APPENDIX N

Models of Potential Impacts to Groundwater

Pinedale Anticline SEIS
Models of Potential Impacts to Groundwater

Prediction of Drawdown

Drawdown impacts in the Wasatch aquifer in the PAPA due to drilling water extractions were modeled for dense drilling patterns. There is little hydraulic information available for the Wasatch in the PAPA, and drilling locations, extraction rates, and such variables are not closely specified, but some bounds may be placed on the extent and amount of drawdown using a semi-analytical method. This consists of developing a probable drawdown cone for a single pumping well, summing a number of cones in a section, and sketching the drawdown about a cluster of contiguous sections with active drilling at one time.

The drawdown cone (half of it in section) in time is shown in Figure 1. The basis for this cone is the Theis equation for drawdown at time t and distance r due to pumping an extensive, approximately homogeneous aquifer with transmissivity T and storativity S. The Wasatch is believed to have T between 300 and 2,000 sq,ft/day; a value of 300 was used to be conservative (lower T causes more drawdown); S = 0.001 is typical for a confined aquifer. Pumping rate is taken to be the higher Operator estimates of usage, namely ten gallons per minute. The water levels decline logarithmically in time.

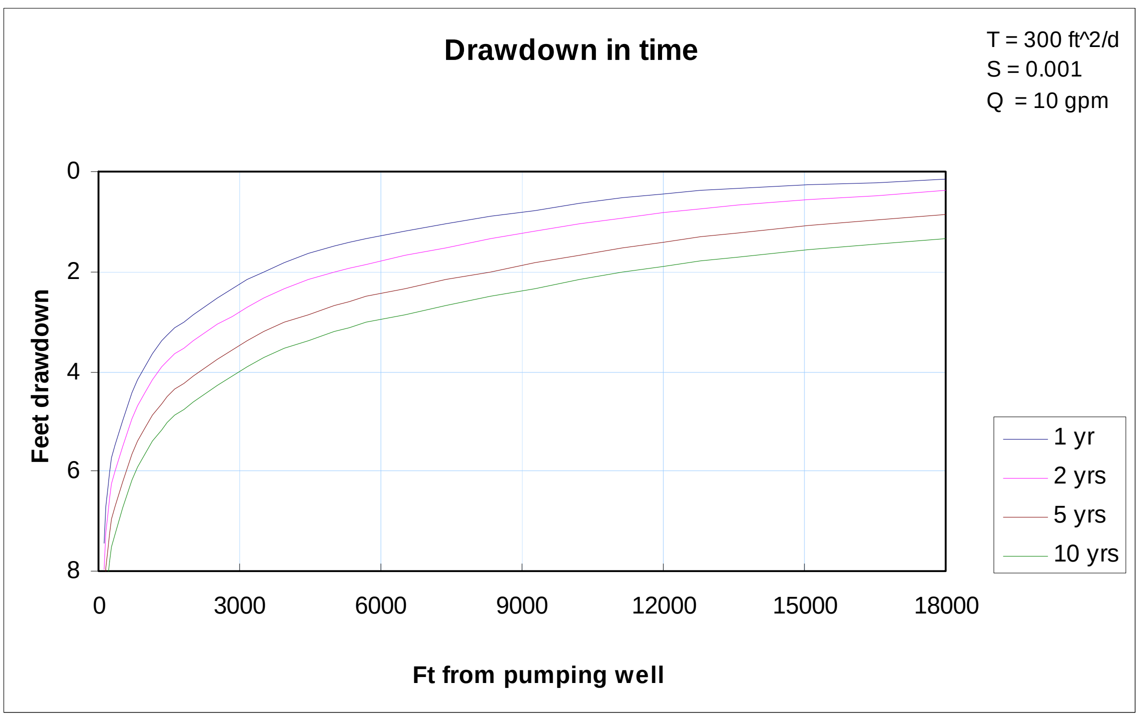


Figure 1
Analytical Model of Drawdown in the Wasatch due to Pumping a Single Well

At a radius of 2,000 ft (a little less than half a section width) the drawdown of the model well is about 1.5 ft after a year on the boundary of the section, and a little over 2 ft in 5 years. Adding the effects of more wells scattered in a section multiplies these values by the number of wells; for instance, five wells spread over a section would give an average of 6 ft drawdown after 1 year, and 8 ft in 10 years. Moving the pumping points with gas drilling (that is, pumping water supply wells at each new pad a gas rig occupies) gives periods of respite in which water levels recover somewhat, but if the moves are short in time and distance the averaging approach is approximately valid for a cluster of active sections.

As an example, a cluster of actively drilling well pads at the southern boundary of Concentrated Development Area 1 in the Proposed Action Alternative for year 2008, the number of rigs active by section (~ square mile) is given as:

4	6	3	2
		1	1

If these rigs withdrew Wasatch groundwater from supply wells located on the well pads steadily and stayed within these sections for 5 years, the average drawdown at the section perimeters (in feet), due to just the pumping within each section, would be:

16	24	12	8
		4	4

Adding all the components of drawdown in each section due to pumping in that section plus all the effects of the other wells (drawdown components can be superposed, which are linear with respect to pumping rate) gives a matrix as below (the six sections with active pumping are outlined in the middle).

2	4	6	10	11	10	8	5	4	2
3	7	11	16	19	18	15	11	8	5
5	10	16	25	29	27	23	17	11	7
7	13	21	37	45	39	31	22	13	8
5	10	17	26	31	31	27	19	12	8
4	8	13	18	22	22	19	15	10	6
2	5	8	12	15	15	13	10	7	5
1	3	5	8	8	8	8	6	4	3

5-9
10-14
15-19
20-24
25-30
30+

Figure 2
Drawdown in Wasatch Aquifer after 5 Years
Pumping with 17 Rigs in Eight Central Sections

It should be emphasized the transmissivity on which this drawdown is estimated is conservatively low, and actual drawdown may be. The Fort Union and Wasatch strata achieve a local maximum thickness in the PAPA area (Glover et al, 1996), which is said to be near 7,000 ft. No estimate of local sand percentages or transmissivities in the Wasatch are available, but a 1,000 ft thickness of sands in the upper part of the “7,000 ft” packet, with hydraulic conductivity 0.3 ft/day, would give the transmissivity assumed in these calculations. If the Wasatch sands were in fact thicker, coarser grained and more permeable, then transmissivity and storage would be higher and the aquifer would yield more water with less drawdown.

This model assumes zero recharge during the period of pumping. If 1 percent of assumed surface infiltration (that is, 0.001 ft/yr) passes through the alluvial cover and reaches the Wasatch, this would yield about 5 acre-ft/yr per section, or 10 bbl/day. This would shrink the drawdown surface in Figure 2 inward, so that the ten-foot contour would be 2 rather than 3 miles from the cluster.

Based on this analysis of potential drawdown impacts:

- up to 4 feet of drawdown may be observed within a distance of a mile of a single water supply well that has been steadily active for 5 years;
- Up to 30 feet drawdown may be observed within a mile of a dense cluster of active drilling well pads (here, 17 wells in six sections);
- Measurable drawdown (more than 2 feet) around a dense cluster of drilling activity and groundwater extraction extends approximately four miles from the perimeter of the cluster, after 5 years of pumping;
- The radius from a dense well cluster at which drawdown is measurable increases as long as pumping continues, but the rate of drawdown at any point declines logarithmically
- Recovery is expected to be rapid overall, although there will be variability where aquifer sandstones are poorly connected. Leakage from shale aquitards would hasten recovery. In the analytical model (without leakage), drawdown doubles from 1 to 5 years in active pumping; if pumping ceases at 5 years, recovery to initial conditions is similarly half complete 1 year later.

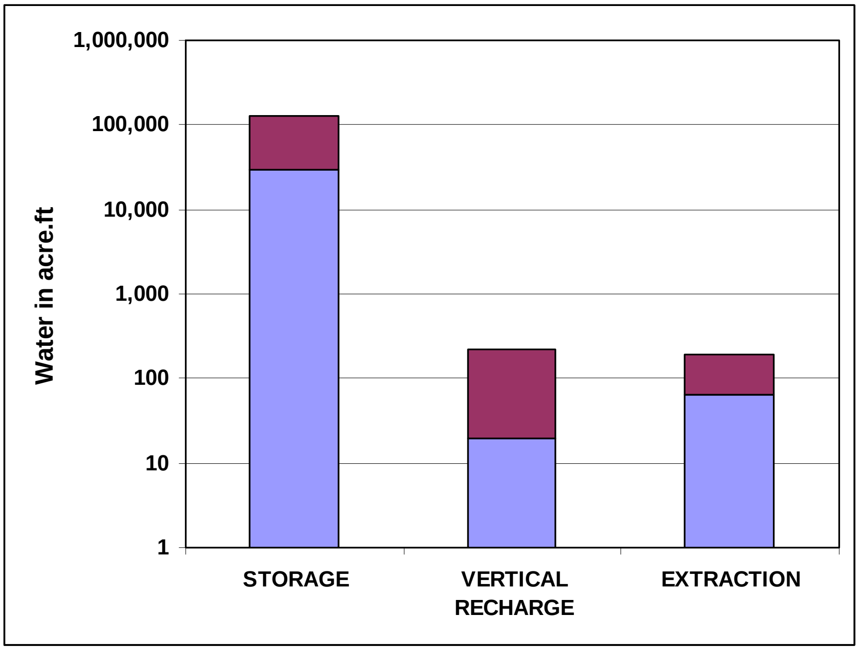
Groundwater Resource and Usage in Wasatch Aquifer

The potential for impacts on the groundwater resource should be judged against the overall resource quantity and recharge rates. The table below compares estimates of water usage by the Operators to the vertical recharge rate, and to the water stored in the Wasatch. The plot beneath the table compares the ranges of estimates on a log scale. Low and moderately high estimates are given in acre-feet (the volume of water covering 1 acre to 1 foot depth) in table and plot, and in oil field barrels (42 gallons) in the right column of the table with prefix M indicating thousands, MM millions and MMM trillions. Note that storage is a *volume*, and usage and recharge are annual *rates*.

Available stored water in the Wasatch is estimated from the surface area of the PAPA, a likely range of confined storativity coefficient, and the amount of available drawdown. Recharge to the Wasatch comes both vertically, as infiltration through the base of alluvium, and laterally from the Wind River and Wyoming ranges. Current extraction is based on Operator provided data, which suggested between 500,000 and 800,000 bbl/year pumped from the Wasatch in 2005-2006.

Likely Groundwater Storage, Vertical Recharge and Drilling Water Demand

Groundwater storage, low and high estimates PAPA area 200,000 acres x Storage 0.0005 x 300 ft drawdown 200,000 ac x Storage 0.001 x 500 ft drawdown	30 M ac.ft 100 M ac.ft	2 MMM bbl 8 MMM bbl
Current Extractions, high and low estimates Operator estimates	64 ac.ft/yr 129 ac.ft/yr	0.5 MM bbl/yr 1 MM bbl/yr



Impacts are local as well as regional. Focused pumping can locally deplete aquifers and discharge to alluvium-stream waters, even though average depletions across the PAPA are minimal. It is a function of the monitoring program to demonstrate such impacts are not significant, or to trigger mitigation. The plot above indicates that regional capacity should allow management of groundwater resource to prevent significant impacts (by for instance retiring or resting wells that may be over-depleting surface discharge, or switching to Fort Union wells in heavy use areas), or to mitigate impacts that do occur (e.g. pumping wells to augment surface water).

Reference

Glover, Naftz, and Martin. 1996. Geohydrology of Tertiary Rocks in Upper Colorado River Basin in Colorado, Utah, and Wyoming. USGS Water Resources Investigation Report 96-4105.