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Technical Memorandum

Prepared for: Upper Big Blue Natural Resources District

Project Title: Synergen Well Permit

Project No.: 195199

Technical Memorandum

Subject: Review of Synergen Well Permit Hydrologic Evaluation, Olsson, December 11, 2023

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Background

Brown and Caldwell has been retained by the Upper Big Blue Natural Resources District (UBBNRD) to assist in processing applications for groundwater withdrawal permits. The requirements for permit application include preparation of a hydrologic evaluation, which provides UBBNRD with an assessment of potential impacts from a proposed large water user. The UBBNRD has developed a brief guideline document (Guideline for Large Water User Hydrogeologic Studies in the Upper Big Blue Natural Resource District, UBBNRD, (August, 2023) (Study Guidance) that outlines basic requirements for the hydrogeologic evaluation and inform the general level of study expected. The primary elements of the Study Guidance include a conceptual site model and a numerical groundwater model. For the numerical model, the anticipated modeling software is MODFLOW 6 (USGS, 2019), and the Study Guidance specifically requires:

- Model area map or maps that include model grid, boundary, and parameters information as well as results of model predictions.
- The study model grid should consist of at least 2 zones where zone 1 is defined by a 3 mile radius around the location of the proposed pumping well. The remainder of the study model domain would be additional zone numbers as required.
- The study model grid should be fine enough to accommodate the each existing well within zone 1 and the proposed pumping well within a single model cell.
- Study model boundaries should be coincident with and based upon natural boundaries or the regional model boundaries.
- Recharge assumptions for the study model should be explained in detail.
- Streams withing the study model should be simulated using the RIV, STR, or SFR packages in MODFLOW.
- Wells within the study model should be modeled as multi-node wells or similar MODFLOW package as required to accurately simulate both existing and proposed pumping in appropriate hydrogeologic layers and in sufficient time increments to mimic relevant (seasonal or otherwise) pumping variations.
- Observation points identified in MODFLOW for evaluating water level predictions must include every existing and proposed well within zone 1.
- The study model must be calibrated to exiting observed conditions prior to evaluation of proposed pumping.
- Simulation of proposed pumping water levels using the calibrated study model will be used to estimate change in water levels compared to water levels under existing conditions in the calibrated study model. In essence this comparison is estimation of drawdown related to proposed pumping withdrawal.
- A sensitivity analysis will be performed on the study model predictive scenario by adjusting input parameters including recharge, hydrogeologic parameters, and boundary conditions.

The UBBNRD has developed a regional scale numerical groundwater flow model that provides a basis for supporting the hydrogeologic studies required by the Study Guidance. This groundwater flow model, referred to as the Blue River Basin (BRB) regional model, is necessarily regional in scale and is intended to support simulation of regional scale impacts from a proposed groundwater withdrawal. The model is constructed in MODFLOW, and model input files are made available to large water users making application for new withdrawal.

Approach

Olsson has been retained to apply the BRB regional scale groundwater flow model in the estimation and simulation of potential groundwater impacts from the proposed withdrawal of approximately 2,300 gpm (10.2 ac-ft/day) at a location near Aurora, Nebraska. The hydrogeologic study and associated groundwater flow model are described in the "Synergen Well Permit Hydrologic Evaluation (Olsson, December, 2023) (Evaluation Report)

Olsson has generally followed the Study Guidelines (described above) in performing this hydrologic evaluation. The specific approach taken by Olsson is to develop a child model based upon the BRB by selecting an area within the BRB grid which surrounds the project site and creating new boundaries for this subregion, which define a new model domain. The elements of Olsson's approach are briefly described in the following sections.

Study Model Grid

The BRB model grid within the new model boundary (or subregion of interest) was refined to provide greater detail in groundwater head and therefore flow conditions in the area immediately surrounding the project site. This refined grid, located within the BRB domain space, is then considered a child of the BRB model, and much of the information used as input to the BRB model can then be repurposed for use in the new, more refined model. Olsson refers to the refined model as the Northern Upper Big Blue Subregional (NUBBS) model. Grid refinement in the NUBBS model ranges from the smallest BRB cell dimension (2,640 feet or ½ mile) down to a cell size of 330 feet on a side (1/16 mile) in the area immediately surrounding the applicant's property. This refinement allows the child or subregional model to simulate groundwater head and flow direction changes in response to the proposed groundwater withdrawal. Olsson separated the NUBBS model grid into 2 zones. Zone 1 is circular in shape with a 3-mile radius and is centered on the location of the proposed new user withdrawal. Zone 2 includes the remaining area of the NUBBS model out to the selected boundaries of the child model. The NUBBS model adopted the vertical discretization used in the BRB by reproducing the same 5 model layers used in the BRB.

Boundary conditions for the NUBBS model were assigned as General head (GHB) along the entire perimeter of the NUBBS mode. The Platte River runs along the northwestern edge of both the BRB and the NUBBS model, and in this area the assigned GHB boundary nodes roughly mimic the natural hydrologic conditions. In other areas of the NUBBS model the GHB nodes are assigned starting head conditions based on the head predicted by the BRB for each NUBBS GHB node location. This approach does not represent a natural hydrologic condition or feature but does serve to tie the NUBBS performance to the regional predictions provided by BRB. In addition to the GHB nodes surrounding the NUBBS model a portion of the West Fork of the Big Blue River is simulated using the MODFLOW SFR package where the river reach passes through the NUBBS domain.

Wells and Parameterization

Olsson provides a description of the input parameters included in the NUBBS and the relationship of those parameters to the BRB. Since the underlying premise of this evaluation approach is to rely upon the previously established BRB and its calibration and associated uncertainties, the degree of adoption included in developing the NUBBS is important to understand. In summary, the existing pumping wells simulated in the BRB are carried forward in the NUBBS by calculating the pumping rate per area represented in each pumping cell in the BRB and importing that same rate per area into the NUBBS distributed over the same area. This results in more of the smaller NUBBS cells containing a reduced total pumping rate (same rate per area times a smaller area) to reproduce the rate withdrawn in the single larger BRB cell. While this approach closely reproduces the BRB model it also reduces some of the advantage gained by refining the grid spacing in the study model. This effect would potentially reduce the simulated drawdown from existing pumping compared to what may be estimated if the same total withdrawal were to be simulated in a single smaller NUBBS grid cell. Placing existing wells in a single smaller cell would require accurate information regarding the location of the existing pumping wells and could potentially affect the results of calibration of the NUBBS model compared to the BRB.

The proposed withdrawal locations for the new user production wells was handled in a similar manner by spreading the total proposed pumping over 4 of the smallest NUBBS model cells. This approach, while covering a larger area of possible well locations, also will result in a reduction in simulated pumping rate at each of the cells with pumping.

The hydrogeologic properties included in the BRB were selected through the calibration process that was completed during development of the BRB. Use of these properties and their distribution throughout the BRB makes the application of the BRB to hydrologic evaluations such as this more efficient. Olsson adopted the values of hydraulic conductivity and storage from the established BRB in much the same fashion as described above for the existing pumping conditions. The parameterization in the BRB was simply exported to the NUBBS grid by overlaying the BRB parameters from the large grid and assigning the values to the NUBBS grid based on spatial alignment. This approach highlights the usefulness and value of a master regional model and is an acceptable method for building a study (or child) model based on a larger, calibrated regional-scale model.

Study Model Results Summary

Model results for calibrations and for evaluating the model's water budget are summarized in Olssons report as required in the Study Guidance. Calibration results for the NUBBS model focus on a comparison of existing condition head values to the same set of calibration target wells used for the BRB model. The approach taken to assigning existing pumping well stress, parameterization, and boundary condition control produced a child model that very closely reproduces the results of the parent model. The calibration statistics reported for the NUBBS model are very similar to those for the BRB, suggesting that the NUBBS is at least as capable as the BRB in simulating groundwater flow in the model domain.

Review of the water budget data from the exiting conditions NUBBS model run show that the model is internally balanced and that error between water moving into and out of the model domain is negligible. Likewise, the water balance results for the new user withdrawal scenario also indicate a good water balance and provide evidence of how the model elements are responding to the new pumping stress. As described in the Evaluation Report the water budget review clearly shows that the proposed water withdrawal will come first from recharge and then out of aquifer storage and that groundwater was being withdrawn from storage in the model predictions during the years prior to the start of Synergen pumping. The model output indicates that some water is being removed from storage even prior to the proposed new withdrawal, suggesting that groundwater mining may be occurring within the NUBBS model domain from pumping of existing wells. In particular, the map of groundwater level decline over the total time period of the existing condition NUBBS model presented in the Evaluation Report (Figure 28, Layer 4 Change in Water Level Elevation) shows substantial drop in water levels along the northern and northeastern areas of the NUBBS domain. Review of monitoring well hydrographs provided in the Evaluation Report indicate some overall declining trends in water levels at a few locations in the NUBBS domain, which is not conclusive with respect to pumping induced mining. Further evaluation of the data and model predictions would be required to confirm if safe yield is being exceeded in any portion of the UBBNRD.

Finally, the results from the new user pumping scenario is provided in terms of additional drawdown estimated for every well within the required 3-mile radius of the new pumping area, and maps are included showing the areal extent of the estimated drawdown. The model results indicate that the maximum estimated additional drawdown at an existing well could be 11.6 feet, which is also reported as an 8% reduction in available saturated thickness. The report conclusions state that "The reduction in static saturated interval for wells within the three-mile radius was overwhelmingly in the range of 2-3%."

Hydrogeologic Study Review Summary

As described in the sections above, the NUBBS model prepared by Olsson generally complies with the Study Guidance provided by UBBNRD. However, Brown and Caldwell identified two exceptions: the performance of a sensitivity analysis and the placement of pumping from individual wells in more than a single model cell.

The sensitivity analysis recommend in the Study Guidance is intended to help understand the uncertainty inherent in any groundwater flow model. By performing additional model simulations using carefully selected changes to various model input parameters, it is possible to evaluate how likely and to what degree a prediction may change as the result of unknown errors in model construction. This process can be very valuable in understanding the reliance that can be placed on the model predictions and the relevance of model results to business decisions such as permitting. Olsson suggests in the report that the uncertainties in the NUBBS model are largely tied to the BRB because "the result of the limitations that accompany regional groundwater modeling are innately present in a subregional model created from the regional conceptual and numeric model." While this is certainly true there are additional uncertainties arising from the assumptions and parameterization approaches taken in constructing the NUBBS. Without a specific sensitivity analysis, it is not possible to evaluate what, if any, additional uncertainty may be present in the NUBBS.

One potential area where the underlying approach to the NUBBS development impacts uncertainty is the assignment of pumping stress to multiple cells for both existing wells and the proposed new well. This approach to the proposed new withdrawal will cover a larger area of possible well locations; however, it will likely also underestimate the total pumping impact and simulated drawdown in the area immediately adjacent to the new withdrawal. The effects of this spreading approach would be less important at greater distances from the proposed pumping location because propagation of the withdrawal impacts are mitigated with distance through the aquifer. While this effect may not be large given the available saturated thickness over zone 1 in the NUBBS it remains an uncertainty in the predicted drawdown values.

A second, and relatively minor potential source of uncertainty arises from the use of GHB cells surrounding the model domain. The approach effectively controls the amount of water that can pass into or out of the model domain during model simulations. Review of the model head and drawdown maps suggests that there are areas where predicted drawdown impinges upon the NUBBS model boundary. This suggests that the combined pumping stress in the model is inducing increased water movement across the boundary. In cases when the GHB condition mimics a natural boundary, the degree of resistance assigned to those specific locations should be modified to best match actual conditions. In cases where the GHB was selected for convenience and was assumed to be a sufficient distance from the model stress (i.e., new pumping well), it is very difficult to reasonably assign resistance to water movement across that boundary. This can affect the amount of drawdown that is estimated in the NUBBS, and without some sensitivity analysis, it isn't possible to understand if the effect is increasing or decreasing the estimated drawdown or by how much. This impact is likely to have the greatest effect in areas of the model domain nearest the boundary which are outside zone 1 for NUBBS and would therefore not likely greatly effect the estimated maximum drawdown dramatically.

Conclusions

- In summary, the study model (NUBBS) constructed by Olsson using the BRB as a parent model appears to sufficiently meet the Study Guidance requirements with the exceptions noted above.
- The NUBBS model is stable, returns a very good water balance and calibrates as well or better than the BRB parent model.

- The uncertainties in the NUBBS model have not been evaluated or described. The magnitude of uncertainties associated with assumptions made in constructing the NUBBS are also unknown.
- The estimated drawdown impacts calculated using the NUBBS model appear to support the statement by Olsson that "…the expected impacts to the groundwater supply and pumping capacity at existing wells should be minimal and should not affect their operations" although the metric of "affects to operations" for various well operators has not been identified.
- Note that the model results suggest groundwater is already being mined under existing conditions in the NUBBS model domain, but this observation is not fully supported by water level trends in local monitoring well records.

Limitations

This document is governed by the specific scope of work authorized by Upper Big Blue Natural Resource District; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Upper Big Blue Natural Resource District and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information. Specifically, BC has not obtained or reviewed the model input or output files developed in support of the Evaluation Report. BC has not run the NUBBS MODFLOW model and has not attempted in any way to verify the model results provided by Olsson.