20 January 2014 KG12-0085

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Re: Well interference measurements and modeling

Greetings Mike:

The following discussion serves to summarize the results of our pumping evaluation and interference between several of the wells near MOWD Well Nos. 4 and 7.

This work is conducted at your request and incorporates data from our March 2012 testing and January 2014 testing. The tests consisted of a series of pumping operations of the MOWD wells to obtain information regarding aquifer characteristics under different hydrologic conditions. Most notably, the conditions of testing during March 2012 were during a period of higher static water levels (depths to water 33 feet in MOWD wells) compared to the January 2014 testing where deeper static water levels were measured (66 feet to water).

Among other utility, the depth to water is a measurement used to determine storage in the basin and unconfined aquifer thickness. These parameters directly relate to well production, aquifer transmissivity, and the degree of interference between wells pumping at different rates under the variable conditions.

Ultimately, it appears that the aquifer yields less water to wells when water levels are low due to the decreased transmissivity (a product of aquifer thickness [*b*] and hydraulic conductivity [K] of the aquifer material [T=K*b*]) and increased pumping lift (TDH) of fixed-frequency drive pumps. As contrasted to higher water level conditions, the cone of depression surrounding a pumping well during low water level conditions is deeper near the pumping well but not as wide. This is more typical of unconfined systems. Interestingly, at distance, the drawdown at high rates during high water levels is similar to the drawdown at low rates during low water levels.

The following pages present our discussion of testing and measured interference between wells, modeled interference between wells, and a discussion of potential effects of the interference.

Testing and measured interferences

During the testing periods, the MOWD Wells were tested at various rates and durations based on demand and well capacity. Typical durations were one day of pumping, which can be expected as "normal" operations.

Well testing in March 2012 was conducted under relatively wet conditions, with depths to water in the MOWD Wells of 33 feet below the reference points. Well testing in January 2014 was conducted in the middle of a third consecutive year of deficient rainfall, just weeks before a "Drought Emergency" would be declared in California. Water levels at that time were 66 feet below the reference point in the MOWD Wells.

During March 2012, a distance-drawdown curve was prepared based on distance from pumping wells and drawdown observed in non-pumping wells. Graphical depictions of these observations are presented on the attached charts, with results in Table 1.

Table 1 – Observed Drawdown - End of full day of pumping		
Well	March 2012: Well 4 Pumping at 820 GPM, Aquifer Thickness 100 ft	January 2014: Well 7 Pumping at 351 GPM, Aquifer Thickness 67 feet
MOWD 4	7.53 ft	6.43 ft
MOWD 7	2.0 ft	7.3 ft
Gramkow South	0.92 ft	--
Gramkow North	0.59 ft	0.27 ft

Raw data were adjusted for pressure and other corrections, and subjected to standard aquifer testing analyses to solve for transmissivity and storativity. AQTESOLV data sheets showing graphical Tartakovsky-Neuman solutions for these parameters are attached. These indicate an expected reduction in transmissivity with less water in storage and an increase in storativity as the aquifer behaves in an increasingly unconfined nature with lower water levels. Results are be summarized below:

Drought conditions:
Aquifer thickness, b = 67 feet
Transmissivity, T = 52.6 ft^2/min (567,000 gpd/ft)
Storativity, S = 0.009805

Wet conditions:
Aquifer thickness, b = 100 feet
Transmissivity, T = 120.6 ft^2/min (1,300,000 gpd/ft)
Storativity, S = 0.003723

Model and calculations

Using data from the testing and various hydrololigc conditions, KG modeled and caclulated various scenarios to estimate the effect of theoretical pumping of the Gramkow Wells on MOWD Wells 4 and 7 at various rates. Rates of 300 and 600 gpm were presented for both Gramkow Wells under both wet and drought conditions.

Calculation tables are attached, with a summary of modeled interference presented below in Table 2.

Table 2 – Summary of Theoretical Interference Calculations		
Pumping Duration, 1 Day		
Well, condition, rate	MOWD 4	MOWD 7
Gramkow South, drought, 300 gpm	0.33	0.35
Gramkow North, drought, 300 gpm	0.23	0.22
Total	0.56	0.57
Gramkow South, wet, 300 gpm	0.17	0.17
Gramkow North, wet, 300 gpm	0.12	0.12
Total	0.29	0.29
Gramkow North, drought, 600 gpm	0.47	0.44
Gramkow South, drought, 600 gpm	0.67	0.70
Total	1.14	1.14
Gramkow North, wet, 600 gpm	0.25	0.24
Gramkow South, wet, 600 gpm	0.33	0.35
Total	0.58	0.59

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Discussion

Based on the analysis described above, the area of MOWD Well Nos. 4 and 7 exhibits variable responses to pumping under various hydrologic conditions. Interference observed and modeled between actual and theoretical pumping wells indicates interference on the order of 0.1 ft individually and 1.0 ft cumulatively with the greatest affects being estimated when wells are pumped at high rates during drought conditions.

Given the specific capacity of the MOWD Wells, the effect of the interference on production can be estimated. Hence, during drought periods when interference would be greatest, MOWD No. 7 exhibits a specific capacity of 47.1 gpm/ft drawdown (344 gpm/(75.7 ft pwl - 66.8 ft swl)). If an additional 1.14 ft of drawdown is induced by cumulative pumping of adjacent private wells, then the theoretical reduction in capacity is estimated at 53.7 gpm. If MOWD No. 4 exhibits a specific capacity of 60 gpm/ft and the 1.14 ft of drawdown is induced due to pumping of adjacent private wells, then the theoretical reduction in capacity is 68.4 gpm.

Hence, the cumulative effect of pumping adjacent wells at high rates (600 gpm each) during drought conditions could be a reduction in MOWD groundwater production capacity of upwards of 122.1 gpm. Lower end estimates of interference effects could be as low as one tenth (a 12 gpm reduction) of the higher end estimates. Further testing can be conducted to calibrate these modeled values.

We trust that this information will be of assistance in deliberations and working toward optimized management of a shared groundwater resource. Do not hesitate to contact me with any questions.

Best Regards,

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