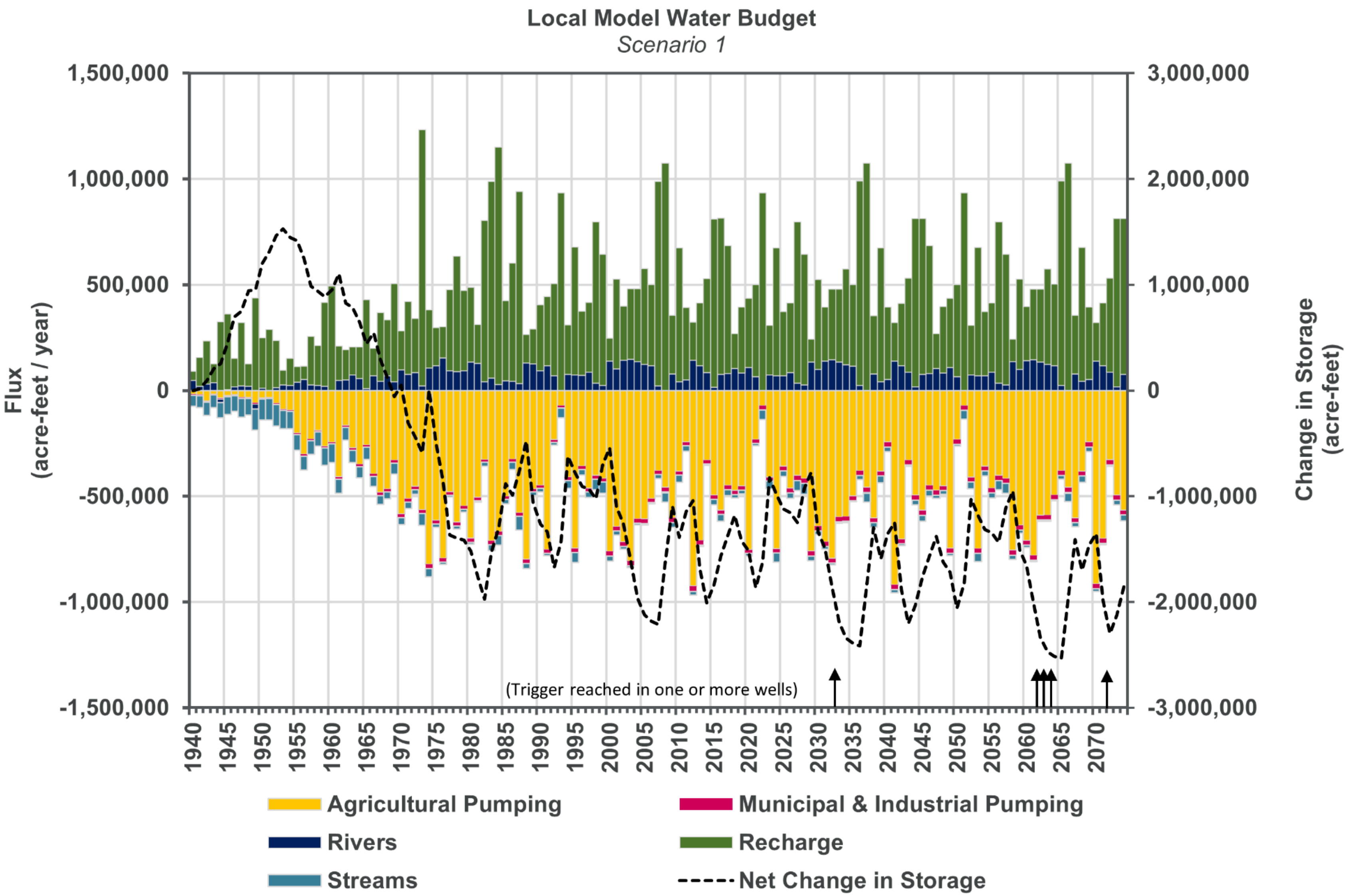


Figure 51. Water Budget of Scenario 1: Maximum Development in the Aurora Area

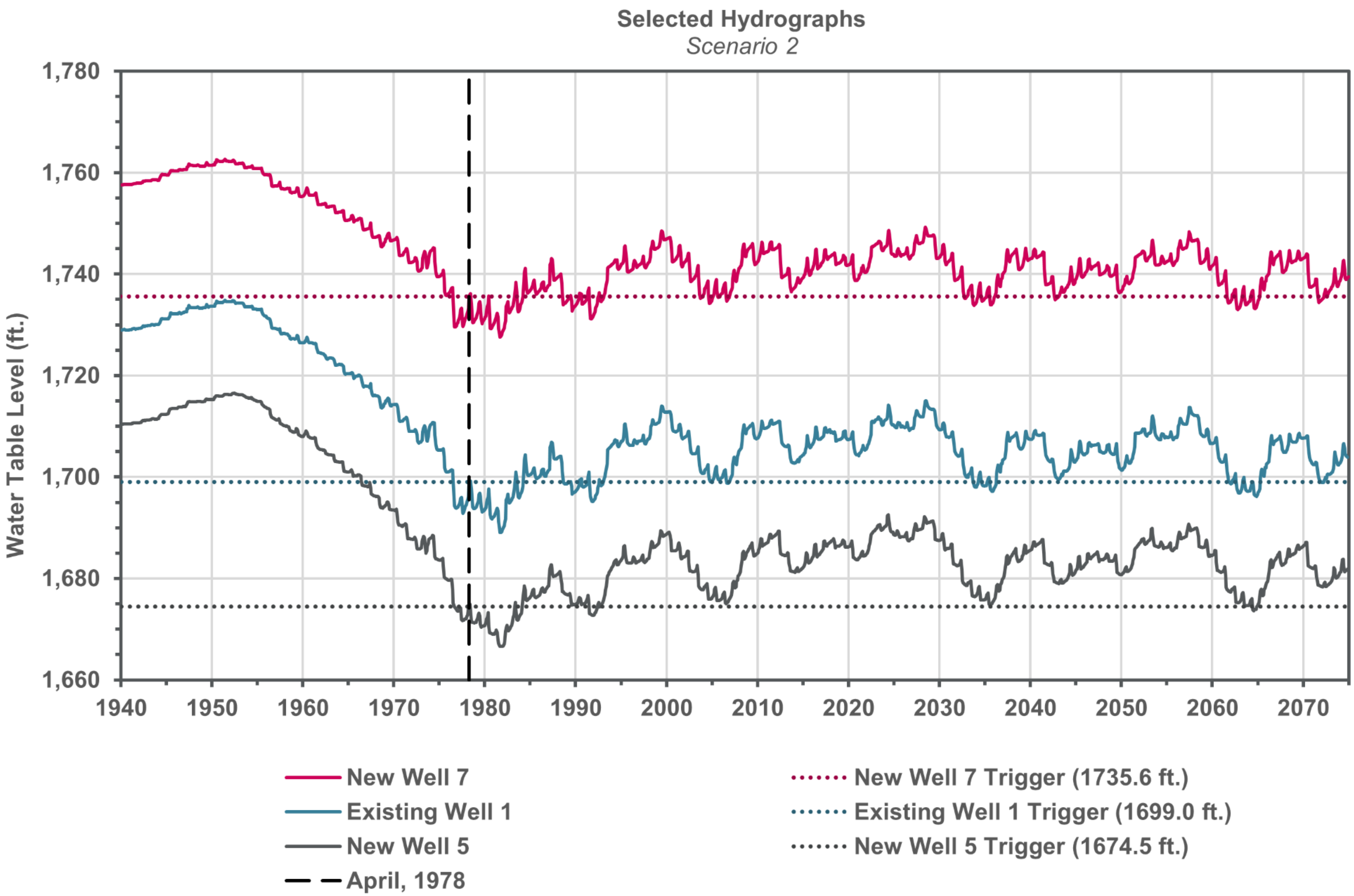


Figure 52. Selected Hydrographs for Aurora's Existing Well Locations During Scenario 2

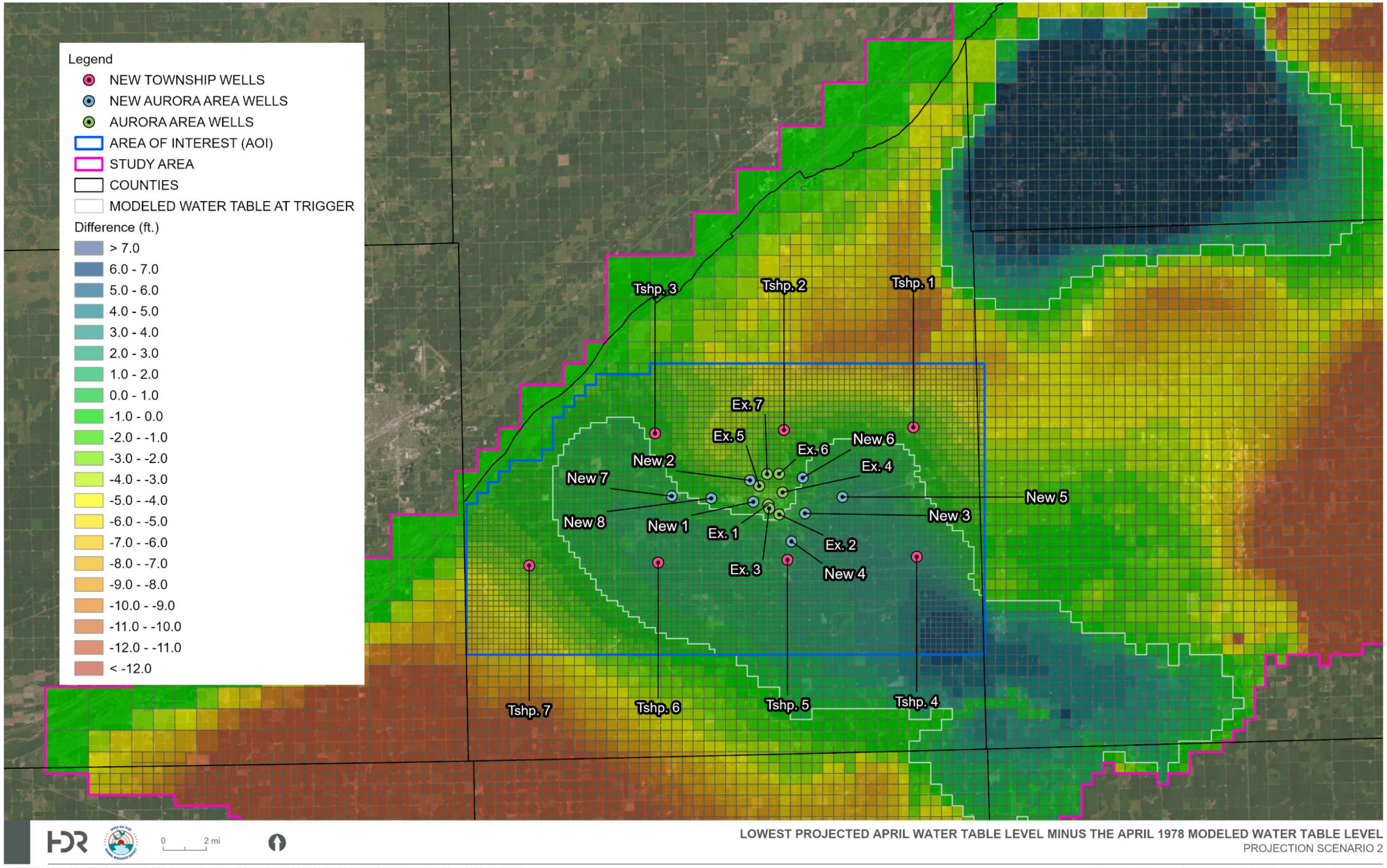


Figure 53. Lowest Modeled April Water-Table Level During Projection Period Minus 1978 Modeled Water Table: Scenario 2

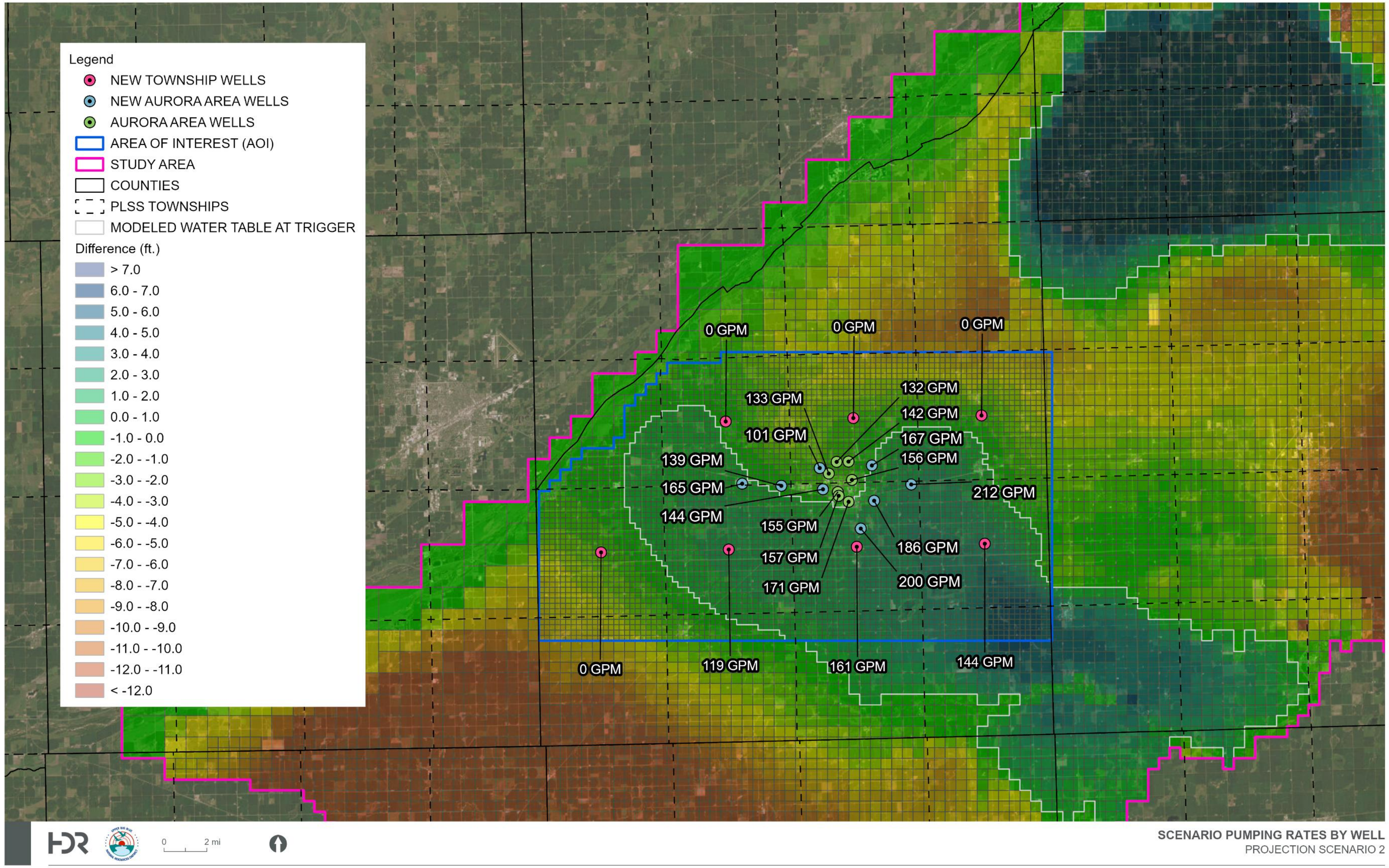


Figure 54. Pumping Rates by Well for Scenario 2

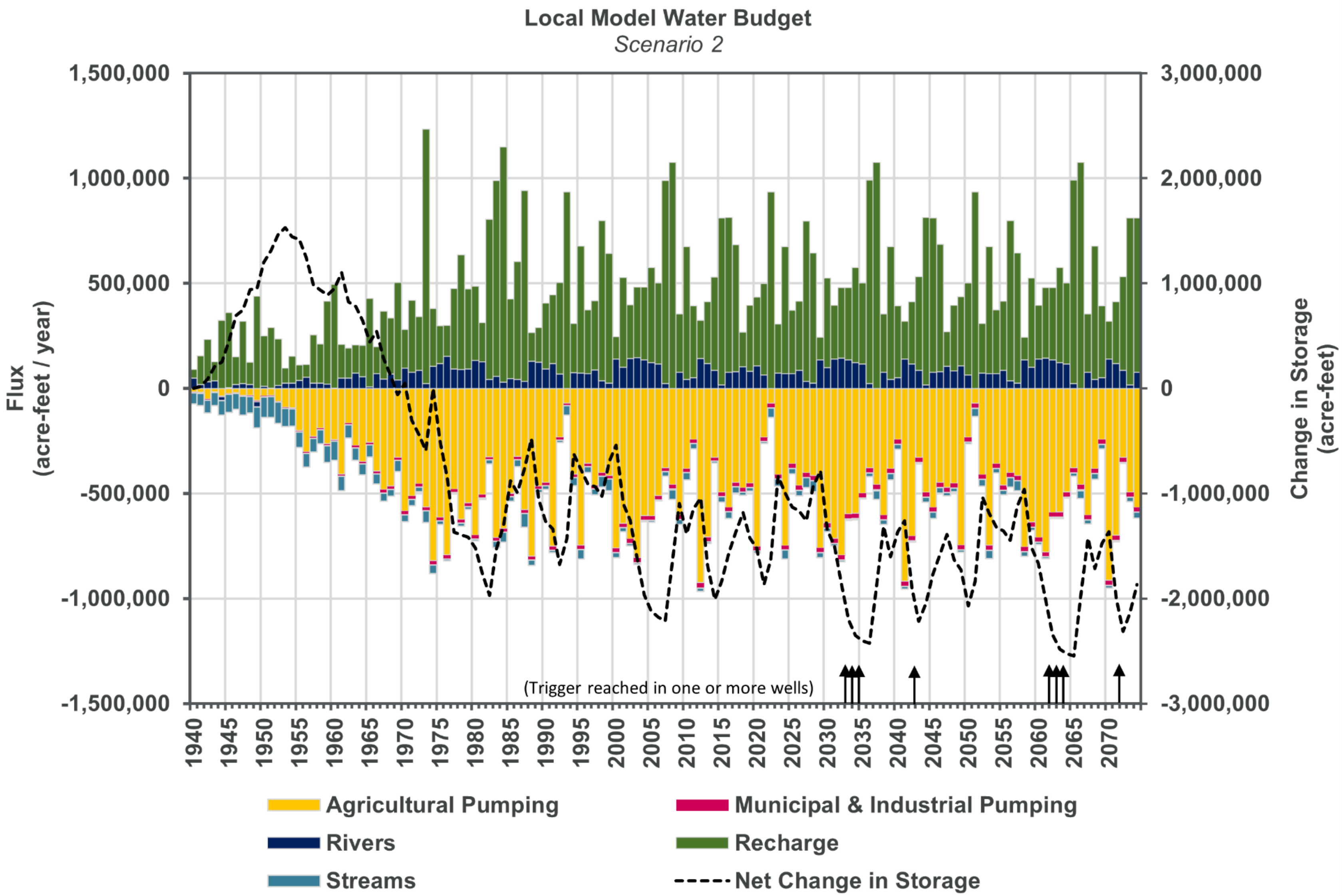


Figure 55. Water Budget of Scenario 2: Maximum Development in the Aurora Area and Townships

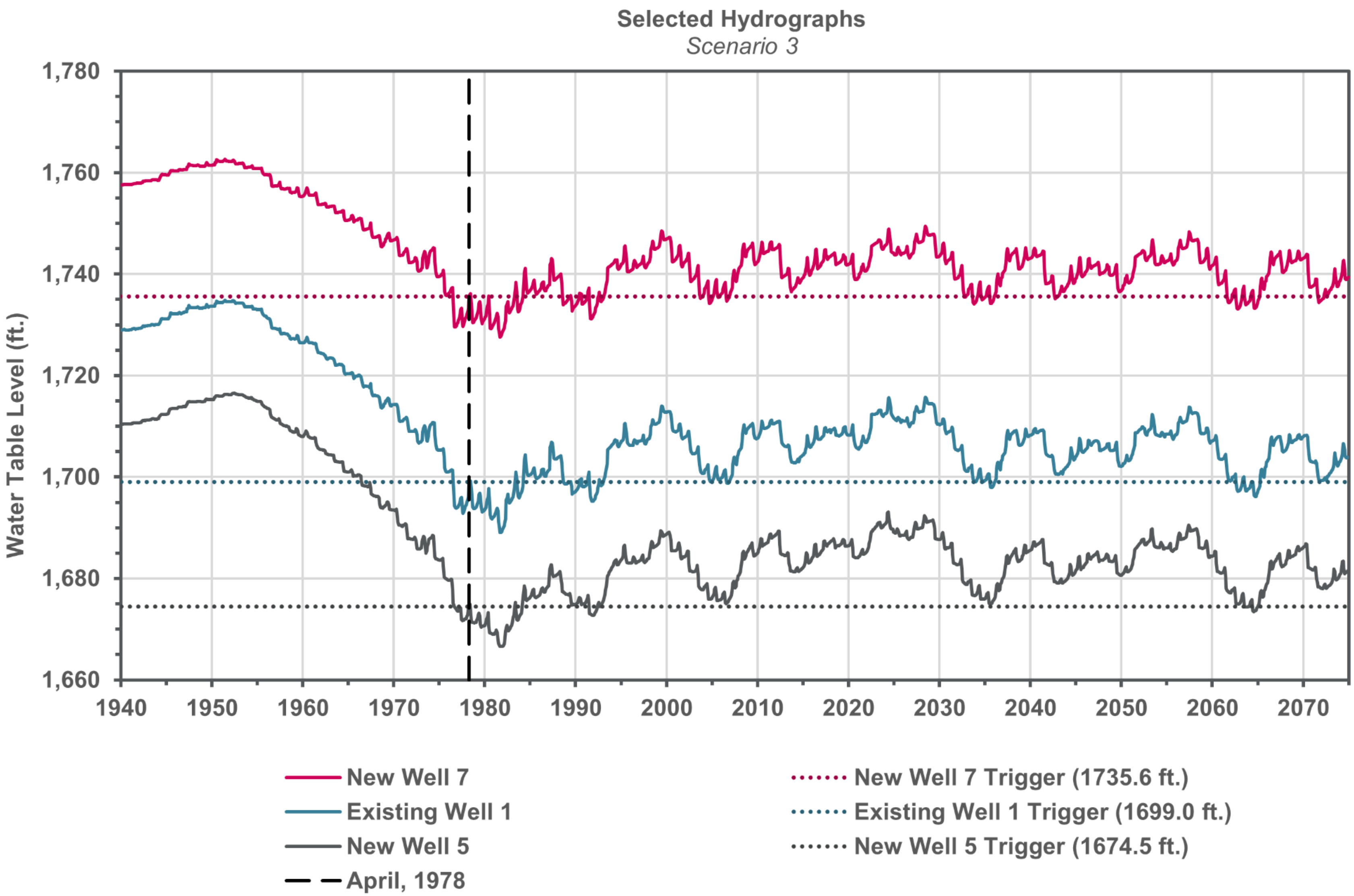


Figure 56. Selected Hydrographs for Aurora's Existing Well Locations During Scenario 3

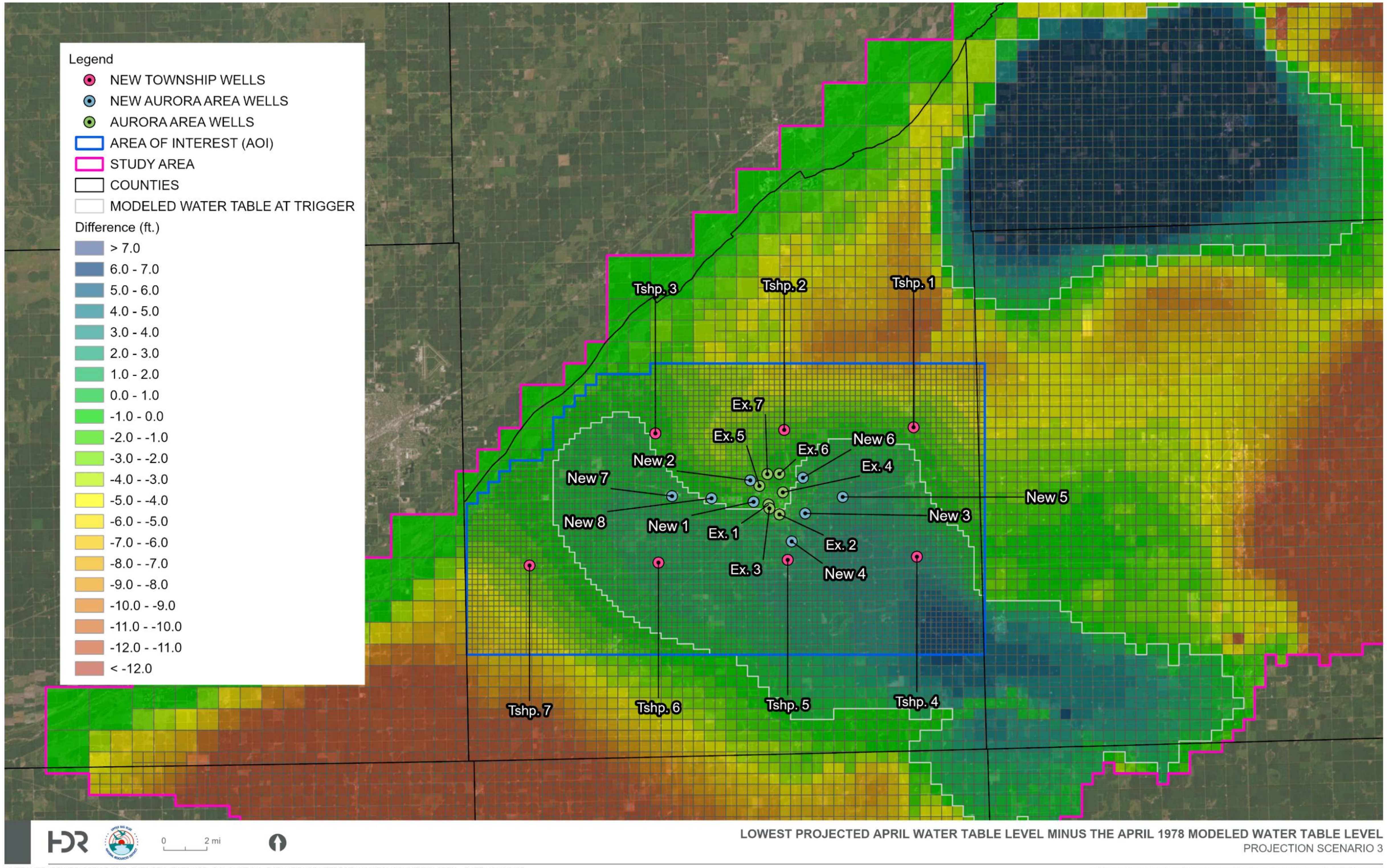


Figure 57. Lowest Modeled April Water-Table Level During Projection Period Minus 1978 Modeled Water Table: Scenario 3

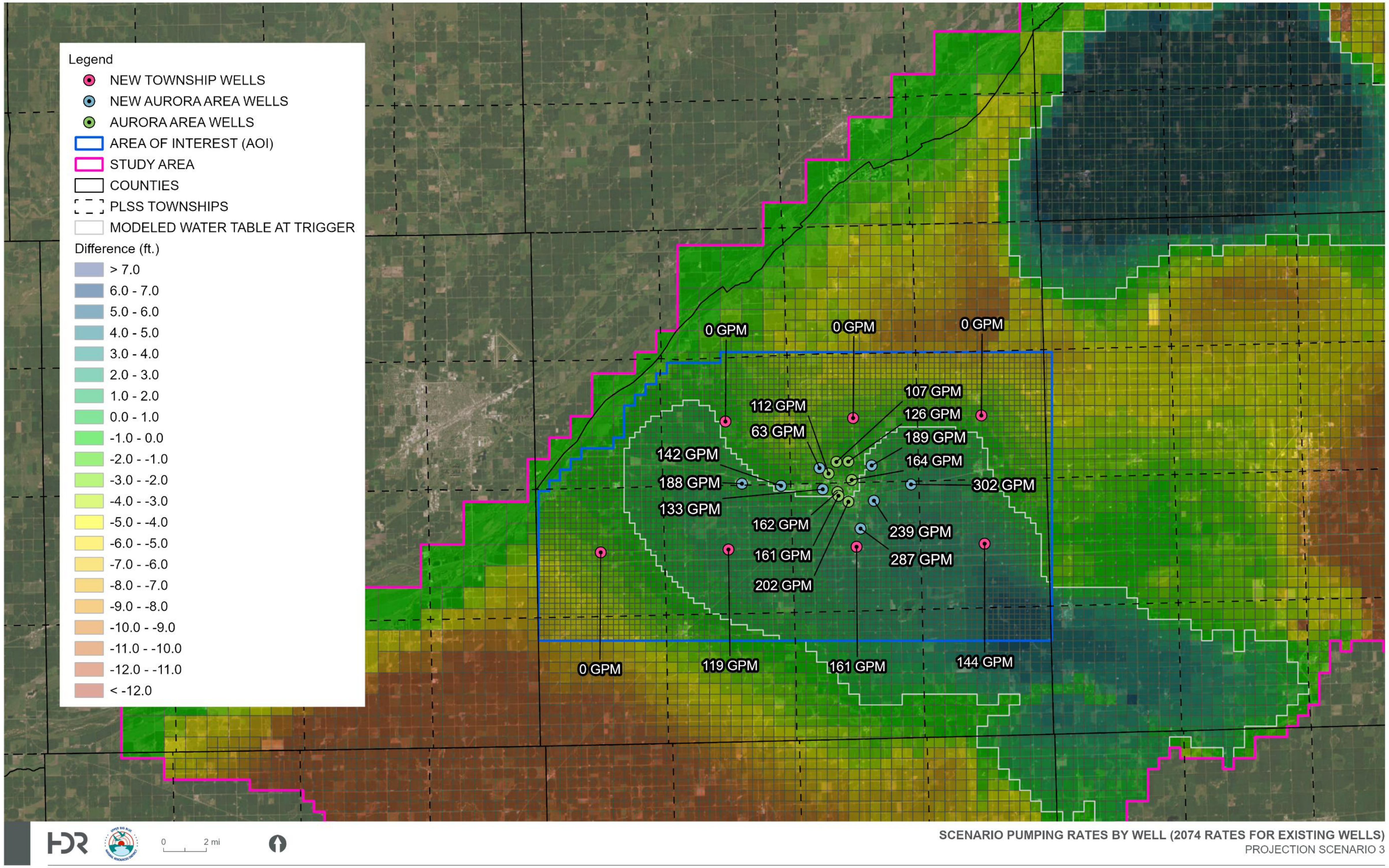


Figure 58. Pumping Rates by Well for Scenario 3

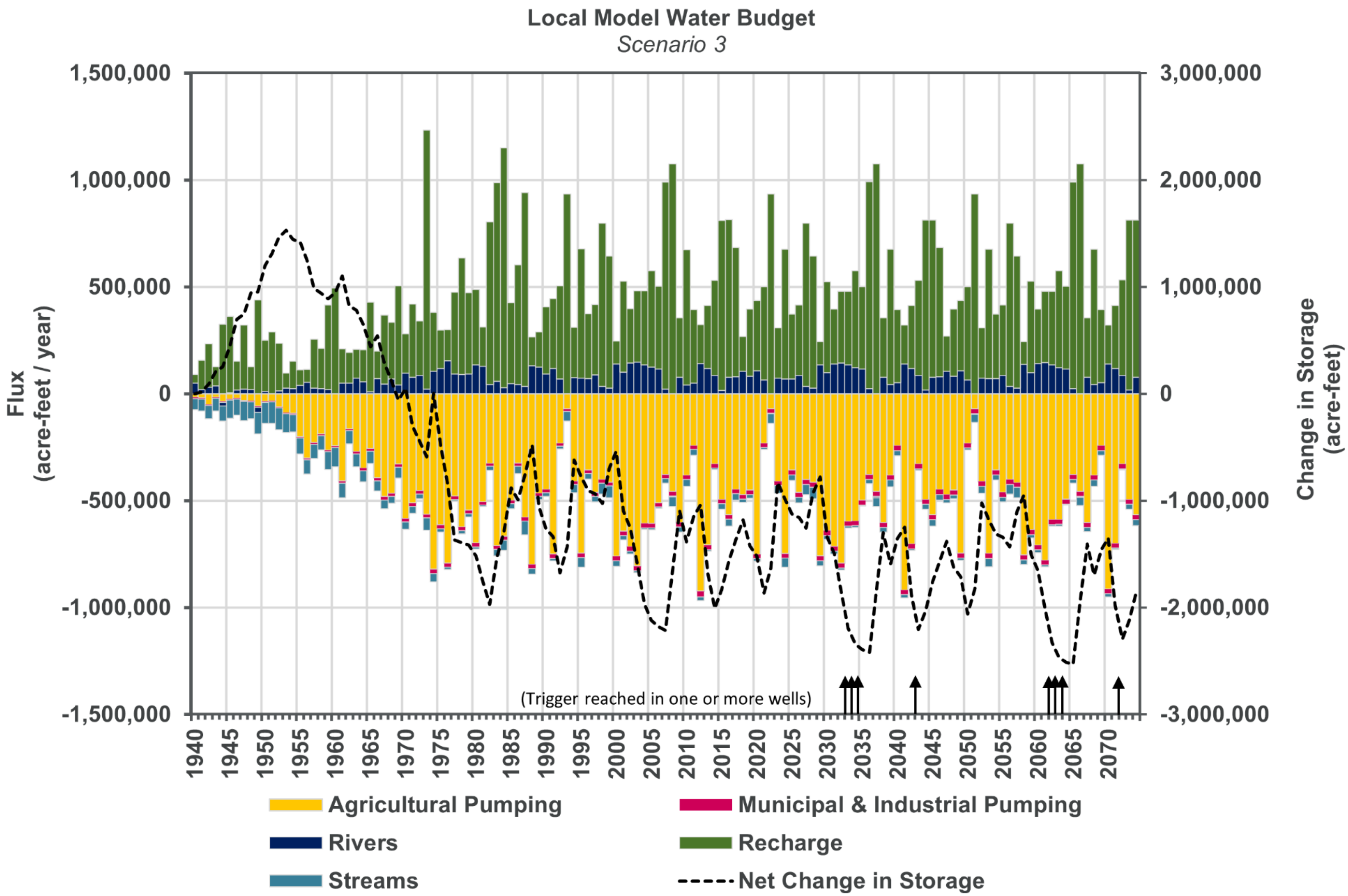
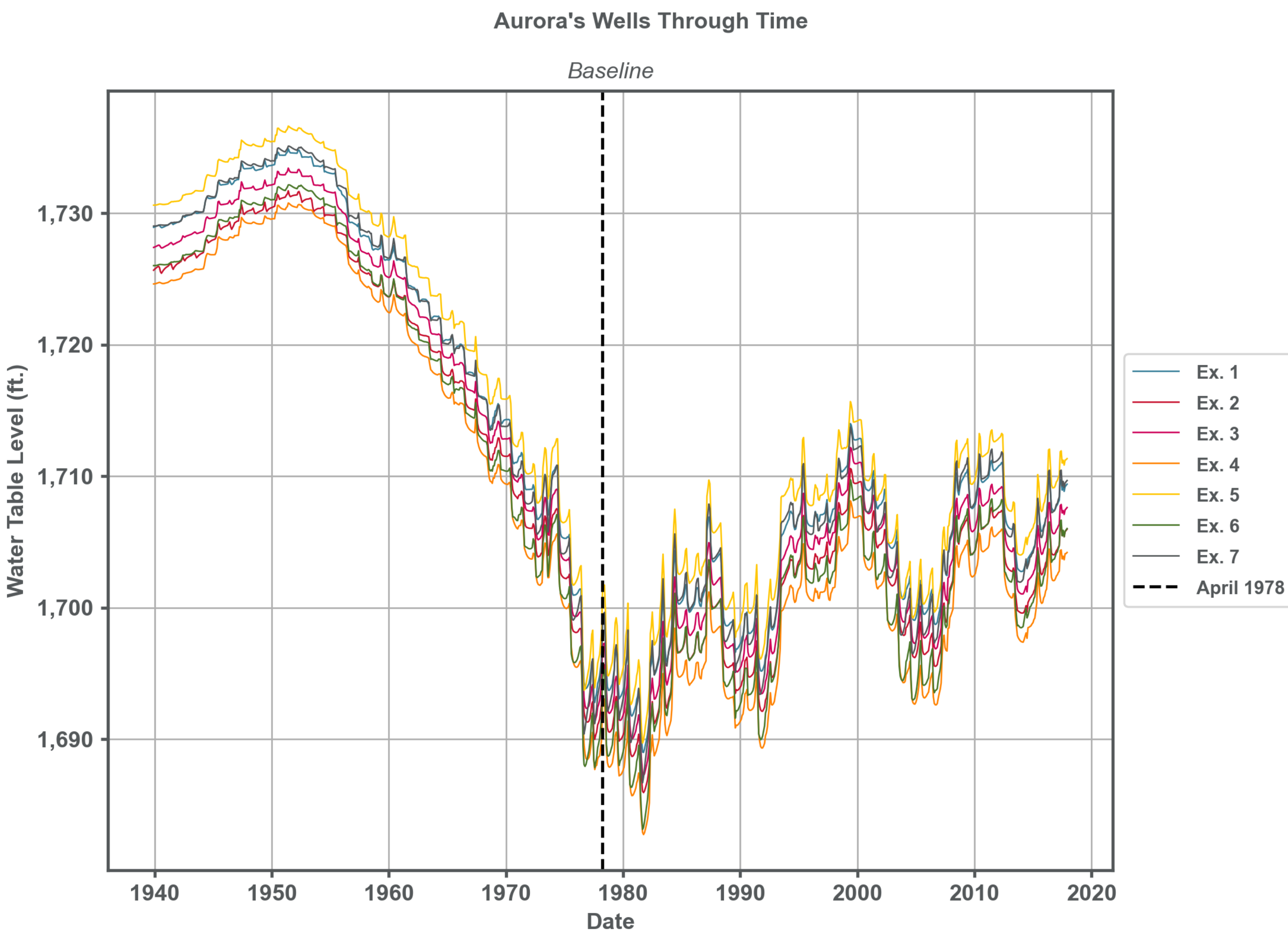
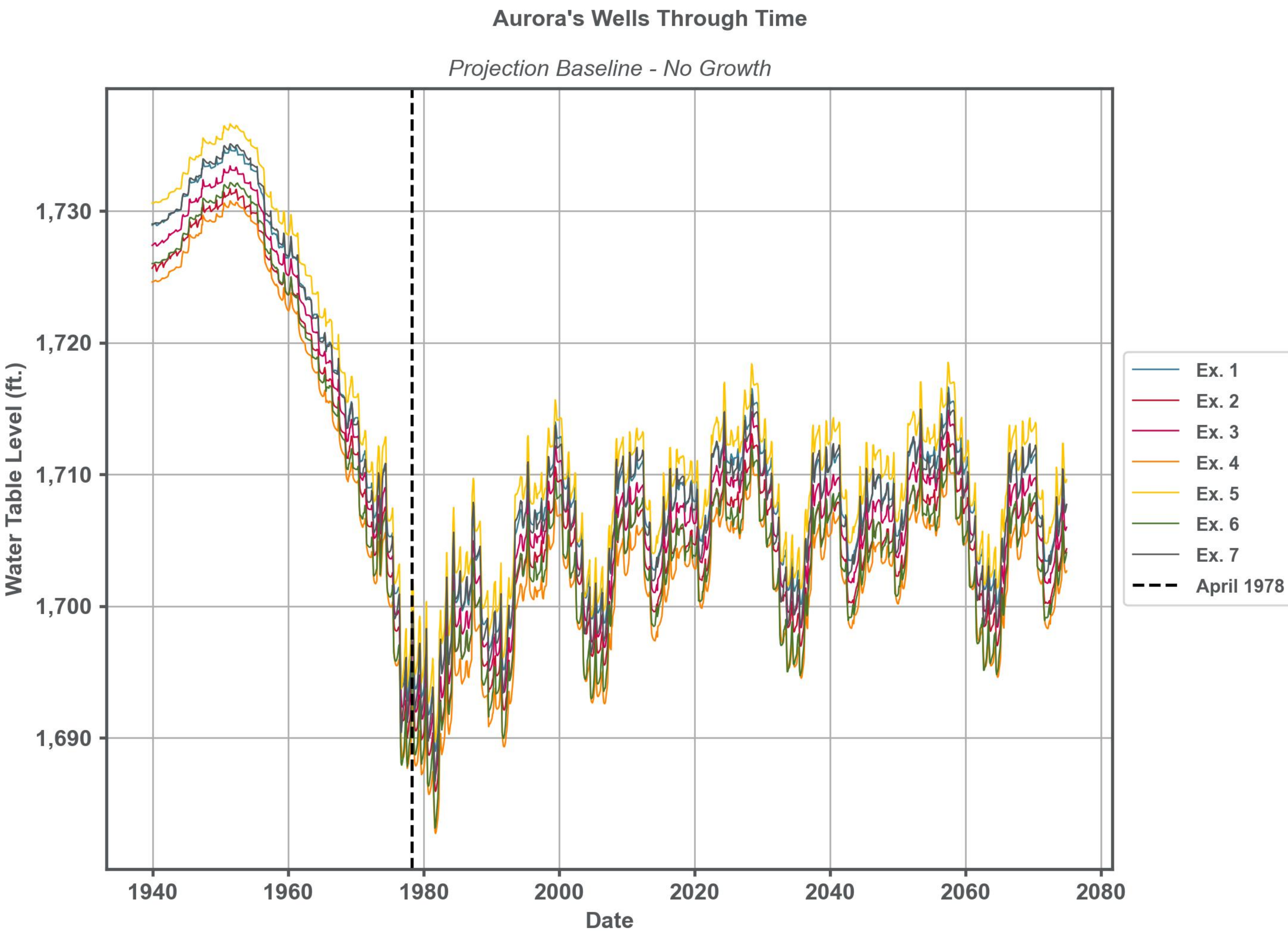


Figure 59. Water Budget of Scenario 3: Projected Growth in Aurora with Maximum Development in the Aurora Area and Townships

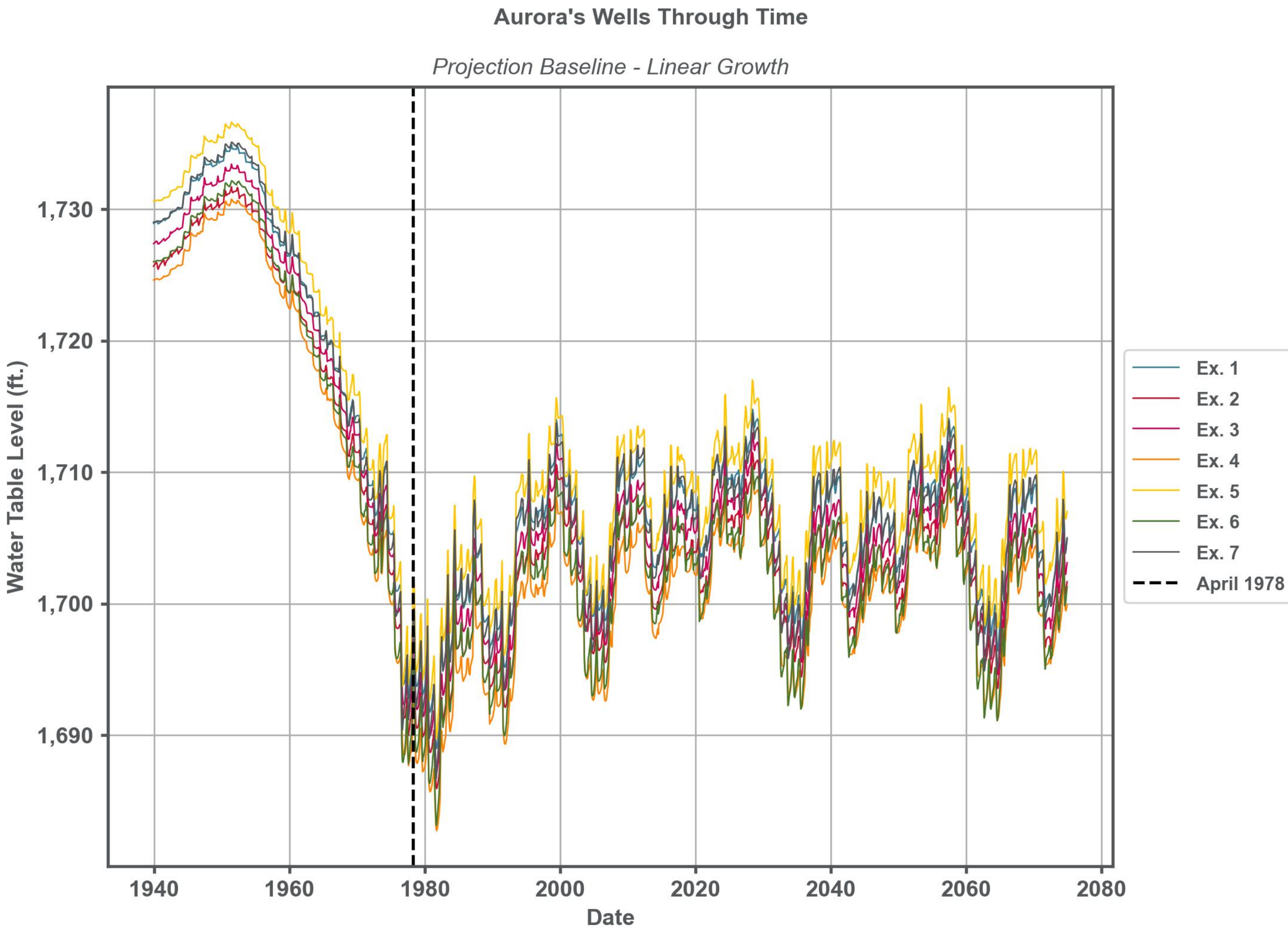
APPENDIX: Study Well Location Hydrographs



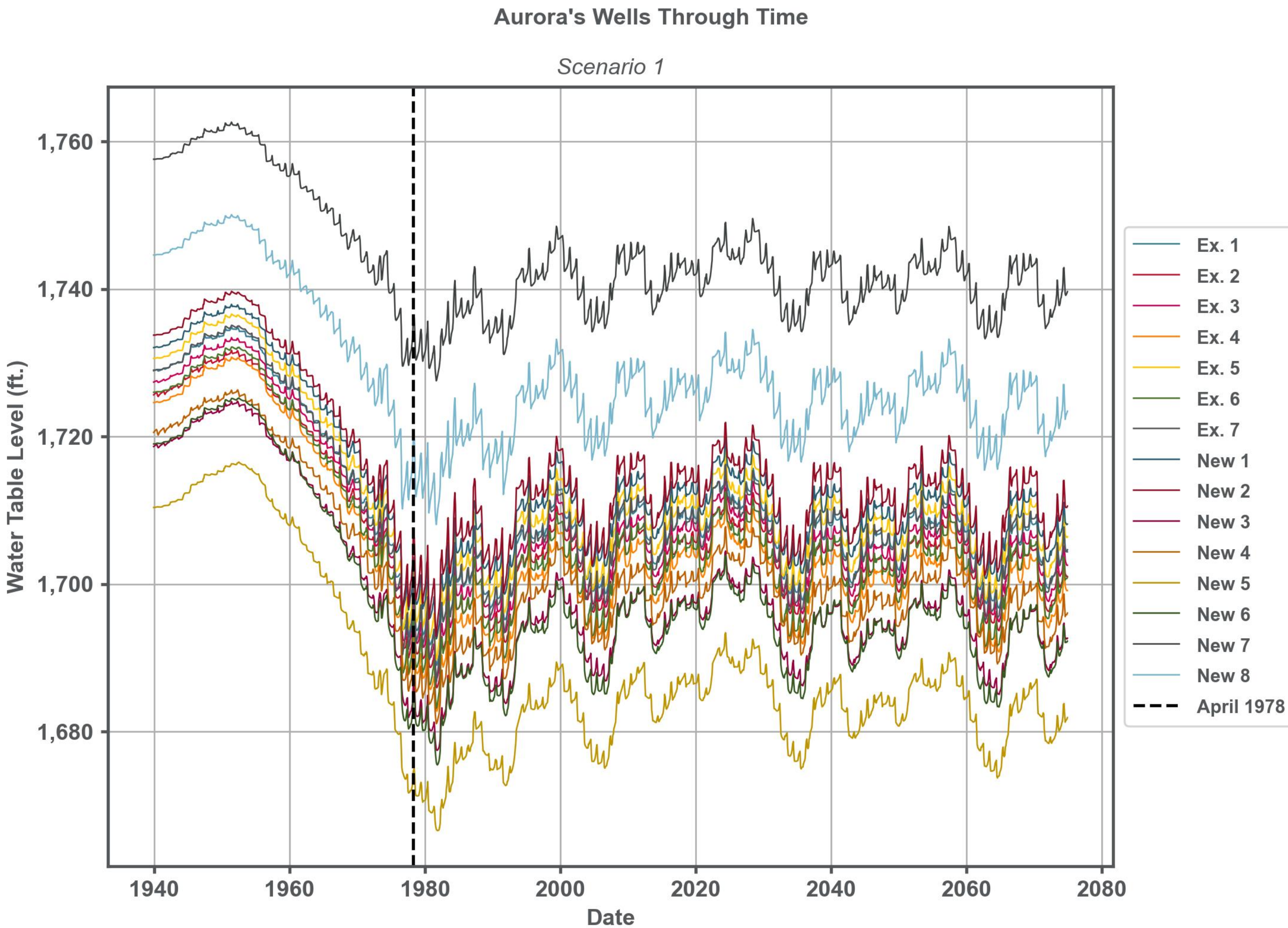
A-1. Hydrographs at All Study Well Locations: Historical Baseline



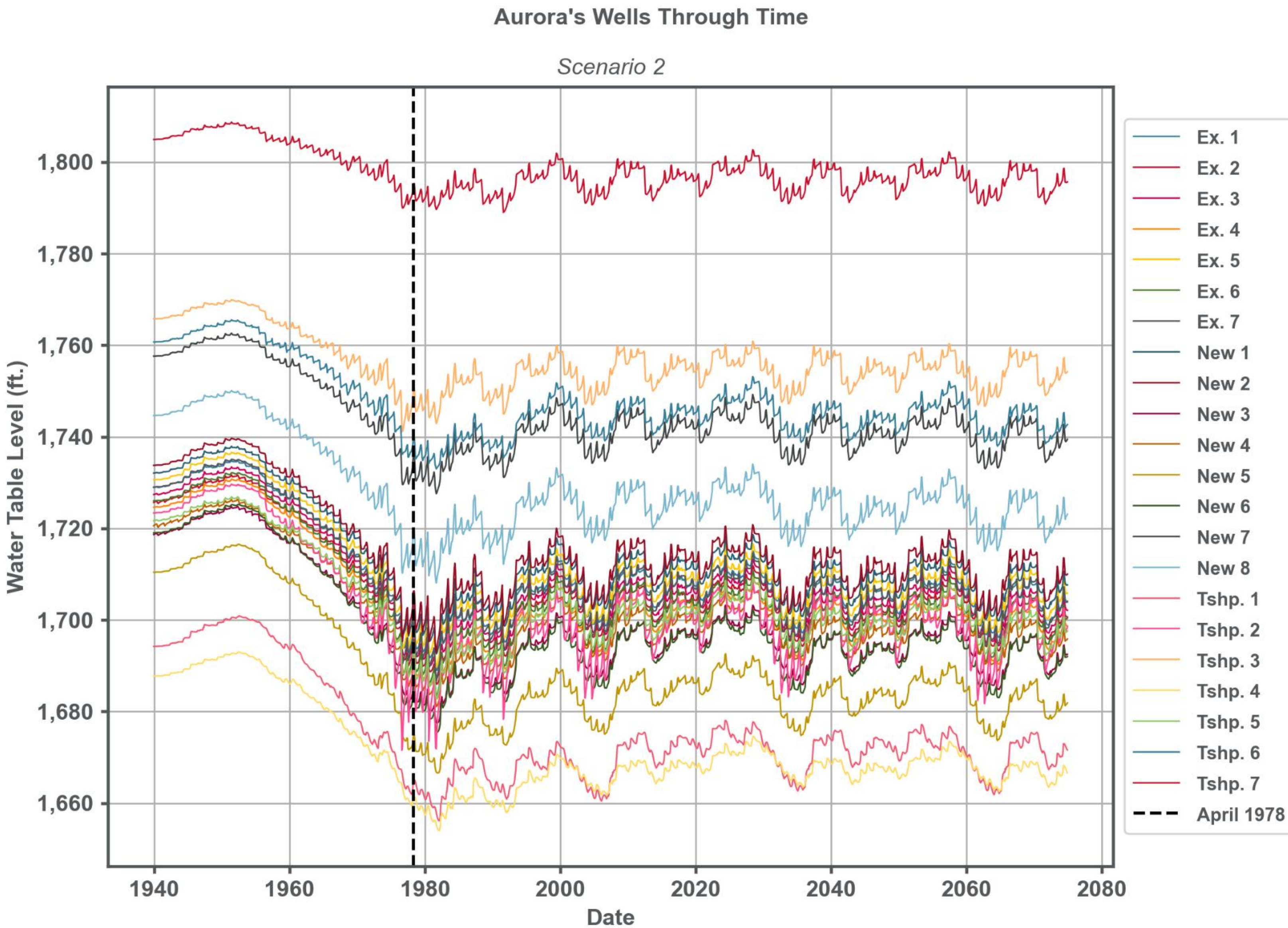
A-2. Hydrographs at All Study Well Locations: Projection Baseline - No Growth



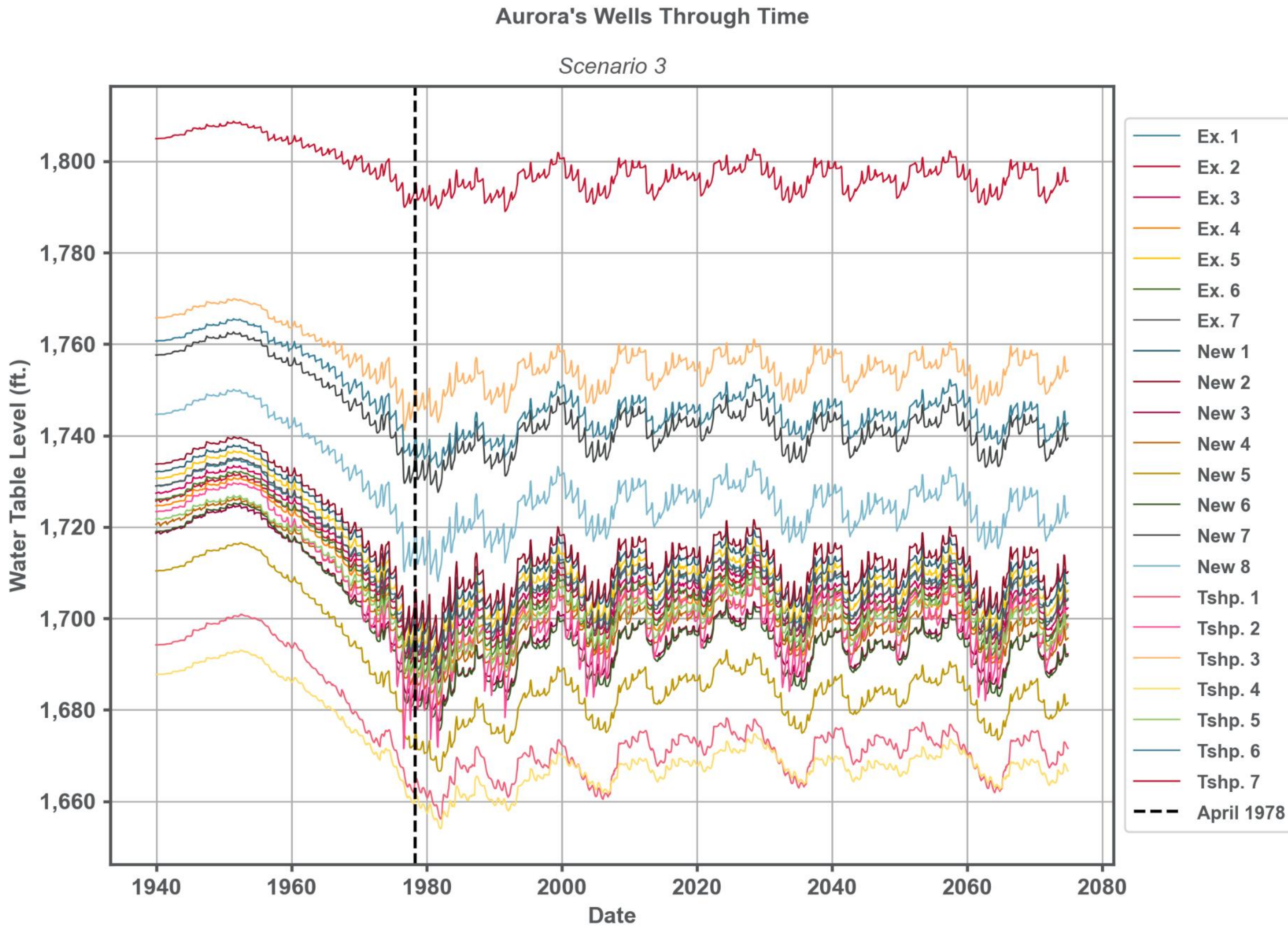
A-3. Hydrographs at All Study Well Locations: Projection Baseline - Linear Growth



A-4. Hydrographs at All Study Well Locations: Scenario 1



A-5. Hydrographs at All Study Well Locations: Scenario 2



A-6. Hydrographs at All Study Well Locations: Scenario 3