Technical Memorandum

To: Ms. Michele Staples
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From: Thomas Harder, P.G., CH.G.
Thomas Harder & Co.

Date: 17-May-19

Re: Summary of a Review of Technical Documents Used in Support of the Borrego Valley GSP Including Topics Discussed at Technical Meetings of the Borrego Valley GSA on April 26, 2019 and May 10, 2019

This Technical Memorandum (TM) summarizes my technical review of documents related to the development of the Borrego Valley Groundwater Sustainability Plan (GSP). The documents and associated conclusions were the topic of discussion at two technical meetings held with Dudek Consultants and other technical representatives for stakeholders in the Borrego Valley; one meeting on April 26, 2019 and a second meeting on May 10, 2019. Specifically, I reviewed the following documents:

- Dudek, 2018. Update to United States Geological Survey Borrego Valley Hydrologic Model for the Borrego Valley Sustainability Agency. Prepared for County of San Diego Planning and Development Services. Dated December 2018.
- Environmental Navigation Services, Inc., 2018. Methodology to Examine Future Groundwater Overdraft in Terms of the Overall Hydrologic Water Balance Considering Recharge Variability and Parameter Uncertainty. Prepared for Borrego Water District. Dated 12-Sep-2018.
- Faunt, et al., 2015. Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley, San Diego County, California. USGS Scientific Investigations Report 2015-5150.

Model Calibration

The model calibration data provided in Appendix C of Dudek (2018) does not allow for an easy review of differences and temporal deviations between model-generated groundwater levels and measured groundwater levels (i.e. residuals) over time. The "Observation Name" cannot be correlated to a well on a map so it isn't possible to assess the calibration across the model area. Further, it is difficult from the table to assess calibration over time. While the model may be validated statistically, it appears that residuals for some wells are becoming larger after 2010 (see for example data after 2010 reported on pg. 18 of 54). In order to address this, I requested at the April 26, 2019 meeting that Dudek develop hydrographs of each calibration well showing graphically both the measured and model-generated data on the hydrograph as well as a map showing the locations and names of the calibration target wells so they can be correlated to the hydrographs and tables in Appendix C.

The hydrographs of the calibration target wells were received on May 16, 2019. Based on a review of the hydrographs, the deviation of residuals after 2010, particularly in groundwater levels from wells in the northern part of the basin, is confirmed. In most cases, the measured groundwater levels are not declining as fast as the model-simulated groundwater levels. This indicates a systematic error in the water budget of the model in this area after approximately 2010. Potential sources of the error could include (but not necessarily be limited to) groundwater pumping, return flow recharge, natural recharge, or a combination of some or all of these.

Annual Water Balance

As discussed during the April 26, 2019 technical meeting, the headings for the annual water balance/budgets provided in Appendices A and B are not clear.

- The water budget tables shown in Appendices A and B include elements of both the MODFLOW water budget and the basin hydrologic budget. The last two columns of each table both appear to represent change in storage but it is not clear what the values represent or which columns are used to arrive at the values. I recommend two separate tables: 1) a table that specifically addresses the MODFLOW water budget, which is used to determine water budget errors within the MODFLOW calculator, and 2) a table that specifically addresses the hydrologic water budget of the basin, which shows each element of basin inflow and outflow that ultimately dictate change in basin storage. Footnotes would also be helpful to clarify what each column represents.
- Based on clarification by Dudek, it is my understanding that "Specified Flows" represents groundwater inflow into the basin from outside the basin. It would be helpful to have a more descriptive title or footnote that describes in more detail what this column represents.
- Based on clarification by Dudek, "UZF Recharge" represents recharge to the groundwater system via the Unsaturated Zone Flow package in MODFLOW. This recharge includes both precipitation recharge (which is negligible) and return flow recharge from applied irrigation water.

- The term "MNW2" represents the exchange of water from one model layer to another through interborehole flow. As with the "Storage" term, this is an internal MODFLOW budget term and is recommended to be shown in a separate table from the hydrologic budget that estimates change in basin storage.
- The "Total In" column of the water budget is the sum of all of the inflow terms.
- Dudek clarified that the "Natural Recharge" column of the water budget is equal to the sum of the "Specified Flows," "Stream Leakage," and "UZF Recharge." As the "UZF Recharge" includes return flow from applied irrigation water, the "Natural Recharge" column also includes return flow from irrigation.
- For the Outflow water budget terms, it was clarified in the meeting that the "Constant Head" column is underflow out of the basin.
- The "MNW2" and "Farm Wells" both represent groundwater pumping from wells. It remains unclear how municipal pumping and pumping for agricultural irrigation are accounted in these terms.
- Total pumping is the sum of MNW2 and Farm Wells pumping.
- It was clarified in the meeting that "Farm Net Recharge" is equal to crop consumptive use.
- The "Total Out" column of the water budget is the sum of all of the outflow terms ("Storage," "Constant Head," "Total Pumping," and "Farm Net Recharge").
- The "Discharge" column of the water budget is the sum of "Constant Head," "Total Pumping," and "Farm Net Recharge."

Discussion of Sustainable Yield

The current "target pumping rate," which is reported under Section 2.2.3.6 Sustainable Yield of the GSP, is 5,700 acre-ft/yr. Dudek indicated that this value was calculated using the United States Geological Survey (USGS) Borrego Valley model by removing all anthropogenic influences from the model for the historical calibration period (e.g. groundwater pumping, return flow, etc.) and calculating the net natural recharge to the basin that would have otherwise occurred.

It is noted that the USGS documentation for the model (Faunt et al., 2015) refers to the "…natural recharge that reaches to the saturated groundwater system" as approximately 5,700 acre-ft/yr (pg. 129, 1st paragraph). However, there is no mention in Faunt et al. (2015) as to how they arrived at this value. Later in the same paragraph the USGS documentation states that "Another approximately 1,400 acre-ft/yr on average comes as underflow from upstream portions of the watershed." This suggests that the total available recharge to the basin is approximately 7,100 acre-ft/yr, which is consistent with the pre-development condition recharge shown in Table 19 of the document (7,114 acre-ft/yr).

No detailed groundwater budget tables are presented in Faunt et al. (2015). In Appendix A of Dudek (2018), the average annual natural recharge to the model for the period 1929 to 2009 is reported to be 7,040 acre-ft/yr (as indicated earlier in this technical memorandum, this value includes return flow of applied irrigation water). The average annual recharge for the time period 1944 to 2009 is 6,881 acre-ft/yr.

I pointed out in the technical meeting that during the 15-yr time period from approximately 1964 to 1978, there was little cumulative change in storage in the basin (2,605 acre-ft increase in storage), as indicated on Figure 13 of Dudek (2018). Average annual groundwater pumping during this time period was 6,345 acre-ft/yr. This suggests that the basin can accommodate at least (if not more than) 6,345 acre-ft/yr of groundwater pumping without a negative change in storage.

I also pointed out to Dudek that Section 2.2.3.6 of the GSP (section on Sustainable Yield Estimate) states that "…the combined average annual natural recharge to the BVGB is approximately 7,100 AFY." Dudek sites the bimodal nature of precipitation patterns in the basin as a reason to site a lower target pumping rate. However, the average annual natural recharge estimates from Appendix A are based on an 80-yr period of record (7,040 acre-ft/yr) and 65-yr period of record (6,881 acre-ft/yr), which are more than sufficient to account for hydrologic cycle variability.

I suggested to Dudek to analyze a forward projection of future anticipated pumping ramp down to the 5,700 acre-ft/yr target pumping rate using the groundwater flow model to assess the impact of that level of pumping on groundwater storage change in the basin. They indicated that they had already done that and it is reported in the GSP. They displayed a chart showing projected change in storage over the model simulation period, which was 50 years into the future. The first 20 years represented a linear ramp down of pumping to a basin-wide rate of 5,700 acre-ft/yr. The last 30 years represented long-term pumping at the target pumping rate. The cumulative change in storage for the last 30 years of pumping showed increasing groundwater storage for the period. When I indicated that this means the basin is projected to be underutilized with respect to pumping at the target pumping rate of 5,700 acre-ft/yr, Dudek said that the time period was not long enough to capture hydrologic variability.

Discussion of Data Gaps and Adaptive Management

Dudek indicated during the meeting that they plan to review the target pumping rate five years after implementation of the GSP. The review would incorporate new data collected in the first five years of the pumping transition period. Target data to be collected into the future would include stream flow, pumping tests on wells for aquifer properties, and equipping agricultural wells with flow meters to measure groundwater production and refine return flow rates.

Additional Questions and Requested Information Following the April 26, 2019 Meeting

As a follow-up to the April 26, 2019 technical meeting, the following questions and additional information were requested of Dudek:

- With respect to the calibration data:
  - A map showing the location of all calibration wells with their names labeled as per Appendix C of Dudek (2018).
  - Hydrographs of each calibration well showing both measured and model-generated data over time.
- In Appendix C of Dudek (2018), what do the red dates represent?
- With respect to the target pumping rate of 5,700 acre-ft/yr, it is not clear how this value was determined. Faunt (2015) references the value in the conclusions of that report and indicates that it is a combination of underflow from the upstream portions of the watershed and streambed infiltration but does not indicate how it is derived. The Basin Setting Section 2.2.3.6 suggests that the 5,700 includes "…stream leakage and infiltrating water through the unsaturated zone…" The Basin Setting goes on to say that the infiltrating water is mostly from irrigation return flows. Thus, it appears that while the USGS reference to 5,700 acre-ft/yr does not include return flows, the 5,700 acre-ft/yr cited in the Basin Setting does include return flows. Further, the USGS citing of 5,700 acre-ft/yr does not include underflow from upstream areas, which is part of the natural recharge of the basin. Please provide an explanation as to how the 5,700 acre-ft/yr target pumping rate was determined.
- With respect to the Environmental Navigation Services, Inc. (ENSI) report, dated September 12, 2018, the uncertainty analysis appears to be focused on future overdraft in the 20-yr period following GSP implementation. During this 20-yr period, groundwater pumpers in the basin are assumed to decrease pumping from current rates to the target rate of 5,700 acre-ft/yr in a linear fashion.
  - The analysis was conducted using a spreadsheet model – has Dudek or ENSI conducted this analysis using the USGS numerical groundwater flow model?
  - If so, how do the results compare?
  - The uncertainty analysis focuses on the inflow and outflow terms of the model. Has any uncertainty been performed that includes the inherent uncertainty in the aquifer parameters of the USGS numerical model? All of these uncertainties should be evaluated together.
  - What is the uncertainty in the sustainable yield estimate (or target pumping rate) of the basin? The current uncertainty analysis addresses overdraft in the first 20 years of transitional pumping ramp down when we know the basin will be in overdraft. I am interested in the uncertainty of the long-term sustainable pumping rate of the basin when both the water budget terms are varied as well as the aquifer parameters in the model.

Topics Discussed at the May 10, 2019 Meeting

Dudek responded to the follow-up questions and requests for information in the May 10, 2019 meeting as follows:

- *With respect to the calibration data:*
  - *A map showing the location of all calibration wells with their names labeled as per Appendix C of Dudek (2018).*
  - *Hydrographs of each calibration well showing both measured and model-generated data over time.*

  Dudek indicated that they would provide hydrographs of model-generated and measured groundwater levels for the calibration wells as well as a map showing the well locations. These data were provided via email on May 16, 2019.

- *In Appendix C of Dudek (2018), what do the red dates represent?*

  Dudek indicated that they weren't sure what the red dates in the calibration data represented but indicated that it wasn't significant as to the calibration data.

- *Please provide an explanation as to how the 5,700 acre-ft/yr target pumping rate was determined.*

  Dudek provided a chart showing change in basin storage between 1965 and 1975 with an average pumping rate over that time. The average pumping rate during that time was reported by them to be approximately 5,000 acre-ft/yr. However, review of the data in the total pumping column in Appendix A of Dudek (2018) for the same time period shows an average pumping rate over this time period closer to 6,000 acre-ft/yr. After some discussion, it appears that Dudek chose the 5,700 acre-ft/yr recharge value from the conclusions of the USGS report (Faunt et al., 2015) as a "good starting target." There does not appear to be any significant technical basis for the value beyond that.

- *With respect to the Environmental Navigation Services, Inc. (ENSI) report, the analysis was conducted using a spreadsheet model – has Dudek or ENSI conducted this analysis using the USGS numerical groundwater flow model?*

  Dudek indicated the answer is no.

- *The uncertainty analysis focuses on the inflow and outflow terms of the model. Has any uncertainty been performed that includes the inherent uncertainty in the aquifer parameters of the USGS numerical model? All of these uncertainties should be evaluated together.*

Dudek indicated that the USGS had provided an analysis of parameter sensitivity and uncertainty. They presented the sensitivity analysis as reported in Faunt et al., (2015). They indicated that they had not conducted an uncertainty analysis with both the aquifer parameters and inflow/outflow components together.

- *What is the uncertainty in the sustainable yield estimate (or target pumping rate) of the basin?*

  Dudek indicated that ENSI had not conducted a sensitivity analysis of the sustainable yield estimate.

Conclusions

Based on the data and reports reviewed to date, Dudek has significantly underestimated the Sustainable Yield and associated pumping target of the Borrego Valley Groundwater Basin, as reported in the Basin Setting section of the Borrego Valley GSP. Assuming that the 5,700 acre-ft/yr pumping target that they are reporting is based on the recharge estimate reported in the conclusions section of Faunt et al. (2015), which is stated as much in ENSI (2018), then the recharge rate is incomplete and neglects to include 1,400 acre-ft/yr of underflow into the basin from adjacent watersheds. Inclusion of underflow would result in a recharge rate of approximately 7,100 acre-ft/yr. This higher recharge rate is also reported in Table 19 of Faunt et al. (2015) and is more consistent with the average annual recharge reported in Appendix A of Dudek (2018). Indirectly, it is further supported by Dudek's forward projection analysis (Figure 3.3-2 of the GSP), which showed increasing groundwater in storage in the basin after 2040 at a target pumping rate of 5,700 acre-ft/yr. It appears that Dudek did not analyze additional forward projection model runs at higher target pumping rates so we cannot evaluate the maximum pumping that can occur in the basin without a long-term negative change in basin storage. Nonetheless, the forward projection analysis shows that the basin recharge exceeds the pumping at a target pumping rate of 5,700 acre-ft/yr.