Well Interference by Analytical Methods
Pixley Groundwater Banking Project
Tulare County, California

Prepared for:
South Valley Water Banking Project

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TECHNICAL MEMORANDUM

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1. Introduction

This technical memorandum evaluates pumping interference as a potential impact of operating the Pixley Groundwater Banking Project (Project). The impact, consisting of water level drawdown as a result of operating a groundwater well, would potentially propagate beyond the Project boundaries during recovery operations. Appendix H (see part H3) of this Project Environmental Assessment/Initial Study describes a numerical groundwater flow model used to evaluate changes to groundwater storage and impacts from pumping interference. This technical memorandum provides an additional planning level assessment using more simplified analytical methods. As discussed below, the numerical model provides much more capabilities with respect to representing a complex groundwater system and the analysis contained herein is intended to provide complementary information on the processes involved with Project recovery operations.

2. Methods

Pumping interference impacts may be estimated through analytic solutions for drawdown (spatially and temporarally) induced by a pumping well as a function of pumping rate, aquifer parameters, hydraulic conductivity/transmissivity, and storage terms. Analytical solutions are derived by simplifying the physical system through a set of assumptions regarding the aquifer (e.g., homogeneous and isotropic properties), aquifer extent (boundary conditions), confined versus unconfined flow, well screen extent, etc. Analytical solutions may be used to understand parameter sensitivity and provide a planning-level basis for aquifer testing, monitoring, and for comparison with results using other tools.

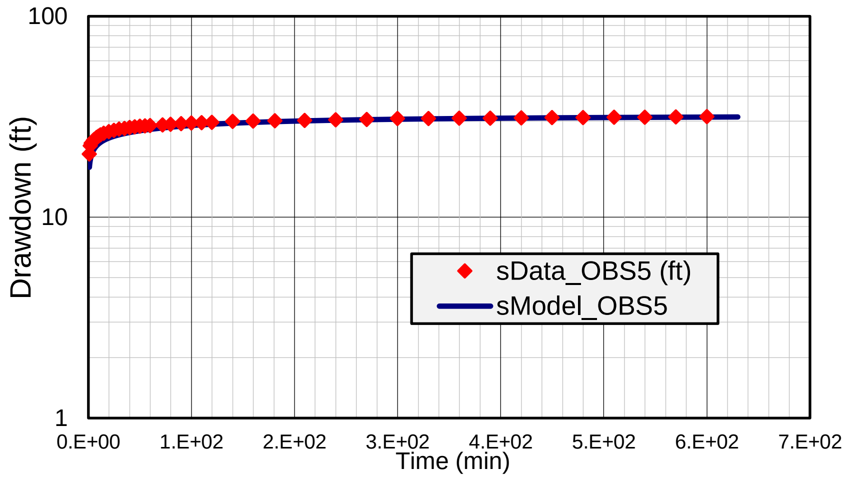
3. Aquifer Parameter Estimation

For the subject Project, various analytical solutions were considered for comparison with the numerical model results. Here, the numerical flow model integrates many more complexities of the physical system including heterogeneity and influences of recharge to the aquifer system targeted by the recovery wells. Two analytical solutions were considered. The first is for a confined aquifer (Theis, 1935) and the other one is for leaky aquifer (Hantush, 1956). Well test data from pumping tests in two wells located next to the project site (Provost & Pritchard, 2010) were matched using both solutions. However, the Hantush (1956) solution was rejected due to the absence of a two-aquifer system in the Project area on which the solution is based (see discussion in part H2 of this appendix). Further west, where the Corcoran Clay clearly divides the groundwater system into an upper unconfined and a lower confined aquifer, the Hantush (1956) solution is more applicable. This is because the solution accounts for leakage from an upper aquifer to a lower aquifer through a confining clay layer separating the two .

Estimated aquifer parameters (transmissivity and storativity) using Theis (1935) solution are summarized below for one of the well tests:

Aquifer parameter	Estimated value	Units
Transmissivity, T	89,000	gpd/ft
Storativity	0.015	Dimensionless

As shown in the figure below, the match in late time drawdown was used to produce a storage term more representative of longer-term pumping.



4. Drawdown Estimate

The estimated parameters values were used to evaluate the effect of operation of recovery wells at different distances from the water bank. The effects are presented in terms of drawdown using the Theis (1935) solution and principal of superposition. The following assumptions were made in applying this analytical solution:

Variable	Value	Units
Pumping Duration	8	months
Number of Wells	11	
Spacing	1/4	mile (square grid)
Aggregate Recovery Rate	25,400	AFY
Pumping rate (per well)	2,100	gpm

The predicted drawdowns by the analytical solution at 4 observation points from the edge of the Project wellfield are summarized below:

Distanced from Wellfield (miles)	Predicted Drawdown (feet)
0.5	89
1.0	64
1.5	47
2.0	35

5. Net Drawdown Considering Recharge Mound

For comparison with the numerical model results presented in this Environmental Assessment/Initial Study (see Appendix H, part H3), the predicted drawdown using Theis (1935) was adjusted to accommodate the effects of groundwater recharge by the water bank; i.e., the rise in a mound due to recharge. An analytic solution for rise in a mound due to uniform recharge rate developed by Hantush (1967) was employed. For the analytical problem, it was assumed that recharge occurred for 8 months followed by 4 months of non-activity and then 8 months of recovery pumping. The following table summarizes parameter estimates needed to predict that rise of groundwater mound consistent with the numerical model.

Variable	Value	Units
Recharge Basin Area	576	acre
Length and width of the recharge basin	0.95	mile (square basin}
Infiltration rate	0.18	ft/day

The results of combining the recharge mounding and pumping drawdown using the two analytical solutions are presented below and compared with the numerical model results:

Distanced from Wellfield (miles)	Predicted Net Drawdown (feet)	
	Numerical Model [1]	Analytical Model (Drawdown - Mound)
0.5	58	72
1.0	30	47
1.5	23	31
2.0	7	20

Estimates from numerical model with consistent hydraulic parameters, recharge, and recovery assumptions.

6. Conclusions

The Theis (1935) solution, as in this analysis, typically overestimates pumping drawdown compared with actual drawdown tests and the numerical modeling described in this report. For the Theis (1935) solution, pumped water is derived solely from storage from a homogenous, confined aquifer system. In the real aquifer system (as more closely represented in the numerical model), recovered water is derived from storage and other sources (e.g. lateral and vertical flow, recharge) in a heterogeneous leaky (semi-confined) aquifer system. By introducing the contribution of recharge in a simplified scenario, net drawdown using analytical solutions can be shown to be generally consistent with numerical model results. Both approaches provide a means to estimate project drawdown effects for determining impact significance and in the development of mitigation measures as incorporated into the Project Environmental Assessment/Initial Study.

For the subject water banking project, proposed mitigation of drawdown induced by recovery wells is based on modeling and analytical solutions that indicate potentially significant impacts of greater than 10 feet may occur beyond the project facilities. A monitoring program based on the radius of potential influences would be designed by the Project Technical Committee and implemented by the SVWBA. Mitigation measures would include but not be limited to the following actions:

- Compensate well owner for added lift due to drawdown influence;
- Reduce flow rates or shutting off selected recovery wells to reduce impacts to nearby wells;
- Provide affected well owner with an alternate source of water;
- Modify or replace a well pump to meet changed lift requirements; and

- Replace a well that can no longer provide an adequate water supply solely due to water bank operations.

7. References

Hantush M.S. 1956. *Analysis of data from pumping tests in leaky aquifers*. Trans Am Geophys Union 37(6):702–714.

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Theis, C.V. 1935. *The relationship between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage*. Trans Am Geophys Union 16:519–524.