KELLER-BLIESNER ENGINEERING, LLC

www.kelbli.com • Phone 435.753.5651 • Fax 435.753.6139 • 78 East Center, Logan, Utah 84321

******Aug 27, 2018 - Inline comments from Balleau Groundwater, Inc. are boldface, italic and red******

August 21, 2018

Kent Moore
President
Water Protection Association of Central Kansas
306-A N. Main Street
St. John, Kansas 67576

RE: Review of Burns & McDonnell Modeling Report to the City of Hays

Dear Mr. Moore,

We have reviewed the Burns & McDonnell (BMcD) February 13, 2018, modeling report (BMcD Report) to the City of Hays, Kansas. We have several concerns with BMcD's modeling approach, results and reporting. Addressing these concerns could lead to significantly different conclusions than BMcD's regarding the amount of water that can be sustainably transferred to the Cities of Hays and Russell from the R9 Ranch without impairment to other water rights. We have not attempted to run the hydrogeological model developed by Balleau Groundwater, Inc. (BGW) for the Big Bend Groundwater Management District No. 5 (GMD#5) with the BMcD scenarios, nor have we quantified the potential impact on model results and conclusions resulting from the concerns we have with BMcD's approach and reporting. However, we believe these concerns are significant and need to be addressed as part of the review of Hays' change of use application.

Nothing here should be interpreted as a criticism of the BGW GMD#5 model or BGW work for GMD#5. We have worked with BGW on other projects and have the highest respect for the company and its groundwater modeling. Out of necessity and for expediency, given the geographic scope of the BGW developed model and the availability of metered pumping data, BGW had to make model-wide assumptions and generalized calculations (for example, consumptive irrigation requirement, runoff, and irrigation return flow). These calibrated model-wide assumptions are valid at aggregate scale but may not be accurate at the local level. We have confidence in the BGW GMD#5 model as an appropriate tool for the purposes intended by BGW and GMD#5 to evaluate regional water-management actions. We also agree the BGW GMD#5 model could be a good basis for modeling localized actions, such as the proposed Hays change of use from the R9 Ranch, provided it is updated and calibrated with measured data from the vicinity of the potentially impacted area rather than relying on the model-wide assumptions and calculations.

Following is a listing and discussion of our primary concerns with the BMcD modeling of the proposed change of water use from irrigation on the R9 Ranch to a raw water supply for the Cities of Hays and Russell. We have organized our concerns under two headings—those related to approach and assumptions and those related to results and reporting. Concerns are numbered under each heading for reference with no intent of implying priority.

Concerns Regarding BMcD Modeling Approach and Assumptions:

1. Model scenarios should be forward looking to study the resultant effect of the proposed change of use against an irrigated baseline future, rather than simulating the change of use against historical conditions. The starting year for all BMcD scenarios is 1991. The purpose of the modeling, once calibrated and validated, is to estimate hydrologic effects resulting from a given scenario going forward from current conditions. Accordingly, the scenario simulation starting point should be 2016 (when BMcD started the modeling work). The BGW GMD#5 model input data should be updated for 2008 to 2016 and the model calibration checked near the R9 Ranch. The scenarios should start with 2016 initial conditions (water levels, lateral flows, no baseflow in the Arkansas River, etc.).

   To illustrate the importance of starting scenario simulations with existing conditions, look at the KGS WIZARD reported water levels for the USGS monitored irrigation wells near the R9 Ranch with data for January 1991 and January 2016. These data indicate an actual average water level nearly 8 feet lower in 2016 than in 1991 (see Table 1 below). Furthermore, for the long-term historical baseline irrigation simulation (BMcD Scenario 3), 11 out of 14 USGS monitored irrigation wells near the R9 Ranch with reported water levels in 2016 had lower actual water levels in January 2016 than the model generated water levels at the end of the 51-year baseline irrigation simulation (BMcD Figure 5). Even the model simulation of the baseline two percent drought ended with most of the January 2016 reporting USGS monitored irrigation wells having lower water levels than the model generated values.

The BMcD long-term simulations (51 years) run from 1991 through 2042, which is a simulation that is half retrospective (1991 – 2017) and half prospective (2017 – 2042). The K-B point that the model scenario should be forward-looking (prospective) is good. However, if BMcD addressed this in the form described by K-B, the updated results might not be significantly different. As described in our Aug 8, 2018 presentation (Slide 26), the BMcD scenarios are based on a difference between two simulations and the difference may be similar whether the 51-year scenario is run beginning in 1991 or beginning in 2017. BMcD could clarify this with a simulation.

K-B also reports that observed water levels at USGS wells in 2016 are lower than simulated water levels at the end of the 51-year simulation that ends in 2042 (note that in making this point, K-B refers to BMcD Fig 5, which is a map of simulated water levels in 2007, not 2042, which confuses the point). Other factors can affect the K-B water-level comparisons. Recharge from wetter than average conditions can cause water-level rise in the future (this behavior is known to occur in GMD#5). It is also not clear from the reports that K-B and BMcD are using the same datum for water-level elevation comparisons. However, if close examination reveals an issue with simulated water levels, then a causal explanation should be sought.

An underlying point is that BMcD ran scenarios of municipal water use and presented results as a comparison to irrigation water use, but did not present the change in water levels associated with water use at the R9 Ranch. We illustrate the change at the R9 Ranch (Aug 8, presentation, Slide 21) for GMD#5 review. Slide 21 is based on the 51-year model simulations and illustrates the BMcD scenarios translate to 15 to 20 feet of drawdown (eastern boundary of R9 Ranch). For planning purposes, that 15 to 20 feet of water-level change can be thought of as a projection from current conditions.

2. For the long-term (51-year) scenarios BMcD simply repeated the 1991 through 2007 climate history and pumping stresses three times. At a minimum, a longer historical climate record extending to the present should be used to better capture climate variability. For example, BGW used the 1940 to 2007 climatology copied forward for 2008 to 2076 for one baseline future ("A"). (BGW also developed a second baseline, "B", from the 68-year historical climatology using the K-nearest neighbor bootstrap technique.) Given climate change and the breakdown of stationarity, we believe that in addition to reference conditions based on the long-term climate history, future climate scenarios should be derived using other techniques (e.g. adjustments to reflect climate model trends). We note that BMcD did develop a 2% drought scenario using the 1952 -1957 historical climate record, however, imbedding this sequence once in a three-times repeat of the 17-year (1991 – 2007) climatology does not adequately capture the climate variability of the longer-term historical record or of current and projected climate trends.

Traditionally, scientists have defined a Climate Normal as an average over a recent 30-year period (https://www.ncdc.noaa.gov/news/defining-climate-normals-new-ways). The long-term BMcD simulations are over a 51-year period. It is true that a longer period can better capture climate variability, but the 51-year simulation chosen by BMcD is longer than the 30-year period typically used to characterize climate. We agree with K-B that the 2 percent drought scenario implemented by BMcD is an inadequate characterization of drought conditions. The general idea is stationary data has the property that the mean does not change over time, so if there is a trend of drying associated with climate, then a trend of drying in the baseline is a better representation of an expected projection for planning. BMcD can address how a climate trend in the baseline affects their reported results with a model simulation(s).

3. There is no baseflow in the Arkansas River near the R9 Ranch. Therefore, the river should be treated as having no flow for all years and scenarios, not just after year 16.

We agree the flow in the simulated Arkansas River is overestimated during low flows (Aug 8, 2018 presentation, Slide 23). On slides 16, 18 and 20, we report average depletion to aquifer storage, ET and the river to clarify impacts for GMD#5. If BMcD simulated the river with no flow for all years and all scenarios, the river depletion reported on slides 16, 18 and 20 would be redistributed to capture of ET and depletion of aquifer storage. The additional depletion to aquifer storage would increase drawdown to local water levels; we estimate the change in water levels on slides 16, 18 and 20 would be on the order of a couple feet or less. A model run by BMcD can quantify this aspect of additional aquifer depletion to address K-B's comment.

4. BMcD assumed the same recharge for the municipal pumping scenarios as the irrigation scenarios (Table 3 and Figure 7). Recharge under the dryland conditions of the municipal pumping scenarios will be less than under the irrigation scenarios because more of the precipitation will be consumed by the non-irrigated vegetation growing on the formerly irrigated fields. We estimate the recharge under established dry land conditions on the R9 Ranch could be as much as 3,000 acre-feet/year less than under irrigated conditions.

This relates to our comments on Slide 35 of our Aug 8, 2018 presentation. K-B is indicating that to maintain a hydrologic balance of the transferred water right, post-transfer consumption of precipitation at the R9 Ranch should be considered. Otherwise, there is a new stress on the hydrologic system resulting from the change in water use.

A factor to consider relates to what condition post-transfer consumption of precipitation is compared to. K-B estimates that post-transfer conditions compared to irrigated fields results in a hydrologic imbalance because non-irrigated prairie grass consumes more precipitation. If the post transfer conditions are compared to unmanaged vegetation conditions that existed prior to irrigation, then the change in the hydrologic balance with the transfer may be less. In either case, BMcD should quantify this imbalance and associated hydrologic effects to address the comment.

Table 1. Recorded (KGS WIZARD well elevation minus January depth to water) and model generated (extrapolated from BMcD report Figures 5 and 8 for well location) water levels for USGS irrigation monitoring wells near the R9 Ranch.

					Recorded Water Level			Model Ending Water Level		
USGS ID	PLSS	Longitude	Latitude	Surface Elevation	January 1991	January 2008	January 2016	Scenario 1	Scenario 3	Irrigation Drought
374558099321601	26S 20W 20BBC 01	-99.540781	37.773918	2251	2240	2238	2234	2247	2243	2242
374428099260501	26S 19W 31AAC 01	-99.436612	37.745585	2250	2210	2204	2196	2215	2205	2200
374427099232901	26S 19W 34BBD 01	-99.390994	37.744917	2232	2190	2182	2175	2193	2182	2177
374658099244302	26S 19W 16BCB 02	-99.413911	37.7902	2234		2190	2184	2195	2187	2182
374935099304801	25S 20W 34CCC 01	-99.515447	37.826685	2230	2222	2222	2216	2225	2220	2217
374954099270701	25S 19W 31CAB 01	-99.454926	37.832537	2220	2201	2201		2203	2197	2193
375106099261801	25S 19W 29B 01	-99.437195	37.851217	2203		2190		2191	2186	2183
375032099222001	25S 19W 26DDB 01	-99.374793	37.84345	2206	2165	2165	2158	2170	2162	2158
375250099260101	25S 19W 17BAD 01	-99.433895	37.881517	2191		2180	2177	2180	2176	2174
375329099260101	25S 19W 08BDD 01	-99.433045	37.892084	2185	2179	2180	2176	2178	2175	2174
375406099303401	25S 20W 03BCD 01	-99.509847	37.906285	2237	2207	2208	2207	2210	2206	2205
375421099254401	25S 19W 05ACC 01	-99.430595	37.906017	2180		2173	2170	2174	2173	2172
375357099211201	25S 19W 01DDC 01	-99.35407	37.899865	2200	2149	2147	2141	2150	2142	2139
374434099343001	26S 21W 25CCC 01	-99.577869	37.748968	2270	2265	2263	2261	2268	2266	2265
374322099243401	27S 19W 04BCD 01	-99.40928	37.73035	2242		2187	2180	2205	2193	2188
374225099275001	27S 20W 12BCD 01	-99.46451	37.71297	2272	2228	2219	2213	2233	2222	2217

5. The yearly average return flow calculations applied model-wide in the BGW GMD#5 model (BGW GMD#5 model report Table 5) and used in the BMcD modeling should be validated for the specific conditions on the R9 Ranch and, as noted in our first concern above, updated to current conditions. The necessary data for such validation and update should be available to BMcD. Based on our 1984 and 1985 (perfection years) consumptive use analysis for the R9 Ranch, we estimated crop evapotranspiration to be 72% of optimal for the ranch, which compares favorably, but is lower than the model-wide adjustment of 80% assumed by BGW. We believe return flow fractions for the R9 Ranch, given its fine sandy soils, are greater than the 17% model-wide average (1991 – 2007) estimated by BGW, although we have not made any return flow calculations for the ranch.

The points raised by K-B relate to analyzing R9 Ranch return flow conditions at a scale more local than the regional approach we used to develop the model. BMcD can resolve the question with model simulations that investigate the sensitivity of their results to variations in return flow.

Concerns Regarding BMcD Model Results and Reporting:

1. The BMcD report water level contour figures (6, 9, 10, and 13) were created by subtracting the model generated ending water levels for the associated municipal well pumping scenarios from the model generated ending water levels for the irrigation pumping baseline scenarios. Not shown or reported are the change in model generated water levels from the beginning to the end of each scenario or the model generated ending water levels for the municipal scenarios. The latter can be derived by combining BMcD Figures 6, 9, 10, and 13 with the associated baseline Figures 5, 8 and 11, however not providing change in water levels and ending water levels masks the magnitude of the decline in water levels under all scenarios. For example, if one compares elevations from Figure 5 (Scenario 1: 1991-2007 Historical Irrigation Pumping) to those at the end of the 51-yr Historical Irrigation simulation (Scenario 3) in Figure 8, on average there is about a 5 to 10-ft drop in water levels. Combining that drop with Figure 9 indicates that at the end of the 51-year municipal pumping of 4,800 acre-feet/year simulation (Scenario 4) the model generated drop in water level is as great as 10 feet from the 2007 levels. Additional figures showing the water level contours at the end of the municipal pumping scenarios, like Figure 8 for the irrigation baseline, and change in water levels from the beginning to end of simulation, would be helpful.

We agree with K-B that showing the change in water levels for the simulations would be helpful, so we showed a generalized summary on Slide 21 of our Aug 8, 2018 presentation for review by GMD#5. The BMcD model scenarios project 15 to 20 feet of change in water levels over a 51-year period that can be considered a projection from recent conditions. That type of information should be assessed and reported by BMcD as K-B suggests.

2. The change in storage reported in all BMcD report tables should be negative values, i.e. there is a net loss in groundwater storage for all scenarios. This explains why model generated water levels are declining. The cumulative decrease in storage should be discussed in the report. The report should also note whether the model is approaching steady and sustainable water levels at the end of the long-term simulations or if water levels and storage are continuing to decline.

The model results reported by BMcD are comparative between a baseline of irrigation and a scenario of municipal water use. The comparative results do not show the regional decline in water levels (or aquifer stored contents) that K-B is describing, but they are in the model results and could be shown. BMcD does not report whether water levels continue to decline at the end of the 51-year simulations. Slide 21 of our Aug 8 presentation shows that a simulated drawdown trend is still occurring at the end of the 51-year simulations. As K-B suggests, information on projected water-level trends should be assessed and reported by BMcD for a more complete picture.

3. The R9 Ranch Hydrostratigraphic Unit (R9 Ranch HSU, Figure 1 in BMcD report) for the mass balance computations should include additional model cells to avoid flow lines crossing multiple times in and out of the HSU. This can be done without incorporating cells with irrigation wells outside of the ranch.

We do not entirely follow this comment. BGW clarified (Aug 8, 2018 presentation) that hydrologic effects from the water transfer propagate outside of the HSU implemented by BMcD and we quantified hydrologic effects without using the HSU approach on slides 16, 18 and 20. An evaluation of that type of information by BMcD might address the K-B comment.

4. The 2% drought condition simulation should also be applied to the 4800-acre-foot/year maximum average municipal pumping scenario. Applying the drought condition to the baseline irrigation and projected municipal operations only masks the probable decline in water levels that would result under drought conditions with the 4800-acre-foot/year maximum average municipal pumping the cities are requesting.

There is a masking here as described by K-B. K-B's comment could be addressed with a model simulation that examines a drought applied to the 4,800 AFY maximum average pumping scenario.

5. From BMcD report page 5, second paragraph: "As shown in Figure 3, water levels calculated by the model from 1991 through 2007 correlate well with the observed water levels from USGS monitoring wells located on the R9 Ranch." We would like to see plots of model generated water levels for the same model cells as the USGS monitored irrigation wells located on and near the R9 Ranch. We note from Table 1 above that the model appears to have a significant bias towards generating water levels higher than the USGS monitored irrigation wells near the ranch. January 2008 reported water levels for some monitoring wells near the ranch are 9 to 18 feet lower than the model generated waters for the baseline irrigation Scenario 1 (see Table 1 above and BMcD report Figure 5).

K-B is clarifying that on Figure 3 of the BMcD report, the simulated water levels are not shown in the same model cells where the USGS monitor wells are located. We interpret BMcD's Figure 3 to illustrate that the model is capturing water-level changes that occur during the historical period from 1991 to 2008 in the area of the R9 Ranch (i.e. rather than specifically at the wells). It is possible that water levels at the model cells that contain the cells may show a somewhat different trend. The model is not a perfect representation of each well, but it generally provides a reasonable representation of well areas. That is, although specific wells may show water levels different from the model, the model can represent conditions that adequately characterize the area where wells are located.

Figure 3 of the BMcD report shows that the model reasonably characterizes the historical change in water levels, which supports the conclusion that the model is suitable for estimating the change in water levels that occurs in the scenarios, despite the fact that there may be a bias in local simulated heads. However, the model comparison to specific wells should be evaluated and reported by BMcD as K-B suggests.

6. From BMcD report page 5, fourth paragraph: "Figure 4 shows the change in water levels in comparison to pumping rates on the R9 Ranch for six of the iterative model runs. Water levels

are dropping at higher pumping rates, rising at lower pumping rates, and are reasonably stable in the zone where the yield is sustainable. As can be seen in this figure, with 4,800 acre-feet of pumping, water levels are relatively stable with a drop of only 0.6 feet at the end of the 1991 to 2007 model runs." Not shown is what would happen to water levels over a longer simulation period with more realistic climatology including drought cycles. Furthermore, Figure 4 implies that under the baseline scenario with a net irrigation pumping average of 4,054 acre-feet/year for 1991 to 2007, we would expect model generated water levels to rise by about 0.8 feet at the end of Scenario 1. Instead, Figure 3 shows a drop by 2.5 to 5 for model observation points No. 1 and 2. Perhaps, Figure 4 is intended to show the model generated water level effect of municipal pumping rates relative to the modeled baseline irrigation pumping water level decline of 2.5 to 5 feet after 17 years. If that is the case, then it is incorrect to conclude 4,800 acre-feet of municipal pumping per year is sustainable.

As described on slides 32, 33 and 37 of our Aug 8, 2018 presentation, 4,800 AFY is prospective for long-term production from the wells at the R9 Ranch. Determining what is sustainable relates to the hydrologic effects from that pumping that are deemed acceptable by area water users and administrators. The 4,800 AFY may be less if the river is managed for a specific quantity of flow for downstream use or if local water levels are managed to maintain a certain water-level elevation.

In summary, the BGW GMD#5 model is a reasonable basis for modeling the hydrological effects of the change of use application from irrigation on the R9 Ranch to municipal raw water supply for the Cities of Hays and Russell provided:

- the model is updated to current (2016 or later) conditions;
- the model is calibrated and validated with measured data from the vicinity of the potentially impacted area rather than relying on the BGW GMD#5 model-wide assumptions and calculations, especially for the irrigation return flow calculations and related parameters;
- the validation shows the model generated water levels for all USGS irrigation monitoring wells near the ranch for 1991 to the current year;
- the recharge under the municipal pumping scenarios accounts for the increased precipitation consumption under dry land conditions;
- the simulation starting point for future scenarios is current conditions;
- the baseline future is developed from a climate record equivalent to the length of the simulation and reflecting climate variability and projected climate future trends;
- the sustainable maximum municipal pumping evaluation incorporates the long-term scenario and drought response;
- the reported water levels for future scenarios show the model generated change in water level by subtracting the starting water levels from the ending levels of each scenario; and
- the report discusses whether the modeled water levels at the end of each future scenario are at equilibrium or continuing to decline.

As it stands now, we find the BMcD hydrologic modeling and reporting of the proposed change of water use from the R9 Ranch insufficient to substantiate 4,800 acre-feet per year yield as sustainable or obtainable without impairment to neighboring water rights.

Per Water PACK's request, we are copying Big Bend GMD#5 and Balleau Groundwater, Inc. If we have misrepresented the BGW GMD#5 model or if the district or BGW have concerns with our evaluation of the BMcD modeling work, we ask that they notify us so that we can take those into consideration.

Sincerely,

Andrew A Keller

Andrew A. Keller, PE, Ph.D.
President

Cc:

Orrin Feril, Big Bend Groundwater Management District #5
David Romero, Balleau Groundwater, Inc.
Richard Wenstrom, Water PACK

******Aug 27, 2018 - Inline comments from Balleau Groundwater, Inc. are boldface, italic and red******