Review of the Monolith Materials Inc. Groundwater Flow Model

Prepared for:

Lower Platte South Natural Resource District

February 2021

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SECTION 1: INTRODUCTION

1.1 PURPOSE OF REVIEW

This Review of the Monolith Materials, Inc. (Monolith) Groundwater Flow Model Report (Report) documents LRE Water's (LRE) peer-review and evaluation of Olsson Inc.'s (Olsson) groundwater flow model (Model) that was completed on behalf of Monolith. The Model was created as part of a hydrogeologic analysis to simulate future groundwater conditions associated with the additional pumping that will be required to meet the water demands of the proposed expansion of Monolith's facility. The modeling approach and Model construction, input parameters, calibration, and resulting estimation of the likely impacts of the additional withdrawal are documented in Olsson's December 2020, Draft Monolith Hydrogeologic Analysis Report (Olsson Report).

The facility, referred to herein as the Site, is located in the Lancaster County just north of the Village of Hallam, Nebraska in the southwest corner of the Lower Platte South Natural Resources District (LPSNRD). LRE was retained by the LPSNRD to complete the review and this Report.

The purpose of LRE's review is to ensure the Model is based on currently available scientific information and the results can be replicated. LRE's review involved evaluation of the Model:

1. Objective and model code,
2. Input parameters,
3. Appropriateness of aquifer and hydraulic boundary conditions,
4. Simulation results for water levels and flows, and
5. Applicability for simulating water level changes in response to the proposed pumping and project operations at the Site.

The Model was built and refined using the MODFLOW-Unstructured Grid (USG) program, which is a version USGS's modeling software code, MODFLOW, which is the standard in the groundwater modeling industry. Much of the Nebraska Department of Natural Resources (DNR, 2018) existing Lower Platte Missouri Tributary (LPMT) Model was used as the starting point for construction of the refined model MODFLOW files. More details on the Model are provided in Olsson (2020) and in this Report.

The Model files were provided to LRE by Olsson as the following zip archive:

- MonolithCal: Calibrated version of the initial Model including MODFLOW input and output files for the time period 1960-2019.
- MonolithFuture: Version of the Model used to compare the differences a no pumping scenario and a pumping scenario for the 50-year time period from 2020 through 2069.
- Additional Files: Olsson also provided a MODFLOW input WEL file that has the Monolith pumping well (Monolith Well), and an older version of the Model in Groundwater Vistas Graphical User Interface (GUI) format.

1.2 MODEL BACKGROUND

The Model was developed by modifying the LPMT Model that simulated groundwater flow and the interaction of groundwater with surface waters across a larger region. Olsson modified the LPMT by converting it into a MODFLOW-USG version, decreasing the model extent, refining the cell size where a resolution increase was desired, altering the hydraulic conductivity (k) distribution, adding relevant aquifer and hydrologic boundary conditions, and incorporating publicly available information to inform the sources and sinks of water in the region during a 60-year time period prior to 2020. This was done using a combination of Groundwater Vistas GUI, Olsson's proprietary modeling software "Get" (https://get.olsson.com), and MATLAB (https://www.mathworks.com/). The MonolithFuture.zip file used the data compiled in the initial calibration Model and used the most recent 25 years of climate data and the irrigation pumping data from 2013 throughout the Model.

The focus of this Review is on the Model files used to simulate future conditions because that was the version of the Model used to estimate the effects of pumping from the Site.

LRE used a combination of FloPy (Python MODFLOW module), Groundwater Vistas, and Esri's Arcmap to evaluate the efficacy of the Model. We note that initial or starting heads were not discussed in the Olsson Report (2020) and were not provided as a separate file for the initial calibrated Model and the predictive or future Model. We therefore assumed that the calibration run final heads are the pumping and no pumping future run starting heads. While not critical for our evaluation, we recommend providing additional information on replicating the Model runs in a brief addendum.

SECTION 2: MODEL OBJECTIVE AND CHOICE OF MODELING CODE

The objective of the Model is to evaluate the changes to the groundwater levels or heads in Quaternary-age buried sand gravel aquifer system, referred to in the LPSNRD's Rules and Regulations as the Crete-Princeton-Adams (CPA) aquifer, and flow in hydraulically connected surface water bodies as a result of the planned increase of pumping at the Site. The CPA aquifer changes were evaluated in the area surrounding the Monolith Well location at the Site. Olsson notes that while they may have as many as three wells, the total production can be approximated with a single pumping well that pumps at the combined demand of all Monolith Wells, therefore we refer to this combined system as the "Monolith Well". As a secondary objective the Model seeks to evaluate where the source(s) of water are coming from when pumping occurs. This is expressed as the timing and magnitude of the reduction in groundwater outflow to the rivers and streams in the area.

Thoughtful selection of a numerical modeling code for simulating groundwater flow is required and a code should be selected with the overall objectives of the simulations in mind (Anderson et al., 2015). The modeling code utilized for the analyses included MODFLOW-USG Beta Version 2.0.0 also known as MODFLOW-USG-Transport. MODFLOW-USG is a publicly-available, widely-accepted USGS groundwater flow numerical modeling code that was specifically developed to allow grids other than the orthogonal structured grids required by previous MODFLOW versions to be used for groundwater flow simulations. While no contaminant fate and transport, or particle tracking packages were activated in the Model, the base MODFLOW-USG code is a good choice to allow for grid discretization and greater resolution.

We agree that MODFLOW-USG is an appropriate code for the Model.

SECTION 3: MODEL INPUTS

This section discusses our review of the inputs to the Model.

3.1 EXTENT, SPATIAL DISCRETIZATION, AND TEMPORAL DISCRETIZATION

The extent and spatial discretization of the Model is shown on **Figure 1**. The projected geographic coordinate system utilized is State Plane Nebraska FIPS 2600. The units are in feet (ft). The southeast corner of the model is located at 245520 ft Northing and 2477635 ft Easting. The spatial discretization is variable and ranges from 165 ft square to 2640 ft square. The smallest discretization surrounds the streams and the Monolith Well on the Site.

The model encompasses a total active model area of approximately 373 square miles and adequately bounds the influence of the Monolith Well location. The temporal discretization consists of 600 transient stress periods. Each stress period has one-time step and is 30.43 days long.

By comparing the results for a Model run with and without the pumping schedule of the Monolith Well we are able to determine the potential impacts due to changes in the CPA aquifer or other sources of water.

It is our opinion that the set-up of the extent, spatial, and temporal discretization allow for an adequate assessment of the Model objectives.

3.2 GEOLOGY, MODEL THICKNESS, AND BEDROCK FLOW INTERACTIONS

To assist in our evaluation of the conceptual hydrogeology of the Model domain, LRE constructed three hydrogeologic cross sections through the locations shown on **Figure 2**. The cross sections are referenced at A-A’, B-B’, and C-C’ and are shown on **Figures 3 and 4.** Based on our review of geologic information, including borehole logs, the cross sections, and peer reviewed publications, it is our opinion that the structure of the CPA aquifer represented in the Model represents the known geology adequately.

The Quaternary material including the CPA aquifer is represented in the Model as four layers. The first and third layers represent low-permeable loess and/or glacial till (i.e., silt and clay). The second and fourth layers represent the CPA aquifer sand and gravel units. The base of the Model terminates at bedrock, which is sandstone and shale of the Cretaceous-age Dakota Group just to the south, west and north of the Site. Permian-age limestone and shale of the Council Grove Group underlie the Site and to the east.

The Model bottom and Model top of the sand and gravel units that makeup CPA aquifer are reasonable and consistent with the local hydrogeologic and surface topographical conditions. Groundwater levels and depth to groundwater within the Model domain vary greatly because of the large scale represented and the variability of measurements over time and the land surface, but reasonably represent the groundwater flow field across area. The CPA aquifer is modeled with the top two layers unconfined and the bottom two confined. The total CPA aquifer thickness varies, but appears to be reasonable for the meeting the objectives of the Model. The active model cells have a wettability type specified as “non-wettable”, which is appropriate for this simulation.

In discussion with the LPSNRD, water chemistry considerations including the higher concentration of Total Dissolved Solids (TDS) within bedrock units was highlighted as a potential concern. The Model does not explicitly consider this potential inflow, and the potential for the Monolith wells to affect this flow. The final paragraph of the Olsson Report states:

> *“The final issue for consideration is any effects of upwelling of underlying water with higher TDS. The mechanism for the upwelling of underlying water would be broad-scale significant declines of water levels. While declines of up to 8.5 feet can be anticipated in the immediate vicinity of the Monolith well, impacts of this extent will be localized and are generally less than 1-2 feet over most of the aquifer. This is because the primary source of water for the Monolith well will come from a decrease in discharge to streams in the area.”*

As discussed later in this report, we agree that the Model simulates that the primary source of water to the Monolith well is a decrease in discharge to streams. However, the Model does not simulate any interaction with bedrock groundwater because the bedrock units are not a part of the Model flow simulation. Exclusion of the bedrock units is based on an assumption that there is little interaction between the deeper bedrock flow system and the surficial CPA aquifer, which may be reasonable. However, in our opinion it would be useful to characterize the gradient (i.e. flow direction) between the bedrock units and the CPA aquifer in the area if bedrock wells exist. If the gradient is currently downward from the CPA into the bedrock units, and is expected to remain downward during future pumping, it is reasonable to assume that there may not be significant impacts to CPA-Aquifer water quality. However, if the gradient is upward, or is expected to change directions from downward to upward, additional monitoring of water quality is recommended. We note that during the 72-hour pumping test at the site, a steady increase in the Specific Conductivity of the water was observed, which likely correlates with steadily increasing levels of TDS and possible bedrock groundwater interaction.

It is our opinion that the physical structure of the CPA aquifer within the model extent is reasonably adequate for model simulations to achieve the desired objectives if the assumption of little to no interaction with bedrock aquifers is justified. If the recommended gradient analysis shows the likelihood of a gradient reversal from downward to upward, further analysis or monitoring is recommended.

3.3 WELLS AND TARGETS

The main calibration target for the Model was groundwater level observations. Pilot points were used along with the parameter estimating tool (PEST) to calibrate 87 targets with multiple water level observations. The calibration process focused on the hydraulic conductivity (k) to range between 20 and 210 ft/day for the CPA aquifer units to match the observed water levels. The full calibration process is not reviewed in this Report. Instead we compared the calibrated values to estimates obtained from the aquifer pumping test (Test) analysis contracted by Olsson to EA Engineering, Science, and Technology, Inc., PBC (EA). In our opinion, the calibrated model properties are appropriate (however, as discussed later in this Report, an additional sensitivity analysis is recommended).

Two files representing groundwater well pumping (WEL files) were provided to compare the pumping and no-pumping scenario in the Model. The no-pumping scenario has 430 wells that represent the current local water use from irrigation, industrial, and municipal use. The pumping scenario adds the proposed Monolith Well pumping at an average of 595 gpm, and ranges throughout the 50 years with a minimum of 393 gpm in January and 774 gpm in September. In general, the pumping rates are highest in the summer and fall and lowest in the winter months, which is based on Monolith's predicted use of the Monolith Well.

3.4 MODEL PROPERTIES AND COMPARISON TO PUMPING TEST RESULTS

The hydraulic conductivity (k) of the four model layers ranges from 1 ft/day to 210.5 ft/day. Layers 1 and 3 represent a lower permeability silt and clay whose horizontal hydraulic conductivity (k_h) was set to 10 ft/day, and vertical hydraulic conductivity (k_v) was set to 1 ft/day. Layers 2 and 4 are separate units that makeup the CPA aquifer, but have similar scales in k_h that ranges from 20 ft/day to 200 ft/day, and 19.4 ft/day to 210.5 ft/day respectively. The ratio of k_h / k_v for both aquifer units ranges from 1.2 to 328 throughout the Model domain.

The range in k_h chosen to bound the PEST calibration of Layers 2 and 4 was based off of the pumping Test at the Site and hydrogeological reports of the area. A review of the Test was completed by LRE. We generally agree with the approach and analysis done by EA and believe it is acceptable and reasonably represents the CPA aquifer system. It is noted that the Test did not stress the CPA aquifer as significantly as would have been desired to get a better calibration under stressed conditions. We note that the maximum displacement of the 72-hour Test at 800 gpm was less than 9 feet in a 60-foot thick aquifer, which is similar to the amount of drawdown predicted from Monolith's pumping in the Model (note that Monolith's long-term average pumping is approximately 600 gpm). Under long term production, regional drawdown could exceed the drawdown observed during this Test. A longer term Test could be considered to stress the CPA aquifer more significantly.

Based on the available data, LRE believes that the k_h value used for the aquifer layers are adequate for the purpose of the Model.

When reviewing the k_h and k_v of the silt and clay, layers 1 and 3, we noted that a uniform 10 ft/day and 1 ft/day, respectively may be misrepresenting the lithology. Based on our experience, silty clays often have lower k_h and have greater k_h / k_v ratios. LRE recommends sensitivity analysis of the k_h and k_v of Layers 1 and 3 to ensure that it does not have a significant impact on the overall result from the Model.

The specific storage (Ss) in Layer 1 is 0.001 and is set to 0.00001 for all other layers. Layer 1 and Layer 2 are unconfined and their specific yield (Sy) is set to 0.2. These storage values are reasonable for the purpose of this Olsson Future Model.

In summary, the model parameters appear appropriate, however an additional set of sensitivity runs for K_v is recommended.

3.5 BOUNDARY CONDITIONS

3.5.1 Stream Package (STR)

Several major streams are represented as 13 stream segments with the stream package in the Model. The conductance of each reach of stream (cell) was calculated by multiplying; streambed thickness (2 feet), width of all steams (50 feet), the length of stream within the cell, and streambed hydraulic conductivity (250 ft/day). Slope of the streams were calculated by average slope of the elevation from beginning and end. River Bed Conductance was set to 10,000 ft^2/day with a 5-foot river bed thickness.

3.5.2 River Package (RIV)

The river package was used to simulate the western boundary condition of the model with the exception of a few general head boundary cells. The Big Blue River flows from the north to the south within the model domain.

3.5.3 General Head Boundary Package (GHB)

The North, South, and Eastern boundaries of the model are set as general head boundaries. The general head elevation was specified as the head elevation of the LPMT model for the corresponding month. The general head conductance was specified as 10,000 ft^2/day.

3.5.4 Evapotranspiration Package (EVT)

This model used the same Evapotranspiration package values that were used in the larger model (LPMT model) that this one was based on. It is LREs opinion that this is a reasonable assumption.

3.5.5 Recharge Package (RCH)

The regional recharge to the alluvial aquifer from precipitation was modeled with the MODFLOW Recharge (RCH) package. The recharge in this model is the same as the LPMT model with an average of about 3.8 inches per year.

In summary, the boundary condition packages used in the model are reasonable, and parameter values for these packages appear reasonable based on our experience.

SECTION 4: MODEL OUTPUT: WATER LEVEL AND STREAMFLOW CHANGES DUE TO MONOLITH FUTURE PUMPING OPERATIONS

One of the main objectives of the Model was to quantify the difference in water levels within the CPA aquifer system surrounding the Site after 50 years of pumping from the Monolith Well. LRE was able to successfully compare the results of a pumping and a no-pumping scenario in this calibrated model to compare 1) where the water is coming from in the model when producing water through the proposed production well, and 2) the regional drawdown of the CPA aquifer system after 50 years of pumping, comparing them to the results presented by Olsson (2020).

Another main object of the Model is to simulate the effect of pumping on surface streams. To review this, we compared the modeled water budget for the Monolith pumping and no-Monolith-pumping scenarios. The model budget difference highlights the source of water to the Monolith Well. The differences from pumping can be seen in **Figure 5** and **Table 1.** The surface water contributions (River and Streams) account for 52% of the water pumped from the Monolith Well over 50 years. Water coming from aquifer storage accounts for 31%. The remaining significant portion (16%) comes from the General Head Boundaries from the North, South, and East. Our results are identical to the results presented by the Model. The predicted reduction in stream flow of 452 acre-feet per year is equivalent to a reduction of approximately 0.6 cubic feet per second (cfs). The impact to the GHB Boundaries of 157 acre-feet per year is equal to an additional 0.2 cfs which is likely to manifest as a reduction in outflow to streams outside of the model domain. Together, these comprise a total predicted stream flow reduction of approximately 0.8 cfs.

A water table drawdown map was created for each layer in the Model, comparing the final time step at the end of 50 years (**Figures 6-9**). The drawdown in all layers (**Figure 10**) was used to create a full drawdown map. Comparing these results to figure 3.14 in the Olsson (2020), (**Appendix A**) we find that they are very similar, but not exactly the same. The first difference is that Appendix A shows the contour interval with a maximum decline of -0.1 feet, but it is not shown. The second is that the maximum drawdown in all layers on the final time step of the Model is 6.9 feet near the Monolith Well. **Appendix A** shows contours up to -8.5 feet and that amount of drawdown is referenced in the Discussion section of the Olsson (2020). Lastly some of the contour intervals are slightly different from each other. These differences in **Figure 10** and **Appendix A** do not change our opinion on the overall Model. We suspect that the minor differences we encountered are due to differences in initial heads, contouring methods, or the exact time used for the drawdown analysis. These minor differences to not affect the overall conclusions of our analysis, however, we recommend providing a model addendum to document exactly how Olsson's drawdown maps were developed.

SECTION 5: SUMMARY AND CONCLUSIONS

Based on our evaluation of the Model we have reached the following conclusions:

1. The Model calibration to observed groundwater level data is adequate to meet the objectives based on our modeling experience.
2. The Quaternary material including the CPA aquifer is represented in the Model as four layers. Based on our review of geologic information, including borehole logs and peer reviewed publications it is our opinion that the structure of the CPA aquifer in the Model represents the known geology adequately.
3. The simulated groundwater level conditions in the Model are reasonable and adequately demonstrate where the sources of water come from for a Monolith Well pumping at an average rate of 595 gpm, and ranging throughout the 50-year simulation period from a minimum of 393 gpm in January to 774 gpm in September.
4. The surface water contributions (River and Streams) account for 52% of the water pumped from the Monolith Well over 50 years. Water coming from aquifer storage accounts for 31%. The remaining significant portion (16%) comes from the General Head Boundaries from the North, South, and East. The total reduction in streamflow predicted by the model is approximately 0.8 cfs. Our results are identical to the results presented by the Model.
5. The Model also reasonably represents regional drawdown in the CPA aquifer due to the Monolith Well pumping at an average rate of 595 gpm, and ranging throughout the 50-year simulation period from a minimum of 393 gpm in January to 774 gpm in September.
6. The assumptions included directly and indirectly into Olsson's Future Model are adequate for reasonably reliable drawdown predictions
7. It is our opinion that the physical structure of the CPA aquifer within the model extent is reasonably adequate for model simulations to achieve the desired objectives if the assumption of little to no interaction with bedrock aquifers can be strengthened. If the recommended gradient analysis shows the likelihood of a gradient reversal from downward to upward, further analysis or monitoring is recommended.
8. The extent, boundary conditions, and calibration to water level observations incorporated into Model, in LRE's opinion, is appropriate for the achieving Model objectives if it can be shown that bedrock interactions are minimal or downward.

SECTION 6: RECOMMENDATIONS

Based on our evaluation of the Model we recommend the following:

1. Complete a more detailed sensitivity analyses on the following:
    a. Scale of hydraulic conductivity in model layers 1 and 3 (low-permeability layers); and,
    b. Horizontal / vertical hydraulic conductivity ratio (kh/kv) in all layers.

2. Provide an addendum with directions for exact replication of future drawdown simulations presented by Model results. This will be useful for documenting and comparing the current model results.
3. For future reference, we recommend the current Model have less Model refinement or discretization (i.e., grid and cell size) to make it more "user friendly". It is likely that the same results will be achieved with a simpler model.
4. Better characterize the gradient (i.e. flow direction) between the bedrock units and the CPA aquifer in the area if bedrock well water level measurements exist. If the gradient is currently downward from the CPA into the bedrock units, and is expected to remain downward during future pumping, it is reasonable to assume that there may not be significant impacts to CPA aquifer water quality. However, if the gradient is upward, or is expected to change directions from downward to upward, additional monitoring of water quality is recommended.
5. LRE recommends that a groundwater monitoring plan be developed and implemented before the Monolith Well begins operating. The plan should be designed to address future potential changes in groundwater quality and quantity at the Site and surrounding area. The plan is recommended based on changes to groundwater quality (indicated by elevated total dissolved solids) that have 1) occasionally been observed in the general area of the Site that may have been a result of pumping and leakage from the underlying bedrock (personal communication with LPSNRD staff), 2) the increase in the specific conductance in the Monolith Well during the 72-hour aquifer pumping test, and 3) because the Model does not include bedrock, and therefore cannot predict leakage from the underlying bedrock where the poor water quality may be originating.
6. Identify and document details (i.e., owner, location, depth, pump setting, static water levels) on all private and public supply wells within 1 ½ miles of the Site, and provide a well interference contingency plan in the event that any issues should occur to these wells as a result of the Monolith Well pumping.

SECTION 7: REFERENCES

The following references were relied upon when performing this model review:

FloPy.https://www.usgs.gov/software/flopy-python-package-creating-running-and-post-processing-modflow-based-models

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, NJ, Prentice-Hall, 604 p.

Olsson, Inc. December 2020 Monolith Hydrogeologic Analysis Report (DRAFT). Prepared for Monolith Materials Hallam, Nebraska.

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013, MODFLOW-USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

Modeling Files Relied Upon

The following electronic files were relied upon when performing our Model review:

MonolithCal.zip and MonolithFuture.zip

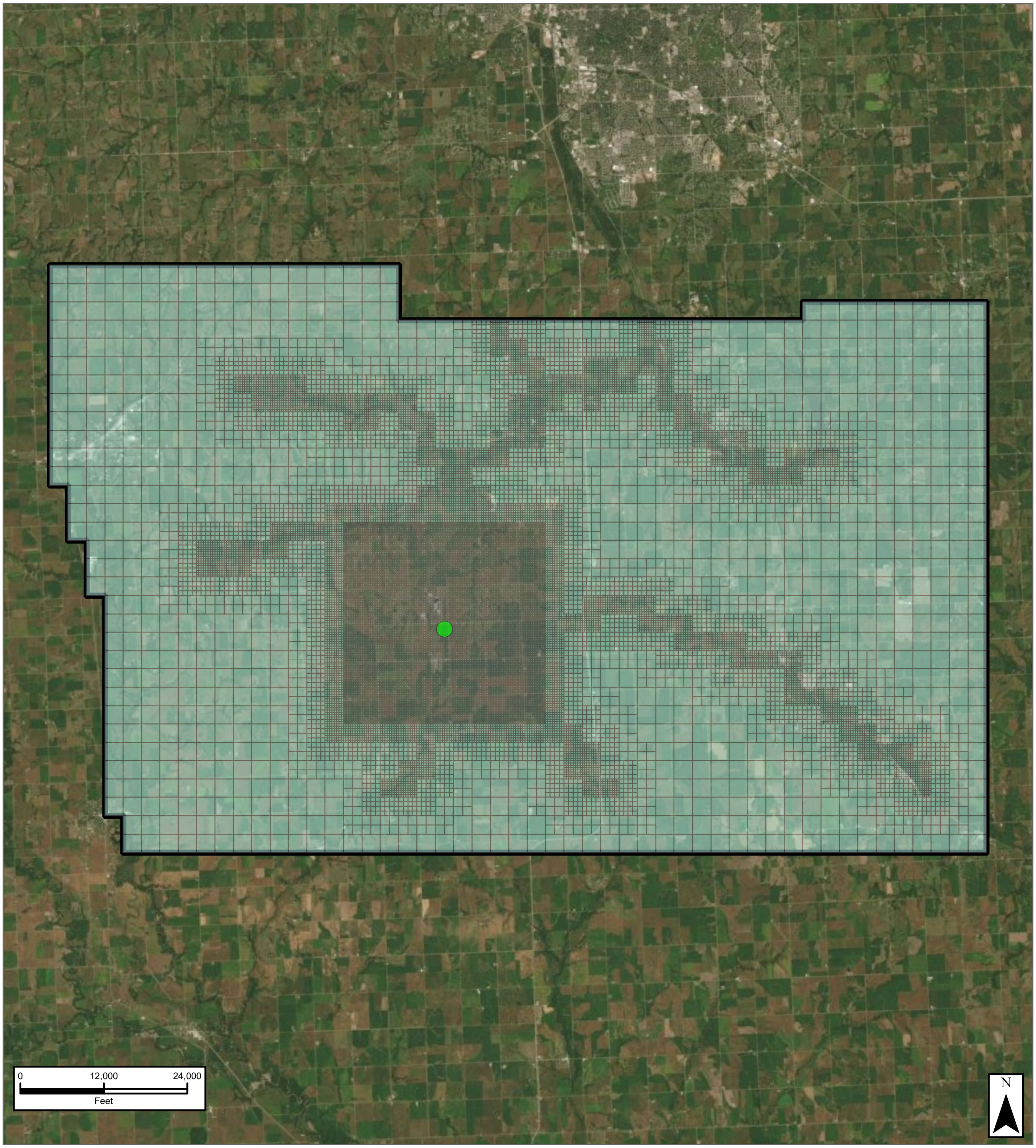
Groundwater Vistas (GWV) MMusg_Final.gwv file. Groundwater Vistas Graphical User Interface (GUI) (Environmental Simulations, Inc., http://www.groundwatermodels.com/)

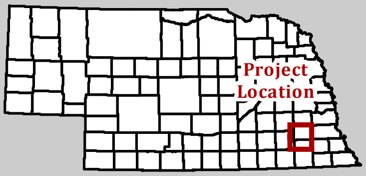
ScenarioWellFile.WEL file, for pumping scenario

MODFLOW USG – Beta Version Executable Version 2.0, Based on MODFLOW 2005 Version 1.11.0

Table 1: Water Budget Comparison

Budget Source or Sink	Without Pumping Totals	With Pumping Totals	Difference	Percent of Total
	acre-ft per 50 years	acre-ft per 50 years	acre-ft per year	
Wells	-600,800.75	-648,773.19	-959.45	-100.0%
Stream	-2,149,153.33	-2,126,533.45	452.40	47.2%
Storage	-94,452.05	-79,424.48	300.55	31.3%
GHB	-341,970.01	-334,122.57	156.95	16.4%
River	-372,596.62	-370,353.30	44.87	4.7%
Evapotranspiration	-56,524.94	-56,305.39	4.39	0.5%
Recharge	3,615,452.02	3,615,461.45	0.19	0.0%
Total (IN - OUT)	-46.95	-50.84	-0.08	0.0%





● Monolith Production Well

▭ Active Grid

▭ Active Model Outline

FIGURE 1
ACTIVE GRID AND WELL LOCATION

5041LPS01
Feb 2021

⊕ NeDNR Well on Cross Section
▲ CSD Test Hole on Cross Section
★ Public Water Supply Well
— Cross Section Transect
▭ NRD Boundary

Bedrock Formation Name

Cret.	▨	Greenhorn-Graneros Shale	Undifferentiated Interbedded Shales, Limestones, and Sandstones
	▨	Dakota Formation	
Permian	▨	Chase Group	
	▨	Council Grove Group	
	▨	Admire Group	
Penn.	▨	Wabaunsee Formation	

N

0 3 Miles

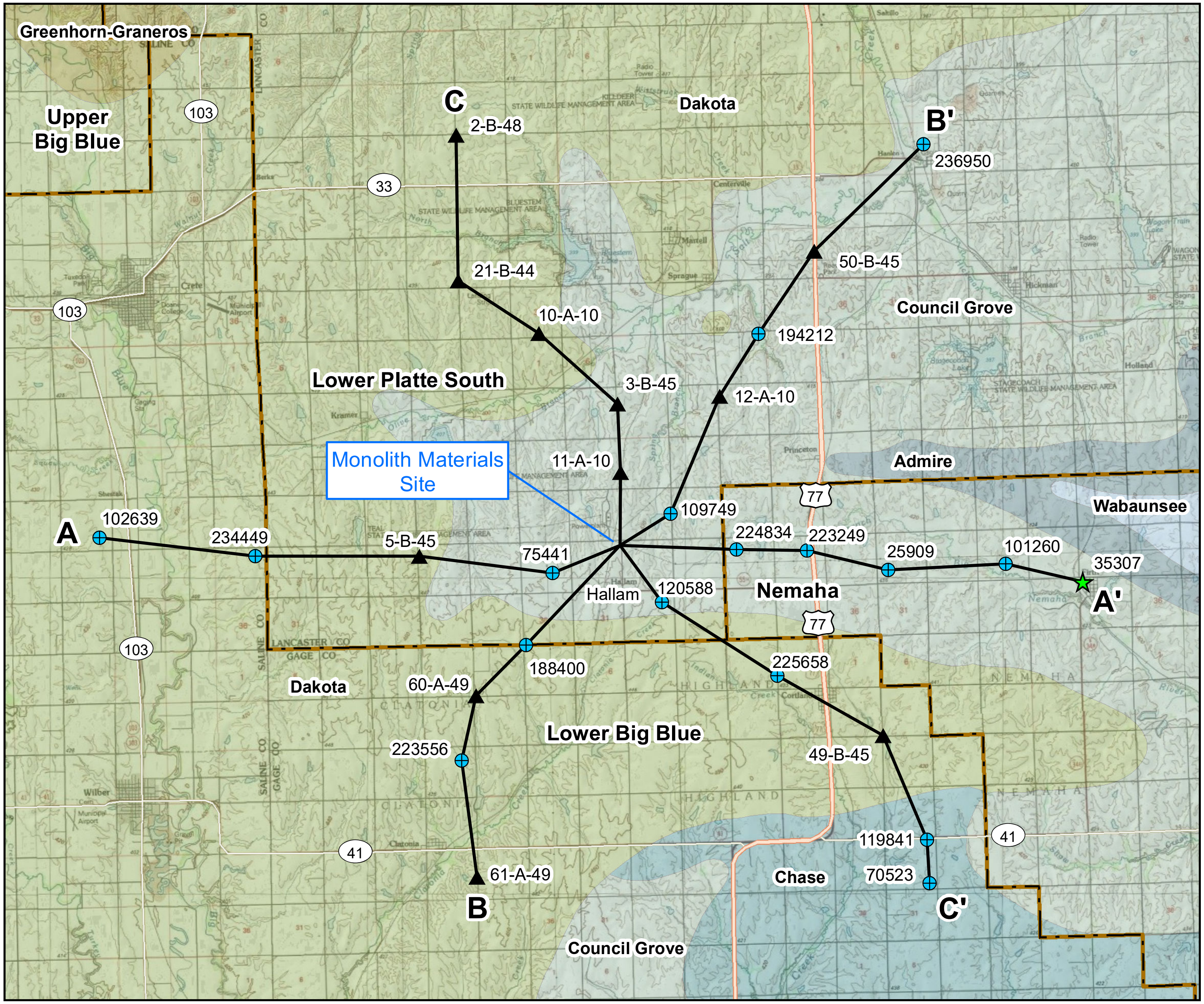
Notes:

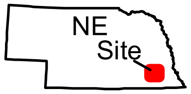
Sources:

First encountered bedrock from University of Nebraska-Lincoln School of Natural Resources database.

Service Layer Credits: Copyright:© 2013 National Geographic Society, i-cubed

Well locations from Nebraska Department of Natural Resources wells database, and test hole locations from the University of Nebraska-Lincoln Conservation and Survey Division database.





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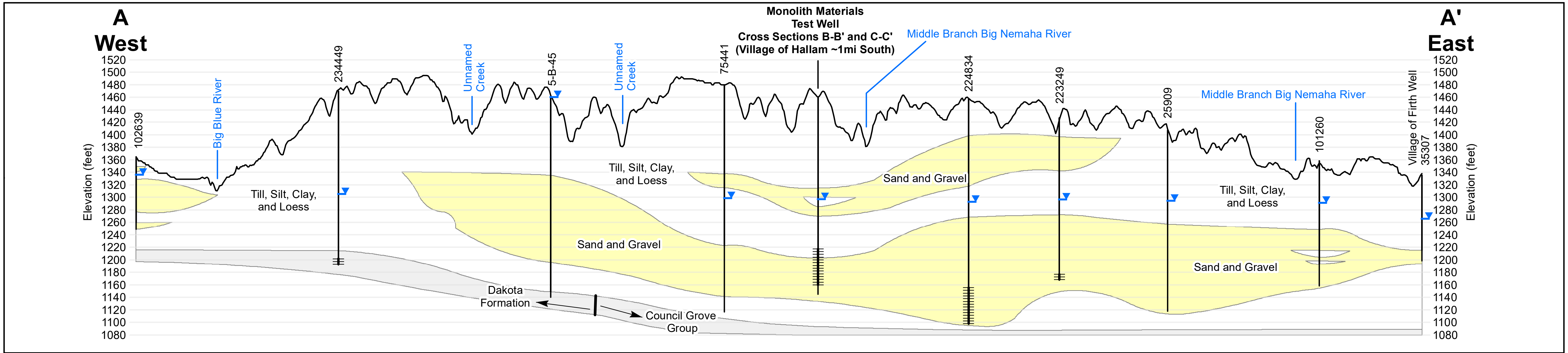
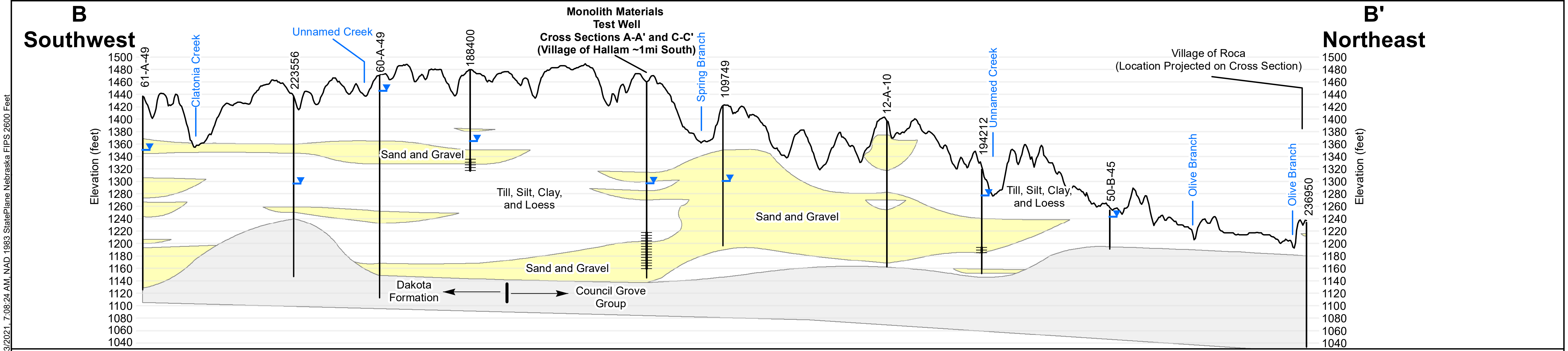
LOWER PLATTE SOUTH NATURAL RESOURCES DISTRICT
MONOLITH MATERIALS 3RD PARTY HYDROGEOLOGIC REVIEW
HALLAM, NEBRASKA

SITE LOCATION
AND HYDROGEOLOGIC CROSS SECTION TRANSECT LOCATIONS

FILE: 5041LPS0101C.MXD	DATE: 2/22/2021	FIGURE: 2

D:\GIS\GIS\Lower Platte South NRD Monolith\maps\5041LPS0101C.mxd, 2/22/2021, 3:05:32 PM, NAD 1983 UTM Zone 14N





Geologic Contact (interpreted based on geologic logs, and all contacts are inferred)

☐ Till, Silt, Clay, Loess (may have sandy fractions)

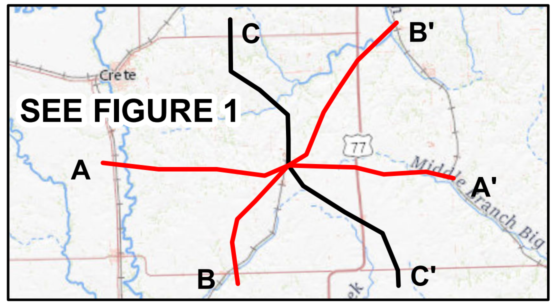
🟨 Sand and Gravel (may have silty, clayey or limestone fractions)

▨ Bedrock (Limestone, Sandstone, or Shale)

Undifferentiated

Potentiometric Surface (Measured at Installation Date)

Screen



Notes:

Cross sections drafted using geologic logs from the Nebraska Department of Natural Resources All Wells Database and from the University of Nebraska-Lincoln Conservation Survey Division Test Hole Database. All geologic contacts are inferred and based on available information.

Sources:

-First bedrock contact from University of Nebraska-Lincoln School of Natural Resources. https://snr.unl.edu/data/geographygis/geology.aspx

-Cross Section Transects: Digitized and snapped to well or test hole locations.

-Grade Profile: Extracted from 30-meter DEM from University Nebraska-Lincoln School of Natural Resources.

-Service Layer Credits: Copyright: © 2013 National Geographic Society

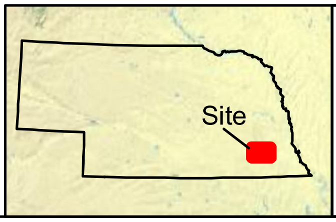
USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed May, 2020.

-Well and Test Hole Locations: Nebraska Department of Natural Resources All Wells Database, and University of Nebraska-Lincoln Conservation Survey Division Test Hole Database.

0 8,000
Feet

1 inch = 8,000 feet horizontal

1 inch = 160 feet vertical (40 scale on engineer's ruler)



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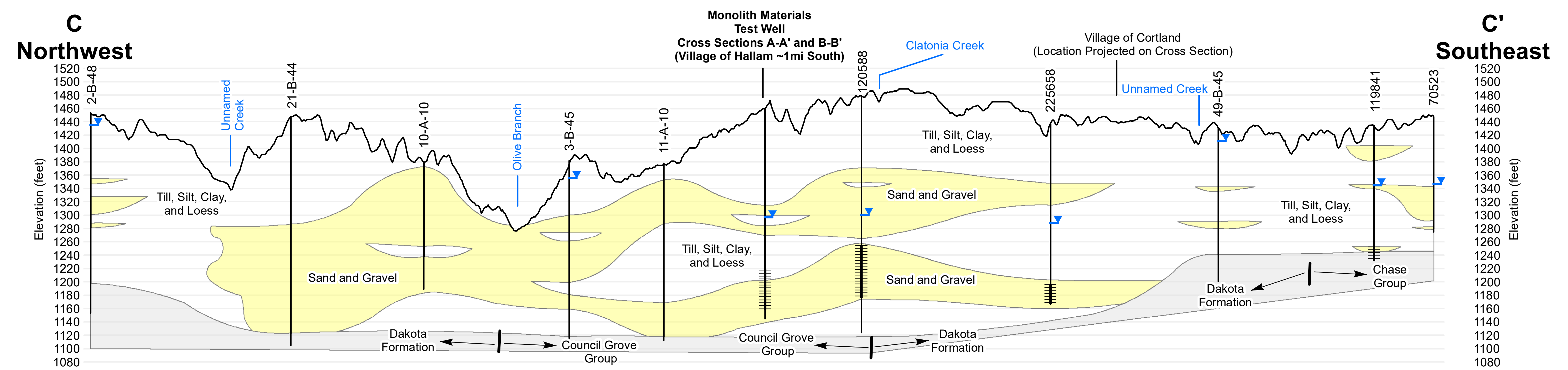
LRE Water
Innovative Water Resource Solutions
Minneapolis - Saint Paul, Minnesota
(612) 805-0919

LOWER PLATTE SOUTH NATURAL RESOURCES DISTRICT
MONOLITH MATERIALS 3RD PARTY HYDROGEOLOGIC REVIEW
HALLAM, NEBRASKA

HYDROGEOLOGIC CROSS SECTIONS A-A' AND B-B'

FILE: 5041LPS0101B - xsects A and B.MXD	DATE: 2/23/2021	FIGURE: 3

D:\GIS\GIS\Lower Platte South NRD Monolith\maps\5041LPS0101B - xsects A and B.mxd, 2/23/2021, 7:08:24 AM, NAD 1983 StatePlane Nebraska FIPS 2600 Feet



Geologic Contact (interpreted based on geologic logs, and all contacts are inferred)

☐ Till, Silt, Clay, Loess (may have sandy fractions)

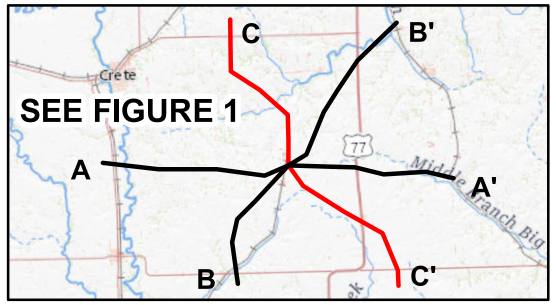
🟨 Sand and Gravel (may have silty, clayey or limestone fractions)

▨ Bedrock (Limestone, Sandstone, or Shale)

Undifferentiated

Potentiometric Surface (Measured at Installation Date)

Screen



Notes:

Cross sections drafted using geologic logs from the Nebraska Department of Natural Resources All Wells Database and from the University of Nebraska-Lincoln Conservation Survey Division Test Hole Database. All geologic contacts are inferred and based on available information.

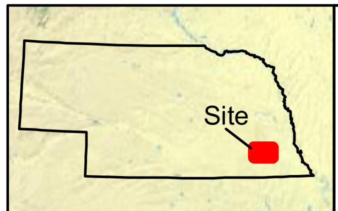
Sources:

-First bedrock contact from University of Nebraska-Lincoln School of Natural Resources. https://snr.unl.edu/data/geographygis/geology.aspx
-Cross Section Transects: Digitized and snapped to well or test hole locations.
-Grade Profile: Extracted from 30-meter DEM from University Nebraska-Lincoln School of Natural Resources.
-Service Layer Credits: Copyright: © 2013 National Geographic Society
USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed May, 2020.
-Well and Test Hole Locations: Nebraska Department of Natural Resources All Wells Database, and University of Nebraska-Lincoln Conservation Survey Division Test Hole Database.

0 8,000
Feet

1 inch = 8,000 feet horizontal

1 inch = 160 feet vertical (40 scale on engineer's ruler)



LRE WATER
CONNECTING WATER TO LIFE

Prepared By:
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Innovative Water Resource Solutions
Minneapolis - Saint Paul, Minnesota
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LOWER PLATTE SOUTH NATURAL RESOURCES DISTRICT
MONOLITH MATERIALS 3RD PARTY HYDROGEOLOGIC REVIEW
HALLAM, NEBRASKA

HYDROGEOLOGIC CROSS SECTIONS C-C'

FILE: 5041LPS0101D - xsect C.MXD
DATE: 2/23/2021
FIGURE: 4

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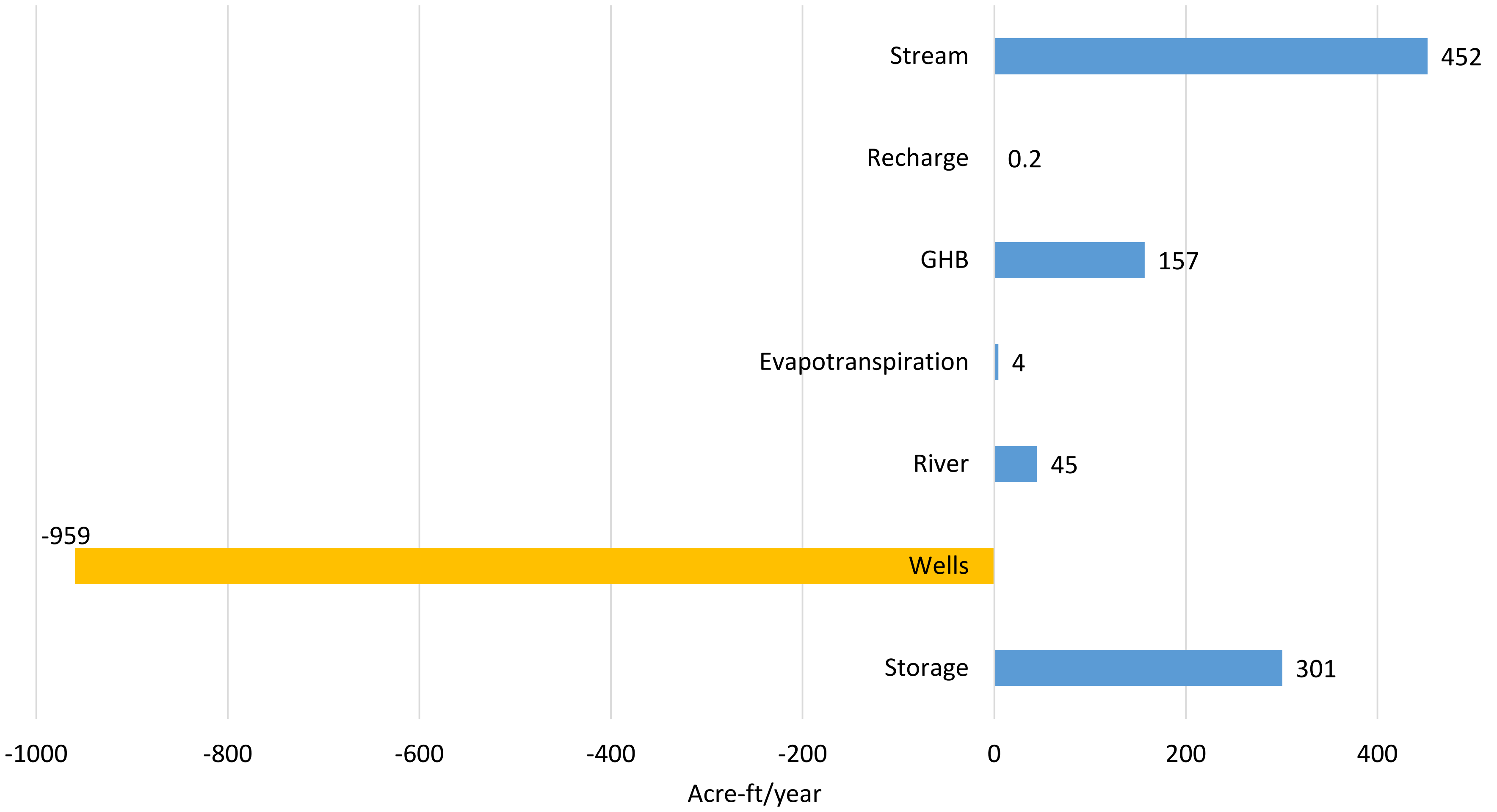


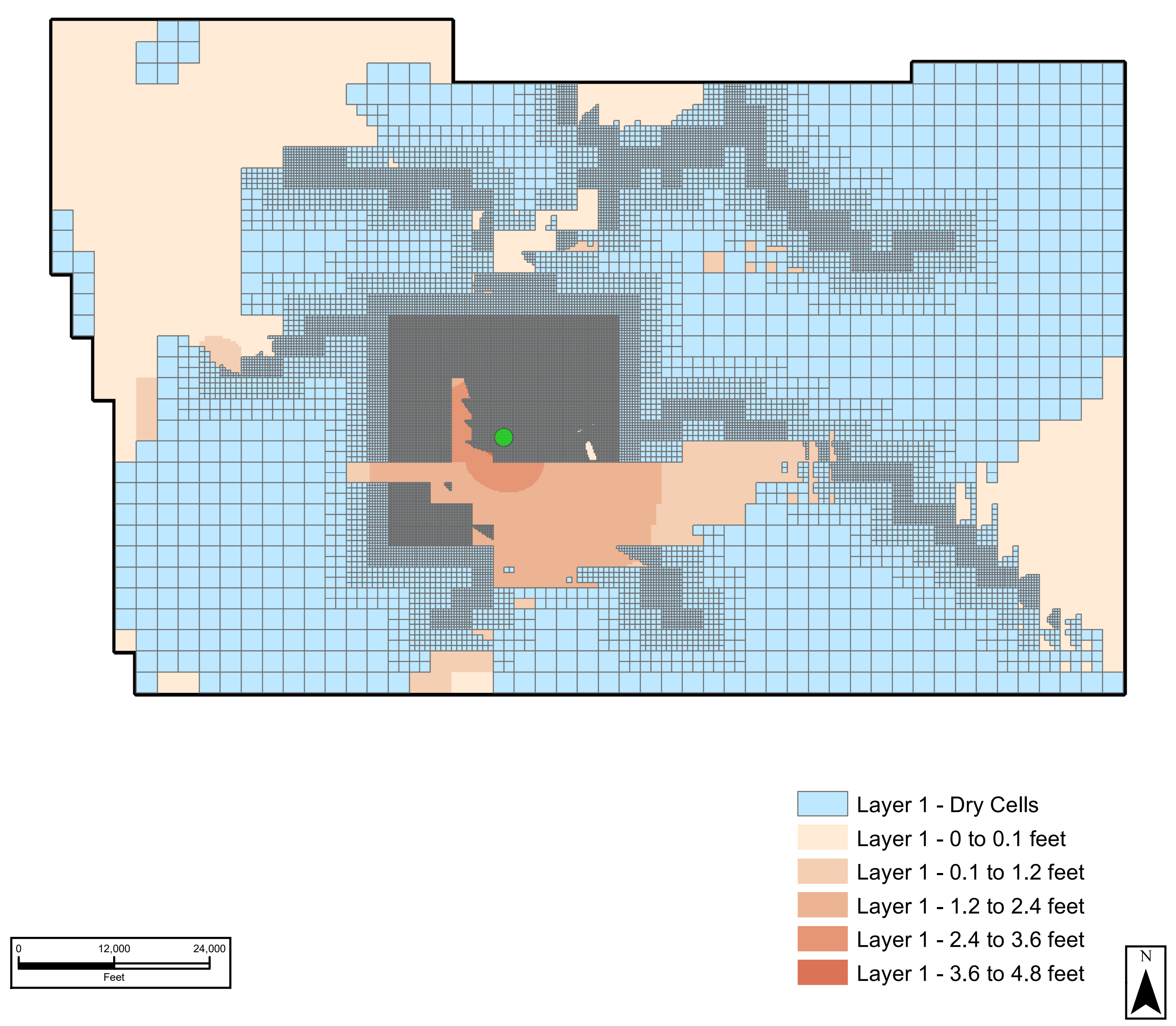
DATE: 2/8/2021

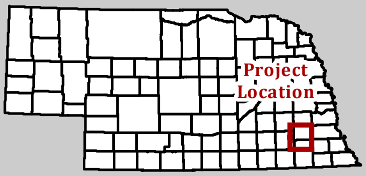
AUTHOR: CDM

CHECKED BY: JB

Figure 5
Cumulative Water Budget Difference For Pumping and Non-Pumping Scenarios (acre-ft/year)

LRE WATER
CONNECTING WATER TO LIFE
1221 Auraria Parkway, Denver, CO
80204





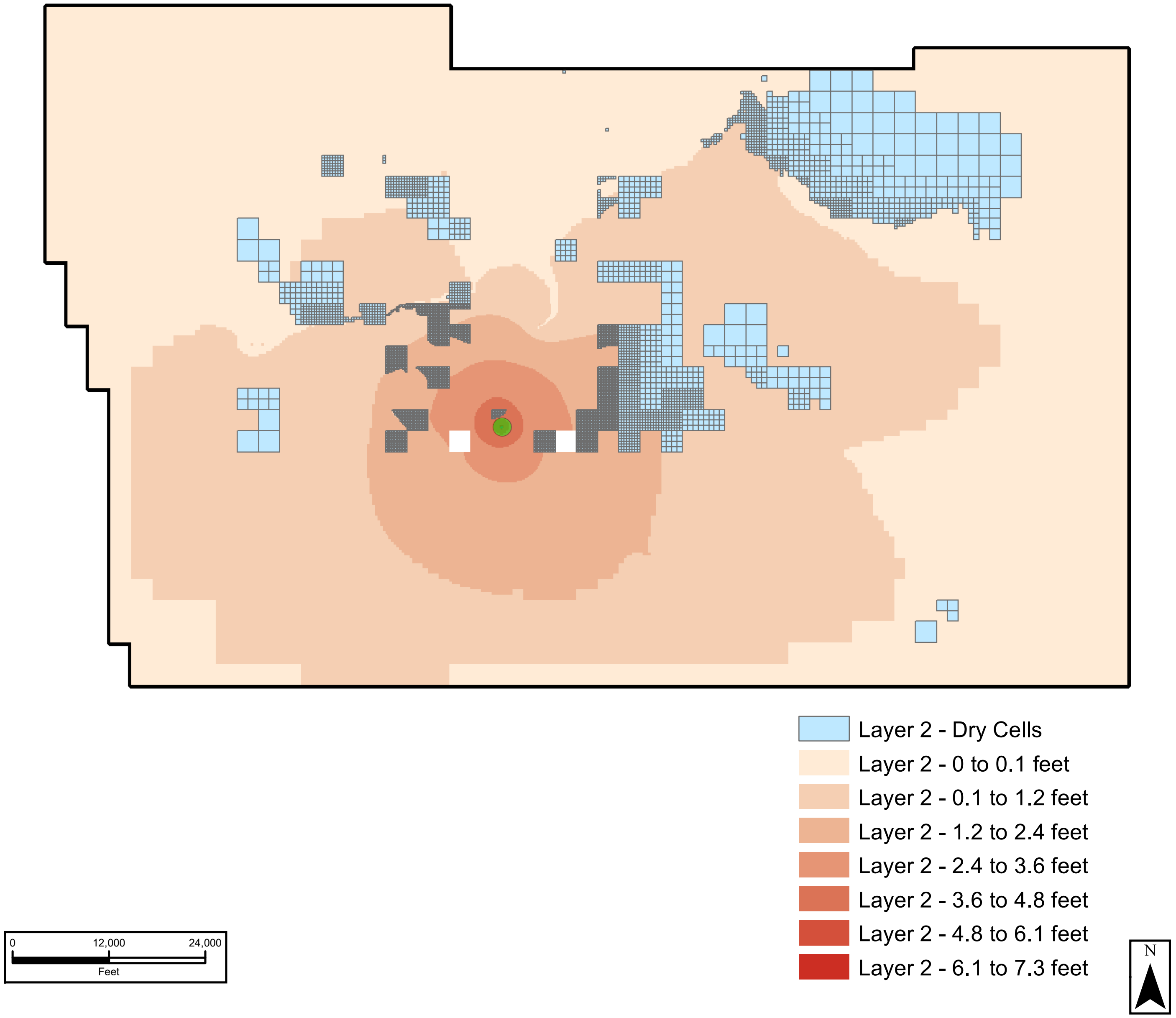
● Monolith Production Well

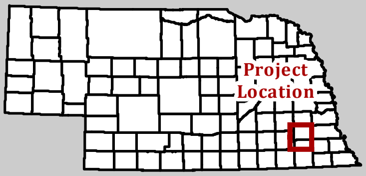
▭ Active Model Outline

FIGURE 6
DRAWDOWN IN LAYER 1 AFTER 50 YEARS PUMPING

LRE WATER

5041LPS01
Feb 2021





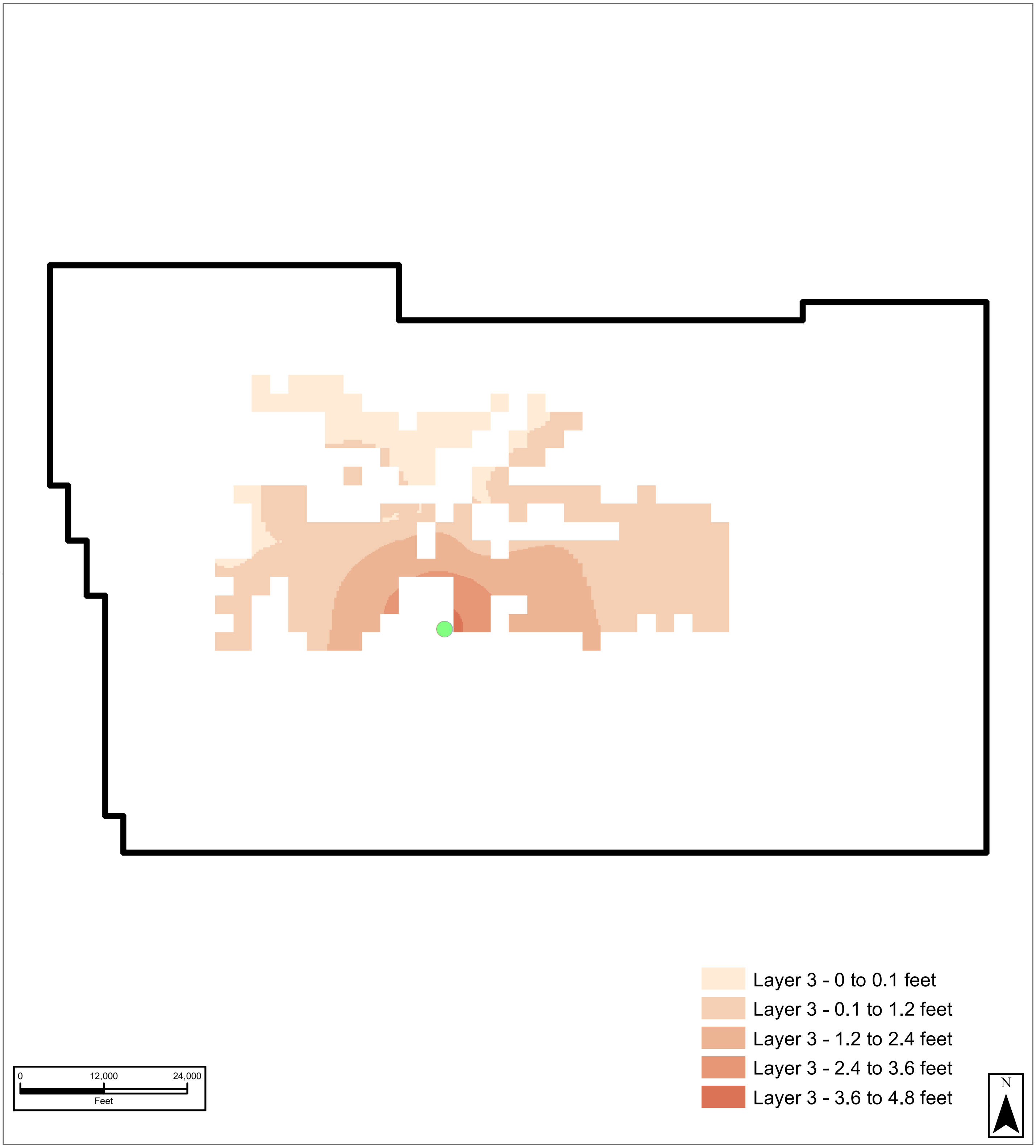
● Monolith Production Well

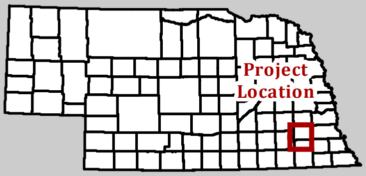
▭ Active Model Outline

FIGURE 7
DRAWDOWN IN LAYER 2 AFTER 50 YEARS PUMPING

LRE WATER

5041LPS01
Feb 2021





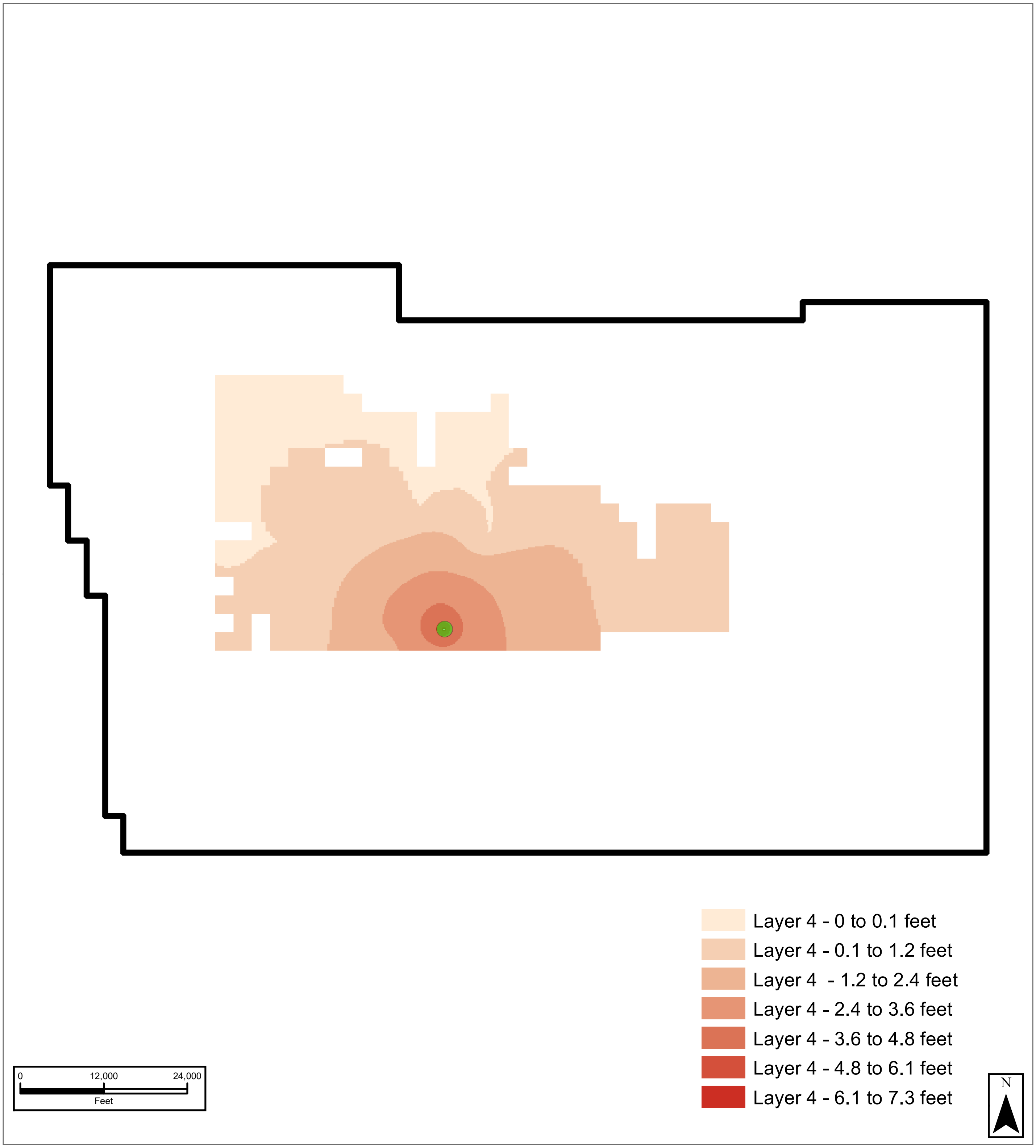
● Monolith Production Well

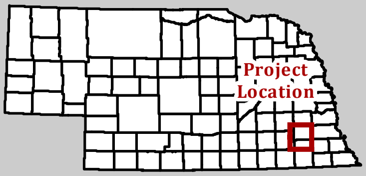
□ Active Model Outline

FUIGURE 8
DRAWDOWN IN LAYER 3 AFTER 50 YEARS PUMPING

LRE WATER

5041LPS01
Feb 2021





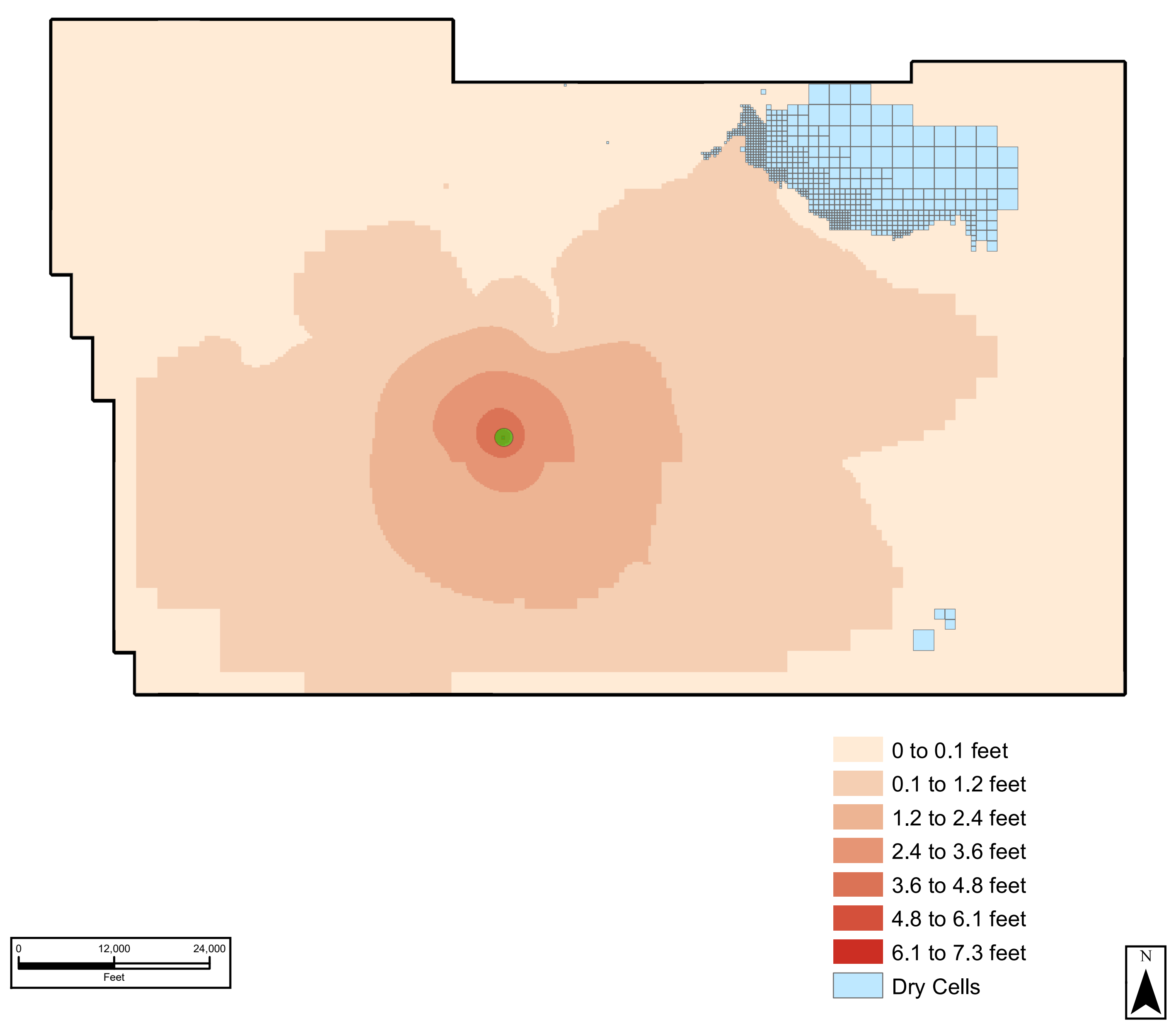
● Monolith Production Well

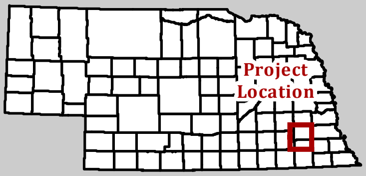
▭ Active Model Outline

FIGURE 9
DRAWDOWN IN LAYER 4 AFTER 50 YEARS PUMPING

LRE WATER

5041LPS01
Feb 2021





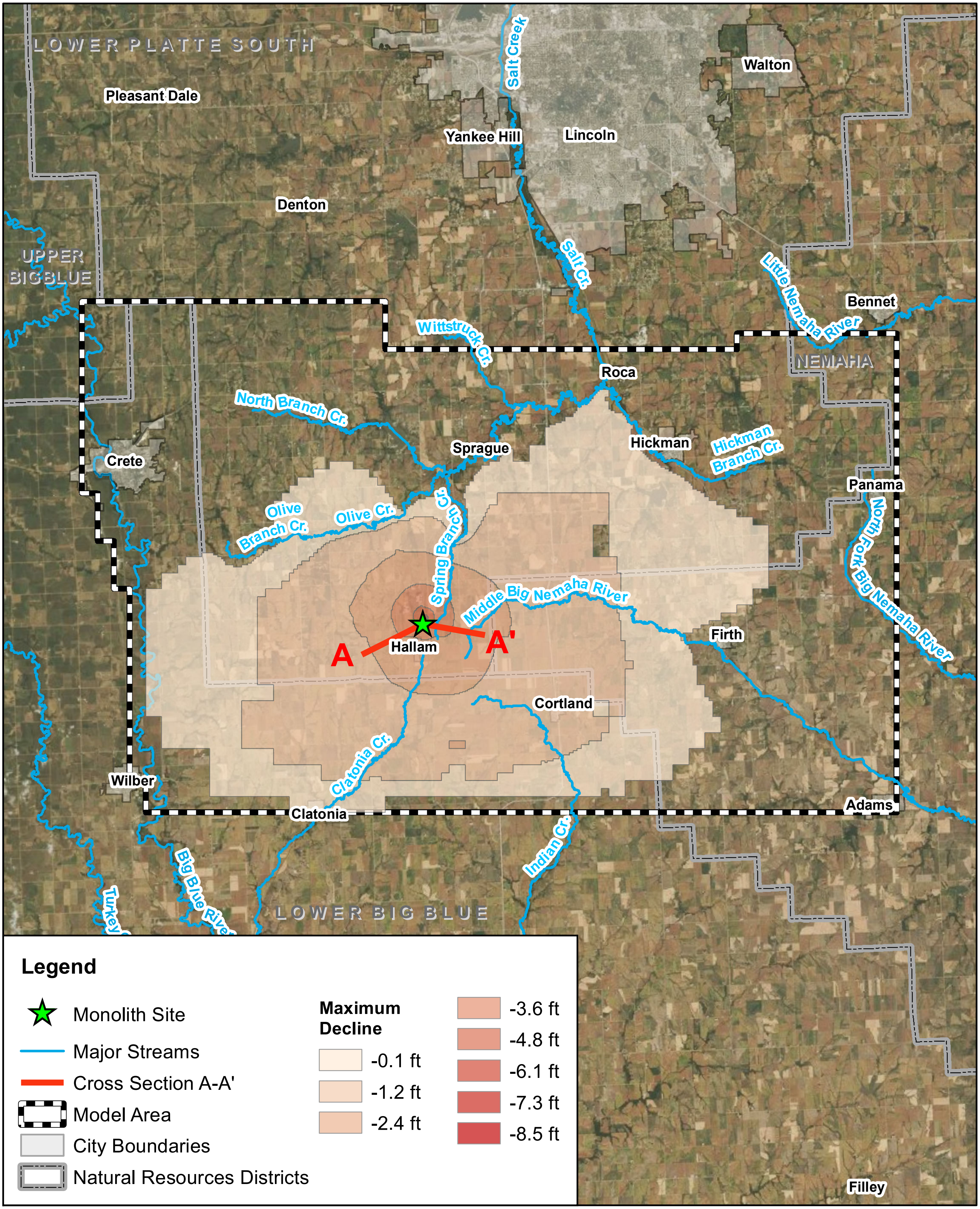
● Monolith Production Well

▭ Active Model Outline

FIGURE 10
DRAWDOWN IN ALL LAYERS 50 YEARS PUMPING

5041LPS01
Feb 2021

Appendix A



F:\2020\2501-3000\020-2639\40-Design\GIS\Maps\FutureScenarioDrawdown.mxd PUBLISHED BY: mmorton DATE: December 07, 2020

olsson

N

0 1 2 4 Miles

1 in = 4 miles

NAD 1983 StatePlane Nebraska FIPS 2600 Feet

Future Scenario Declines With Monolith Pumping

Monolith OC2

Groundwater Modeling Report

Lancaster County, NE

FIGURE

3.14