ET Capture, Equilibrium, and Groundwater Mining

Response to Remand Ruling Directive #2

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“The perennial yield of a groundwater reservoir may be defined as the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir. **Perennial yield is ultimately limited to the maximum amount of natural discharge that can be salvaged for beneficial use.** The perennial yield cannot be more than the natural recharge to a groundwater basin **and in some cases is less**. If the perennial yield is exceeded, groundwater levels will decline and steady state conditions will not be achieved, a situation commonly referred to as groundwater mining.” *- Ruling 6164, pg 56 (cited on pg 10 of remand ruling)*

Nevada State Engineer Answering Brief (2013)

"While there is no statute that specifically prevents groundwater mining, the policy of the State Engineer for over 100 years has been to disallow groundwater mining, and that remains the policy today. The State Engineer's defines groundwater mining as pumping that exceeds the perennial yield over time **such that the system never reaches a new equilibrium**." *- Pg. 54 (cited on pg. 10 of remand ruling)*

Nevada State Engineer Answering Brief, cont.

"Pumping must be supplied from (1) increased recharge, (2) **decreased discharge**, (3) **removal of water from storage**, or some combination of these three." *- Pg. 55*

"The pumping of groundwater always involves the depletion of water from **transitional storage**." *- Pg. 54*

District Court Remand Ruling

“The Engineer is correct that the time to reach equilibrium is not a valid reason to deny the grant of water, but it may very well be a reason to limit the appropriation below the calculated E.T. Here, **there is no valid evidence of when SNWA will capture E.T., if ever**.” *- Pg 11*

“The Engineer 's finding that equilibrium in Spring Valley water basin will "take a long time" was not based on substantial or reliable evidence, and is incorrect. Indeed, **by his own statements - and evidence - equilibrium will never be reached**.” *- Pg 12*

District Court Remand Ruling, Cont.

"This finding by the court requires that this matter be remanded to the State Engineer **for an award less than the calculated E.T.** for Spring Valley, Nevada, and that the amended award has **some prospect of reaching equilibrium** in the reservoir." - Pg 14

"2. A **recalculation of water available** for appropriation from Spring Valley assuring that the basin will **reach equilibrium** between discharge and recharge **in a reasonable time**;" - Pg 23

"Lee defined safe yield as '*the net annual supply which may be developed by pumping and artesian flow without persistent lowering of the groundwater plane.*'" -- *Lee (USGS), 1915*

"Lee went on to state that safe yield is typically **less than** what is indicated by recharge and the actual quantity depends on to what extent ET can be eliminated."

CPB Exh 19 - Jones and Mayo, "Sustainability of the SNWA Pumping Project in Spring Valley, Nevada", June 30, 2017. Aquaveo LLC (pg 11)

“As it is not generally practicable to draw any large part of the ground-water of one segment of a valley to another, **a proper distribution of wells is necessary** in order to reduce the residual losses to the lowest possible quantity.”-- *Comment on Lee article, 1915*

CPB Exh 19 - Jones and Mayo, “Sustainability of the SNWA Pumping Project in Spring Valley, Nevada”, June 30, 2017. Aquaveo LLC (pg 11)

"Under natural conditions ... previous to development by wells, aquifers are in a state of approximate dynamic equilibrium. Discharge by wells is thus a new discharge superimposed upon a previously stable system, and it must be balanced by an increase in the recharge of the aquifer, or by a **decrease in the old natural discharge**, or by **loss of storage** in the aquifer, or by a combination of these." -- *Theis (USGS) 1940*

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“The pumps should be placed as close as economically possible to areas of rejected recharge or natural discharge where ground water is being lost by evaporation or transpiration by non-productive vegetation.. ”

-- Theis 1940

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“In localities developing water from non-artesian aquifers and remote from areas of rejected recharge or natural discharge, the condition of **equilibrium connoted by the concept of perennial safe yield may never be reached** in the predictable future and the water used may all be taken from storage.” *-- Theis 1940*

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"... the maximum amount of water of usable chemical quality that can be withdrawn and consumed economically each year for an indefinite period of time… Perennial yield cannot exceed the natural recharge to an area indefinitely, **and ultimately it is limited to the amount of natural discharge that can be salvaged for beneficial use**." -- *Rush and Kazmi 1965 (published by the State of Nevada, SNWA Exhibit #298, pg 26)*

CPB Exh 19 - Jones and Mayo, "Sustainability of the SNWA Pumping Project in Spring Valley, Nevada", June 30, 2017. Aquaveo LLC (pg 14)

The Water Budget Myth

“Perhaps the most common misconception in groundwater hydrology is that a water budget of an area determines the magnitude of possible groundwater development. Several well-known hydrologists have addressed this misconception and attempted to dispel it. Somehow, though, it persists and continues to color decisions by the water-management community. The laws governing the development of groundwater in Nevada as well as several other states are based on the idea that pumping within a groundwater basin shall not exceed the recharge.” *-- Bredehoeft et al 1982*

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“**The ultimate production of groundwater depends on how much the rate of recharge and (or) discharge can be changed—how much water can be captured.** Although knowledge of the virgin rates of recharge and discharge is interesting, such knowledge is almost irrelevant in determining the sustained yield of a particular groundwater reservoir. … Somehow, we have lost or misplaced the ideas Theis stated in 1940 and before.” *-- Bredehoeft et al 1982*

Other Researchers

Meinzer 1923; Alley and Leake 2004; Alley et al. 1999; Banks 1952; Conkling 1946; Devlin and Sophocleous 2004; Kendy 2003; Scanlon et al. 2012; Sophocleous 1997; Sophocleous 2000; Todd 1959; Bredehoeft 2002; Davids and Mehl 2015; Hubbel et al. 1997; Alley et al. 1999; Romano and Preziosi 2010; Sophocleous 1997; Rush and Kazmi 1965; Kalf and Woolley 2005; Balleau 2013; Alley and Leake 2004; Mays 2013; Zhou 2009; Llamas et al. 2006; Seward et al. 2006; Ragone and Llamas 2006; Konikow and Leake 2014

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3.5 Summary

In summary, the following points are firmly established in the scientific literature:

1) Quantifying the safe yield of an aquifer system using a water budget analysis is fundamentally flawed.
2) In large basins, it may take an extraordinarily long period of time for a system to come to equilibrium, and massive amounts of groundwater may be mined in the process.
3) The spatial relationship between the wells and natural discharge regions has a significant impact on the time required for a system to come to equilibrium. If wells are not sufficiently close the natural discharge zones, equilibrium may never be reached, leading to perpetual groundwater mining.

4.2 Updated Model Simulations

Starting in 2016, we performed a new series of model simulations. The objective of this new round of simulations was to develop a model that can be used to explore the following questions:

a) Does the Spring Valley groundwater system ever come to equilibrium with the proposed wells pumping at the designated rates and locations? If so, how long does it take?
b) As the groundwater system transitions to equilibrium, how much water is removed from storage? What is the impact to interbasin flow?

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5 SIMULATION RESULTS

To answer questions a-c described in Section 4.2, we performed a long-term simulation with the Regional Model. These questions relate to the sustainability of the proposed pumping project and explore whether the system ever reaches equilibrium. The model stresses are identical to the simulations performed by Watrus and Drici (SNWA 2011), except the pumping rates were reduced from the original maximum rate of 91,000 AFA to 61,000 AFA. This reduced rate corresponds to the amount stipulated by the Nevada State Engineer in the 2012 ruling (King 2012). Also, the simulation period was changed from 200 years to 2000 years to determine if and when the system reaches equilibrium. Two simulations were performed: one using baseline conditions without the SNWA wells and one with the SNWA wells.

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3.3 Simulation Result with the Proper Set of Wells

The model simulations reported by Burns et al. (2017) were performed using the same CCRP model used by SNWA experts in 2011 (Watrus and Drici 2011), but with a set of updates. The primary updates made to the model are as follows:

a) The pumping rate was reduced from 91,000 AFA to 61,127 AFA to match the appropriation levels approved by the NSE in 2012.
b) The ET discharge was increased from 75,000 AFA to 84,100 AFA to match the updated ET estimate provided by the NSE in 2012. This was accomplished by iteratively increasing the recharge until the ET discharge reached the target amount.
c) The baseline simulation was updated to include water rights purchased by the SNWA in recent years that were not included in the 2011 model.

In our June 30, 2017 submittal, we presented a set of simulations analyzing ET capture and time to equilibrium using an updated version of the same 2011 CCRP model used by the SNWA (Jones and Mayo 2017). We also made modification (a) listed above (reduced pumping rate to 61K AFA). However, we did not make updates (b) & (c). We acknowledge that these two updates are appropriate and result in a more accurate simulation.

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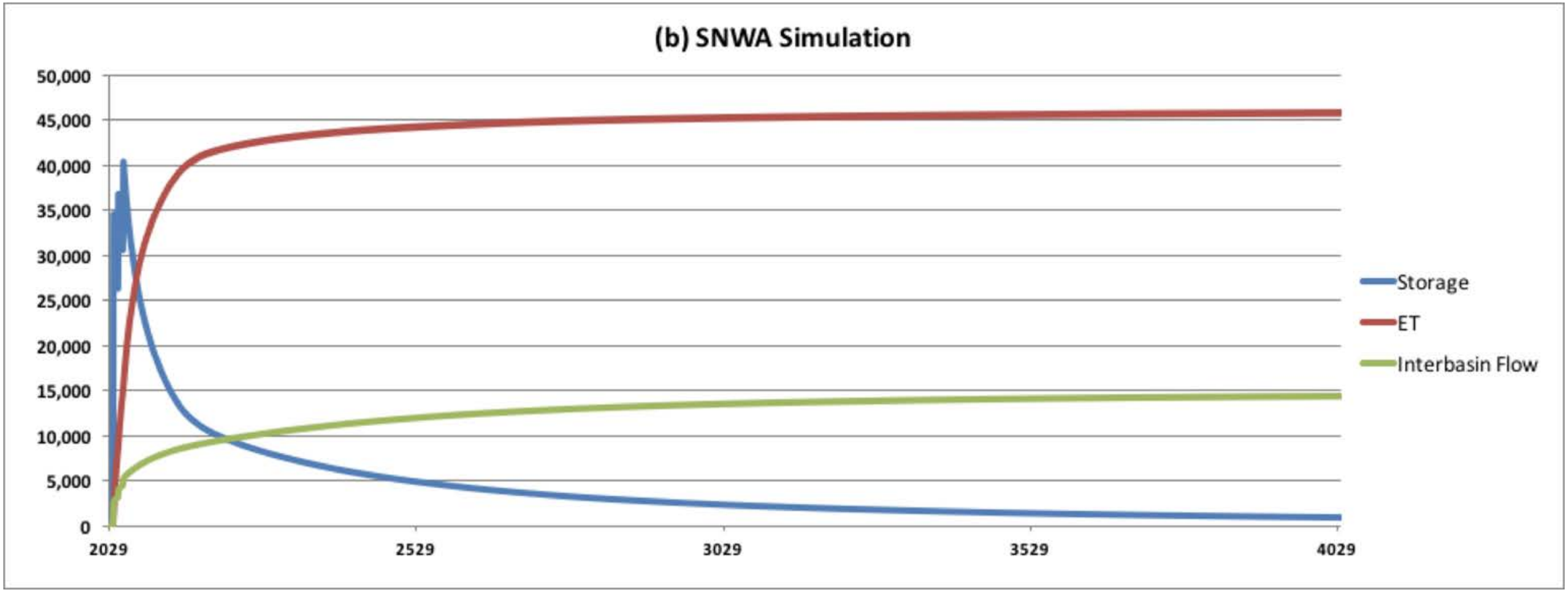
Results - Net Change in Flow Budget



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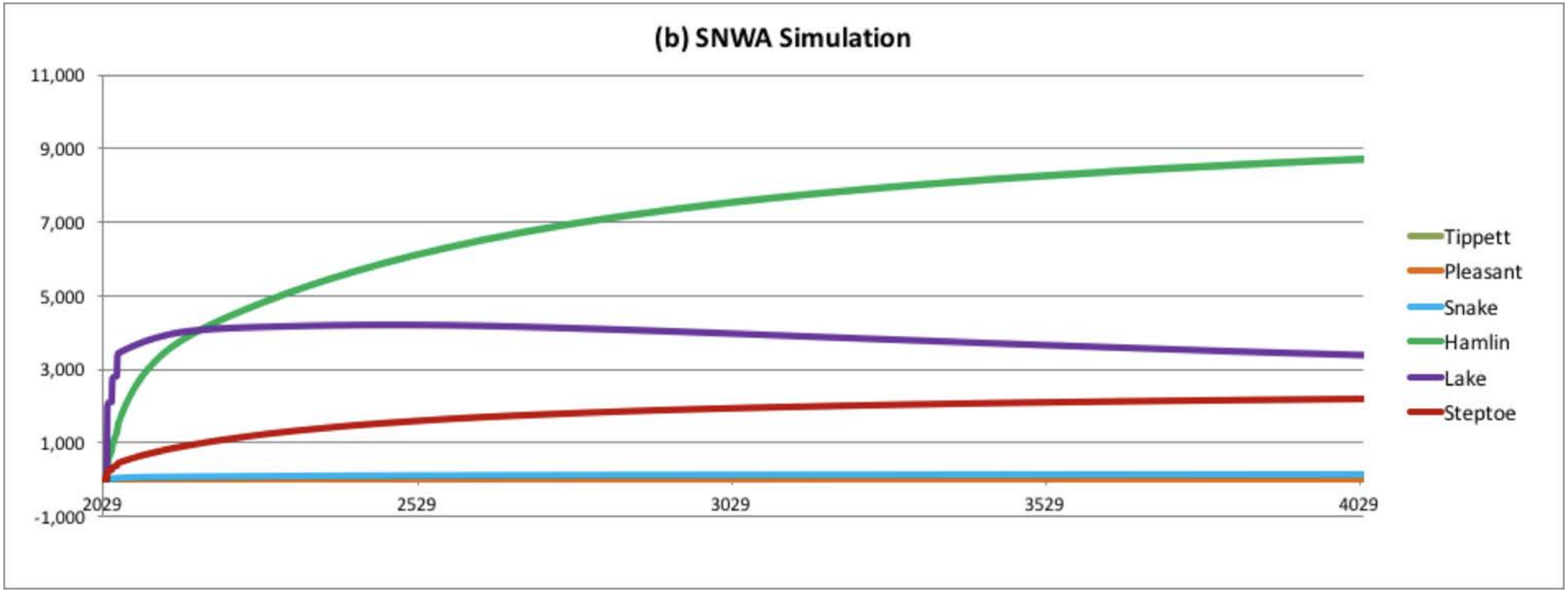
Results - Net Change in Interbasin Flow



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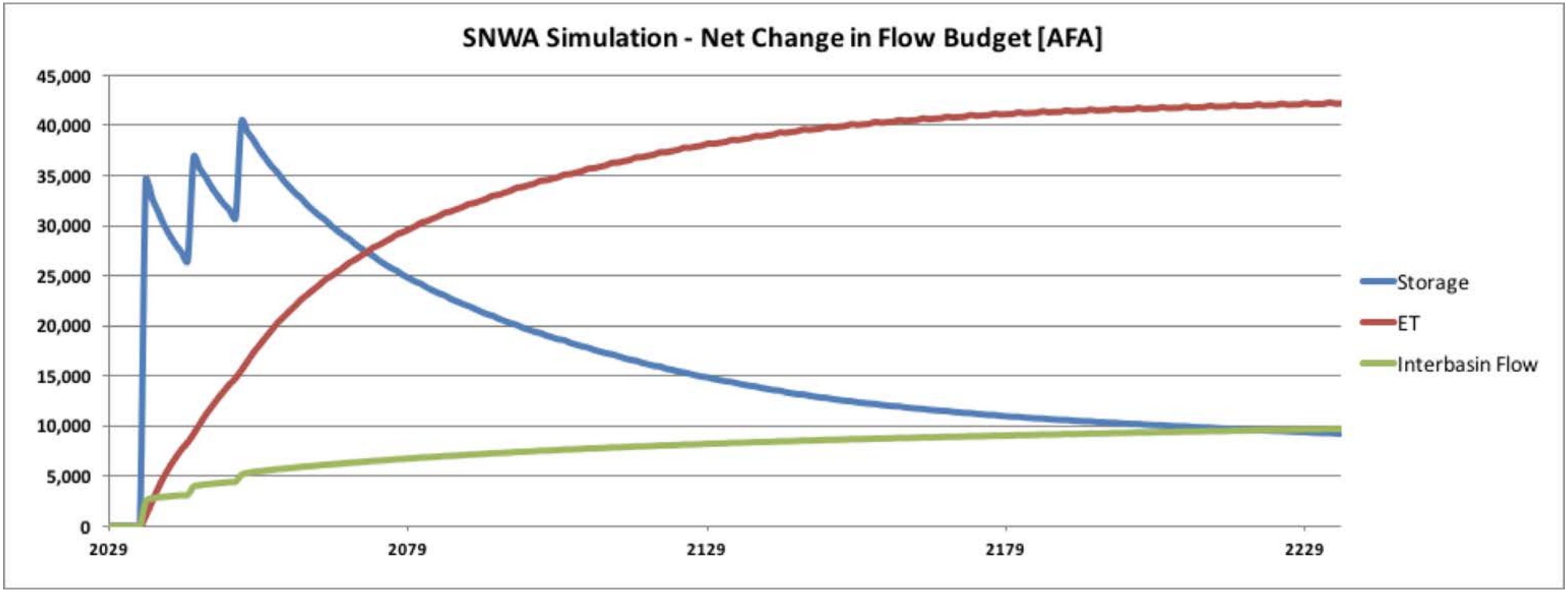
"Basin boundary flows are not a component of the perennial yield of Spring Valley. Any outflow to Snake Valley and/or Hamlin Valley is reserved for those basins." - *NSE Ruling 6164, 2012*

Results at 200 Yrs - Net Change in Flow Budget



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Net Change in Flow Budget at Selected Points in Time

Year	Time	ET Capture [AFA]	ET Capture [%]	Storage [AFA]	Interbasin Flow [AFA]
2051	Full Build-Out	15602	26%	40315	5168
2126	+75 Years	37711	62%	15155	8218
2151	+100 Years	39818	65%	12543	8703
2251	+200 Years	42338	69%	8787	9959

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B.3.0 CALCULATIONS

The groundwater storage in the valley fill of Spring Valley for each model cell was computed as the product of the model cell acreage, the specific yield of the model cell, and an assumed aquifer thickness of 100 ft. The cumulative groundwater storage in Spring Valley is the summation of the storage from the individual model cells. The overall storage for the two different model simulations is presented in Table B-1 and ranges from 4.79 maf to 8.57 maf. The large range is entirely dependent on the specific yield values. For the ucth935 simulation, the majority of model cells in the valley bottom had a specific yield value of 0.18 (dimensionless). In the ucth971 simulation, the majority of model cells in the valley bottom had a specific yield value of 0.10 (dimensionless).

Table B-1
Summary of Recoverable Groundwater in Storage in Spring Valley

Simulation	Specific Yield Range (-)	Storage (maf)
ucth935	0.01 to 0.18	8.57
ucth971	0.01 to 0.10	4.79

SNWA Exh 475 - Burns et al., "Simulation of a Groundwater Production Scenario Related to Southern Nevada Water Authority Groundwater Applications in Spring Valley, Nevada", June 30, 2017. SNWA (pg B-2)

Storage Depletion

Year	Time	Total Mined Storage [AF]	Total Mined Storage [MAF]	Fraction (Min) [%]	Fraction (Max) [%]
2051	Full Build-Out	547774	0.55	6%	11%
2126	+75 Years	2309133	2.31	27%	48%
2151	+100 Years	2651478	2.65	31%	55%
2251	+200 Years	3678921	3.68	43%	77%

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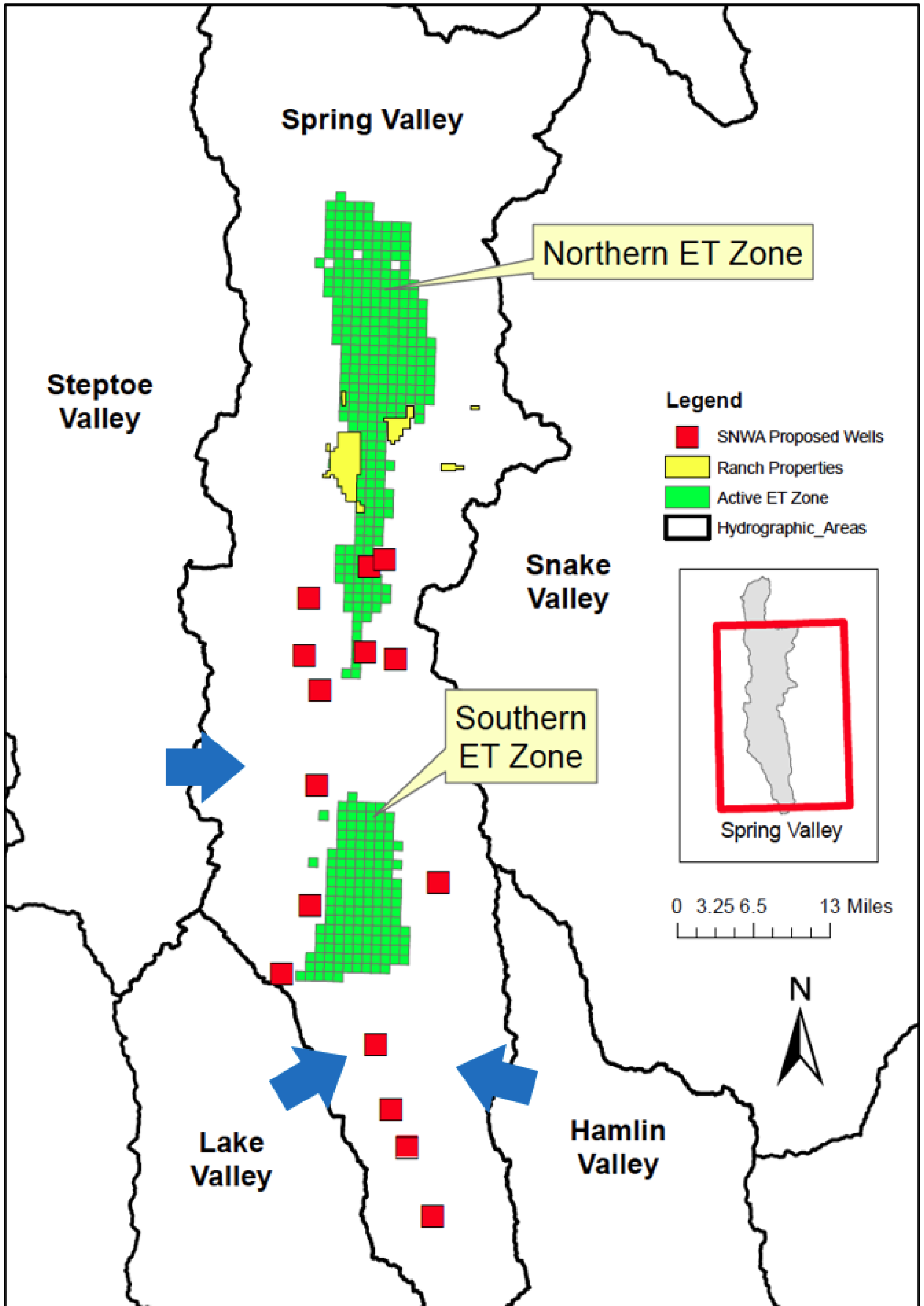

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Fractional Pumping Analysis

District Court Remand Ruling, Directive #2:

*"A **recalculation of water available for appropriation** from Spring Valley assuring that the basin will reach equilibrium between discharge and recharge in a reasonable time"*

Pumping Rates Used in Fractional Analysis

Fraction	Total Pumping [AFA]
10%	6,108
20%	12,217
30%	18,326
40%	24,501
50%	30,543
60%	36,651
70%	42,760
80%	48,868
90%	54,977
100%	61,085

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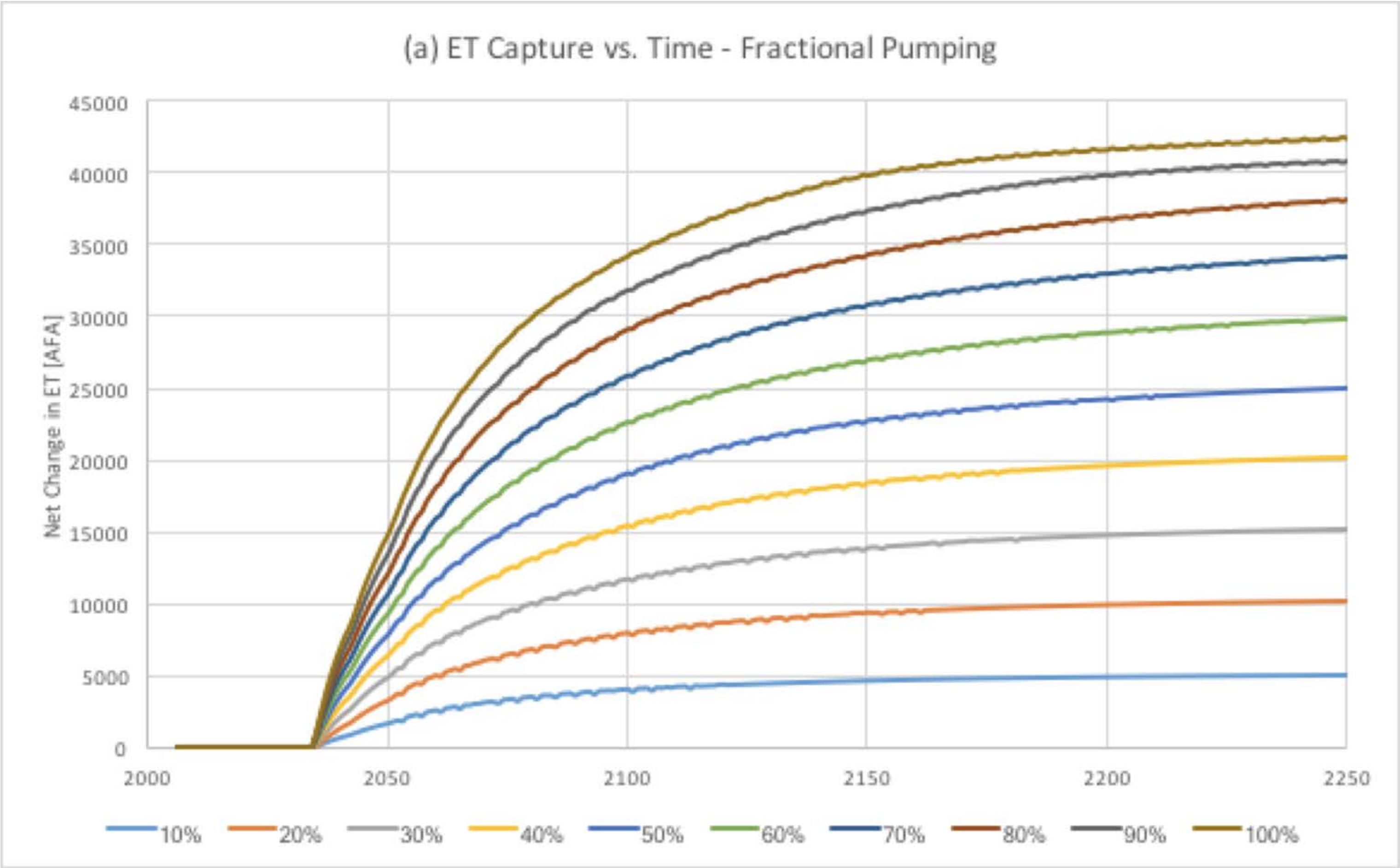
Results - ET Capture vs. Time (200 yrs)



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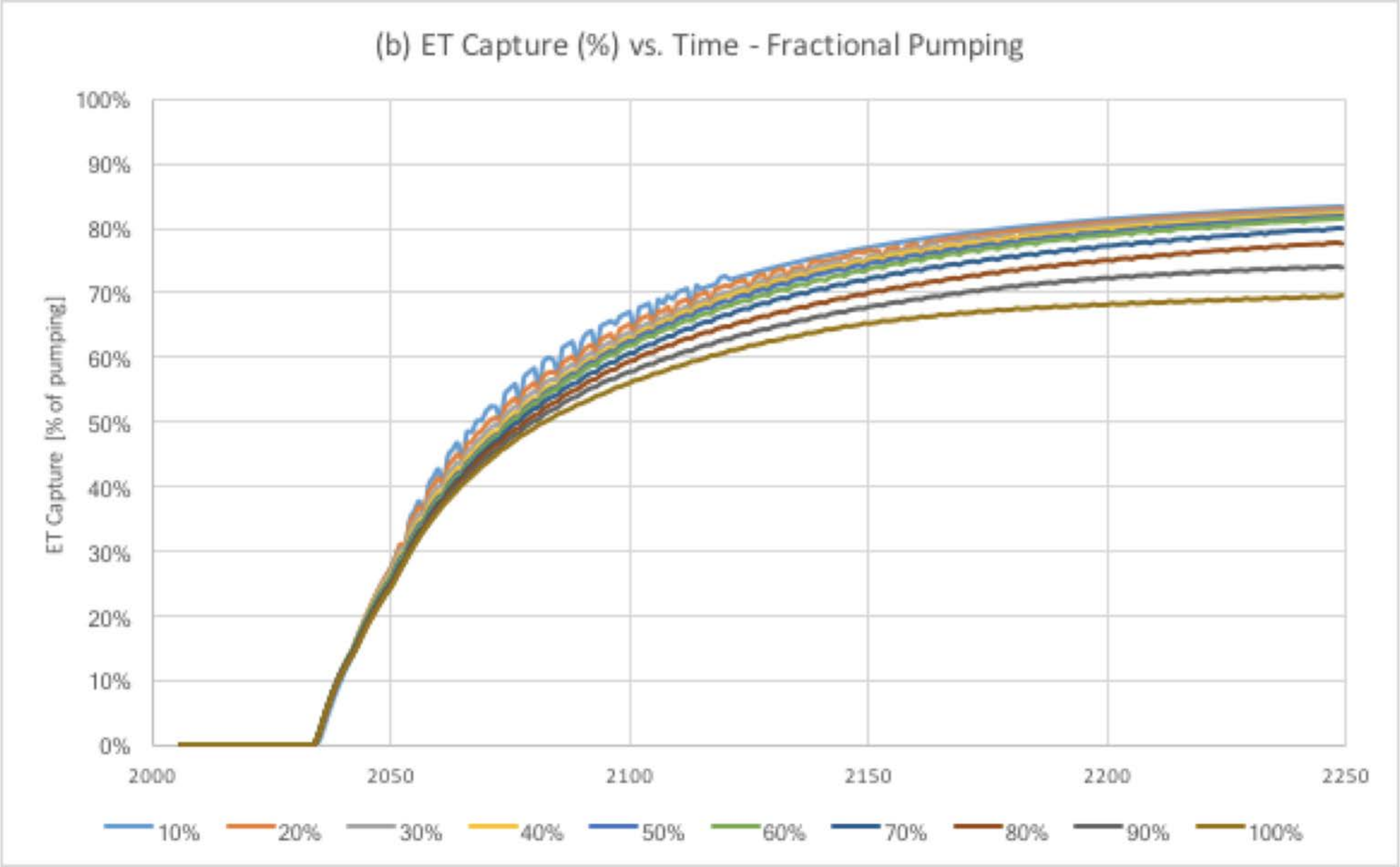
Results - ET Capture (%)



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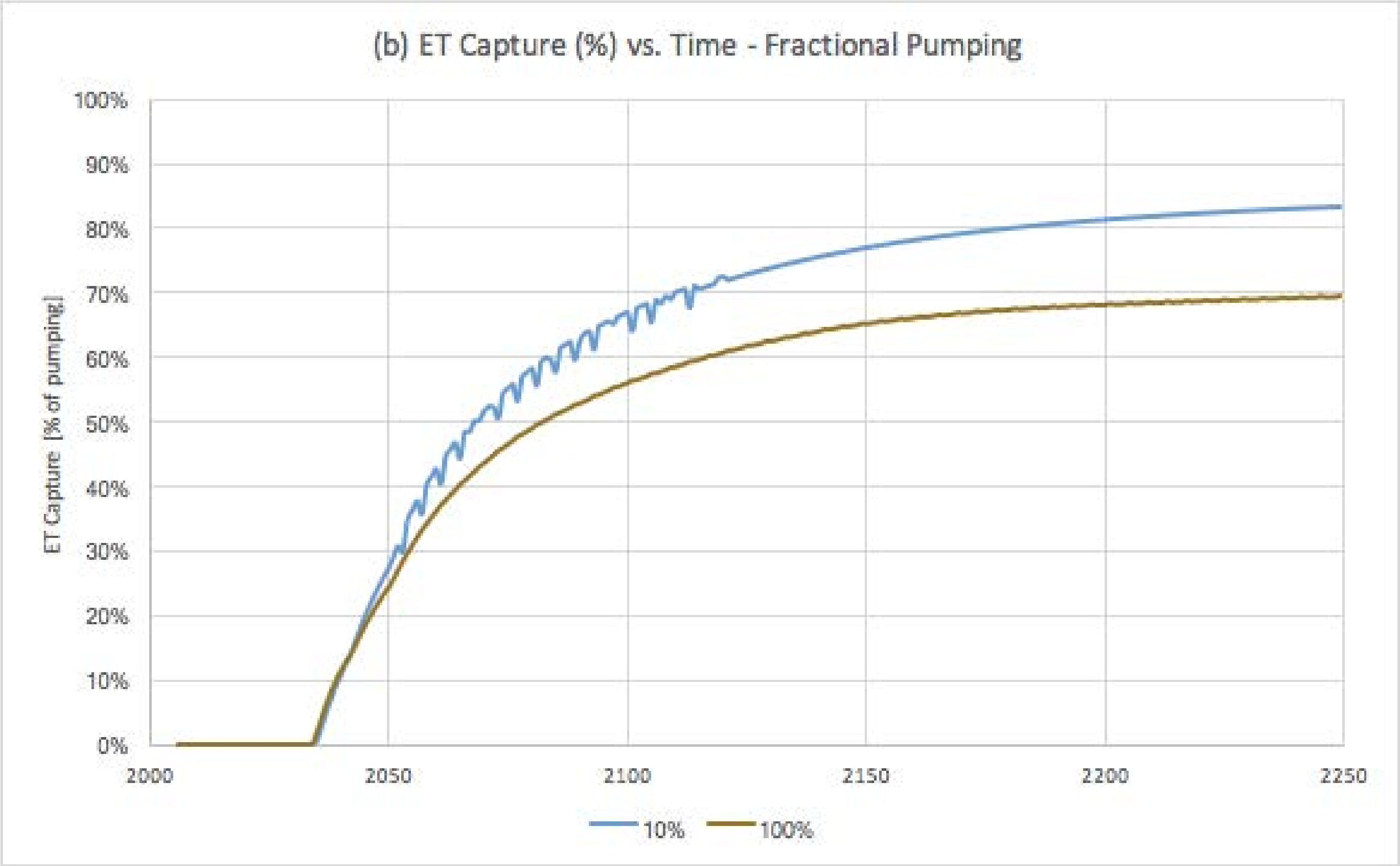
Results - ET Capture (%)



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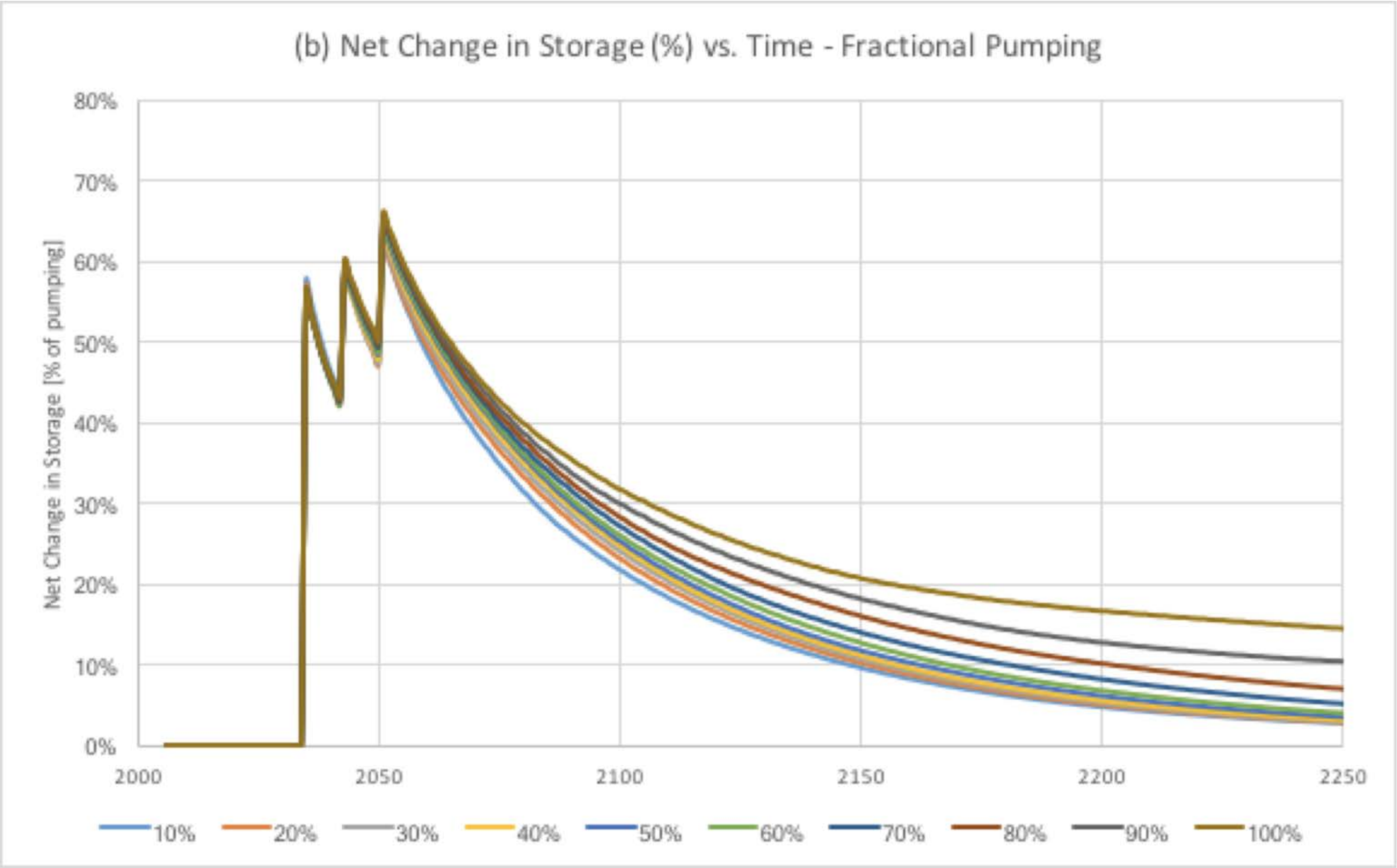
Results - Net Change (%) in Storage



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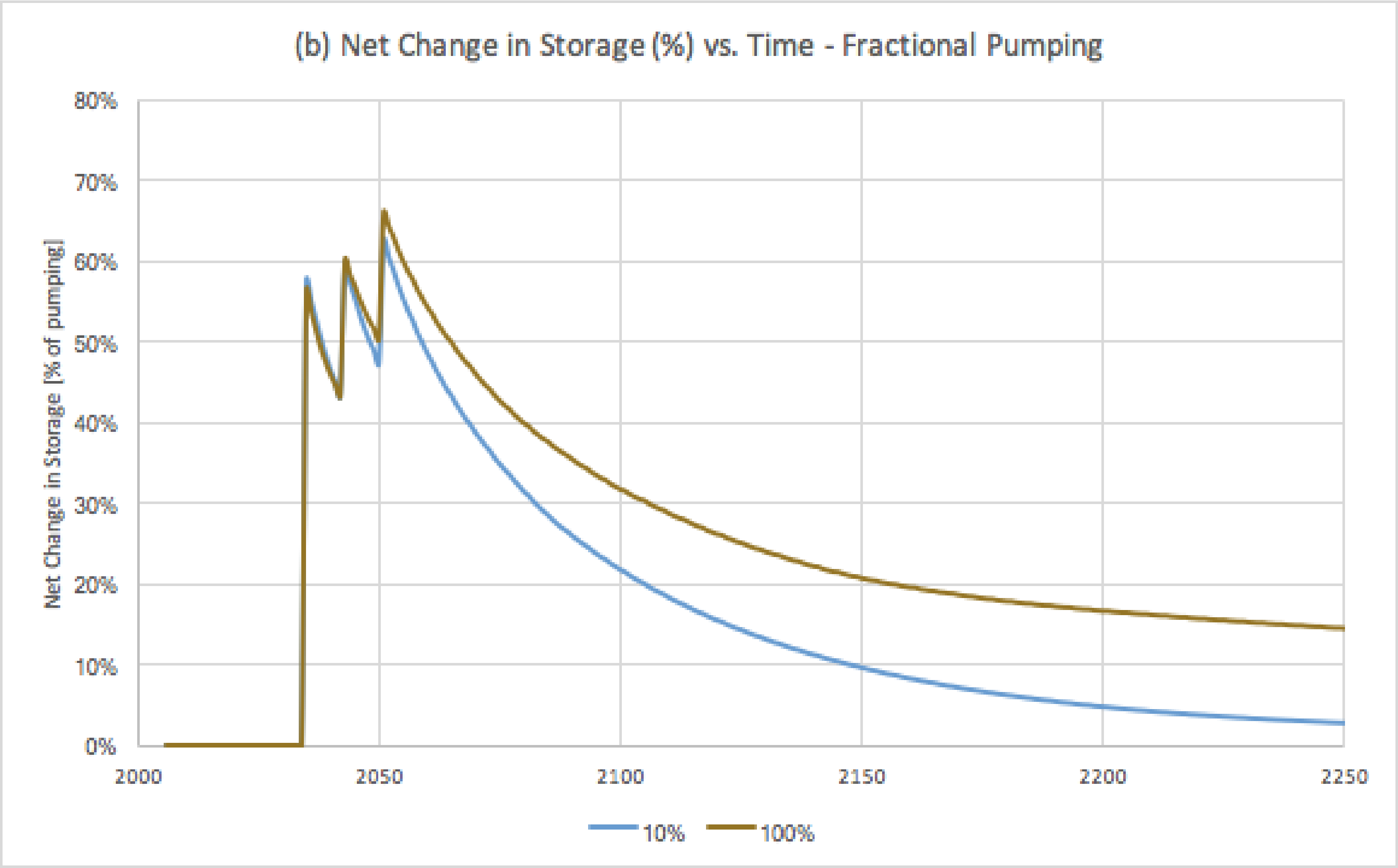
Results - Net Change (%) in Storage



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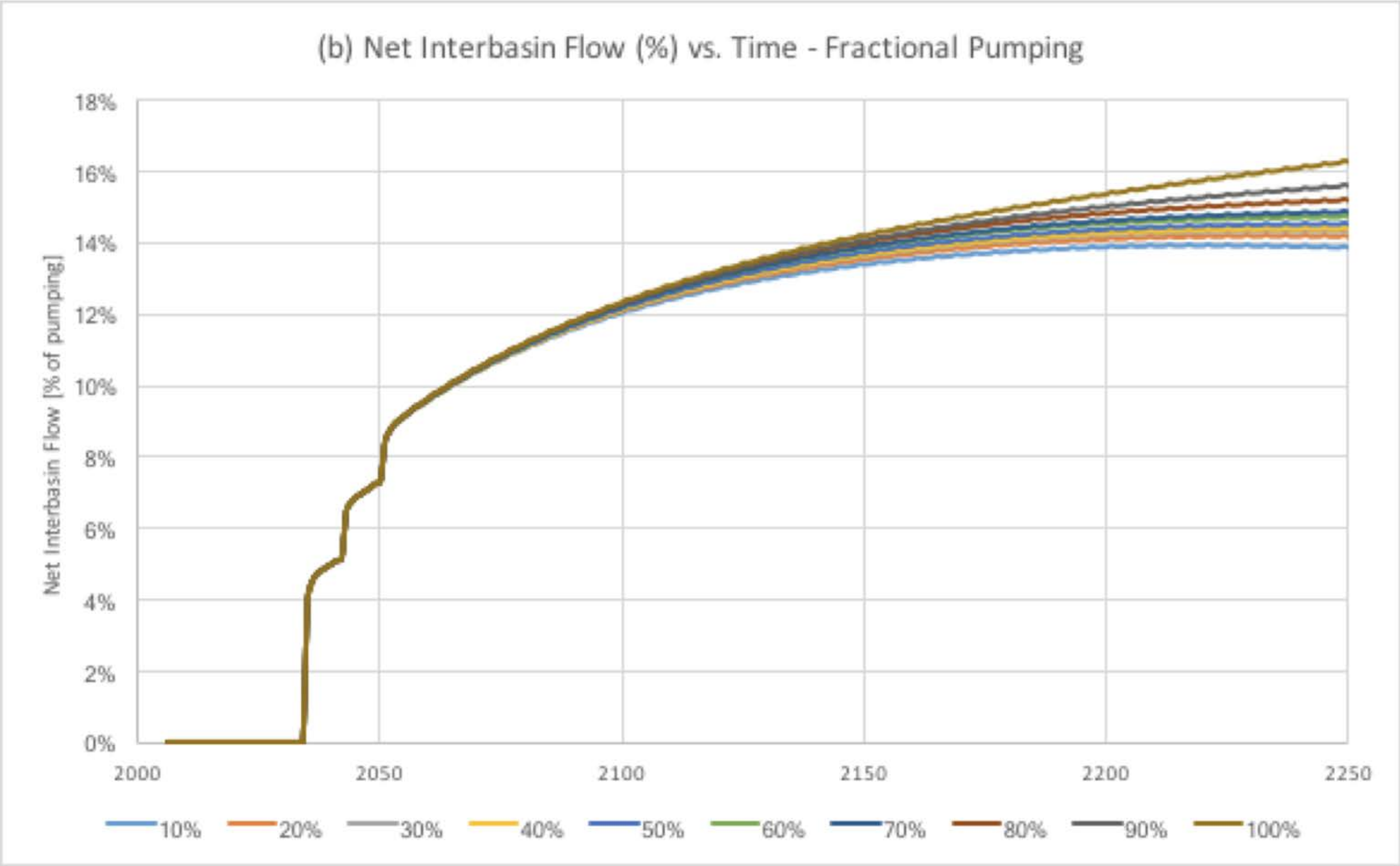
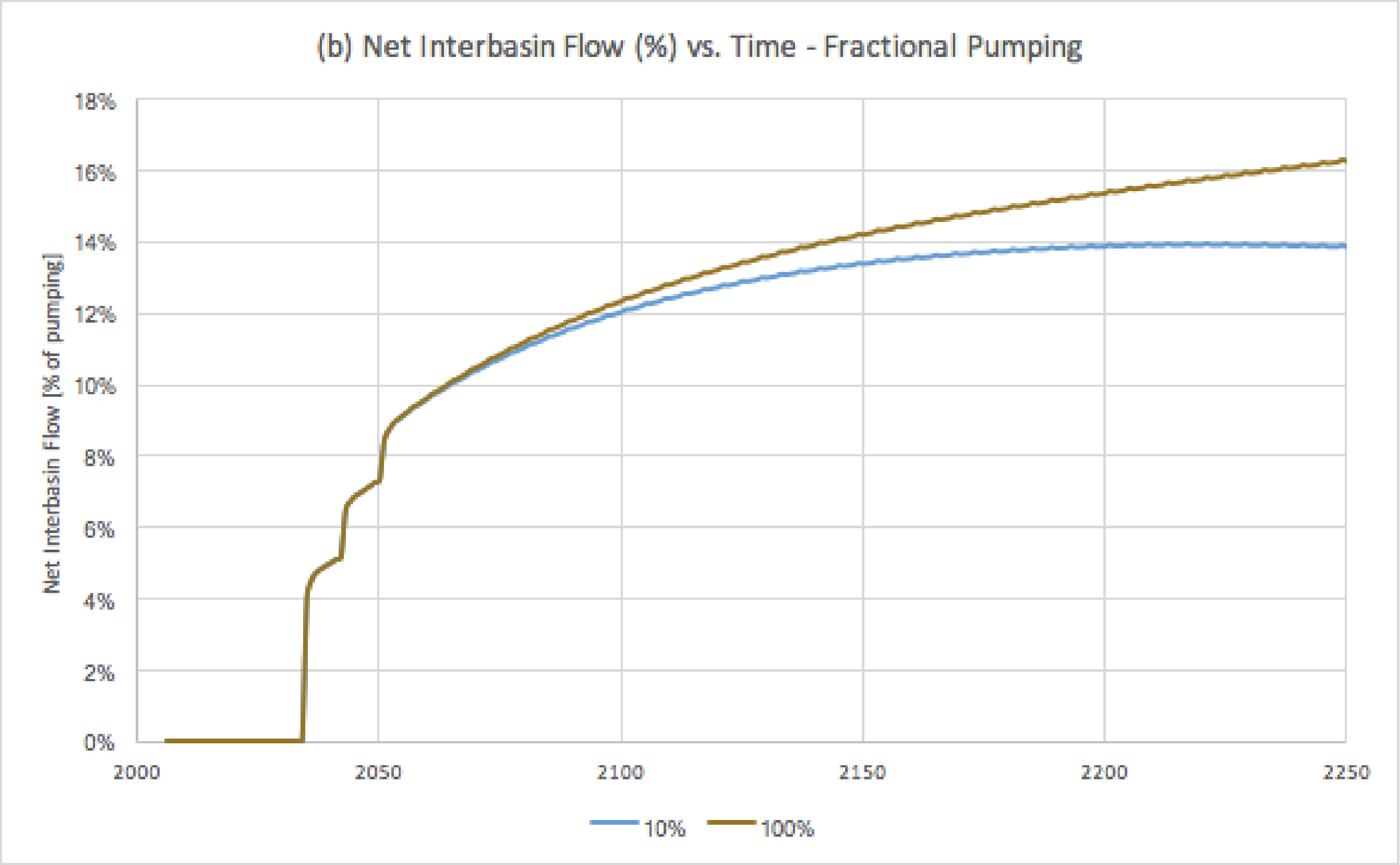
Results - Net Change (%) in Interbasin Flow



CPB Exh 25 - Jones and Mayo, "Response to the June 30, 2017 SNWA Exhibits Related to Spring Valley", Aug 11, 2017. Aquaveo LLC (pg 18)

Results - Net Change (%) in Interbasin Flow



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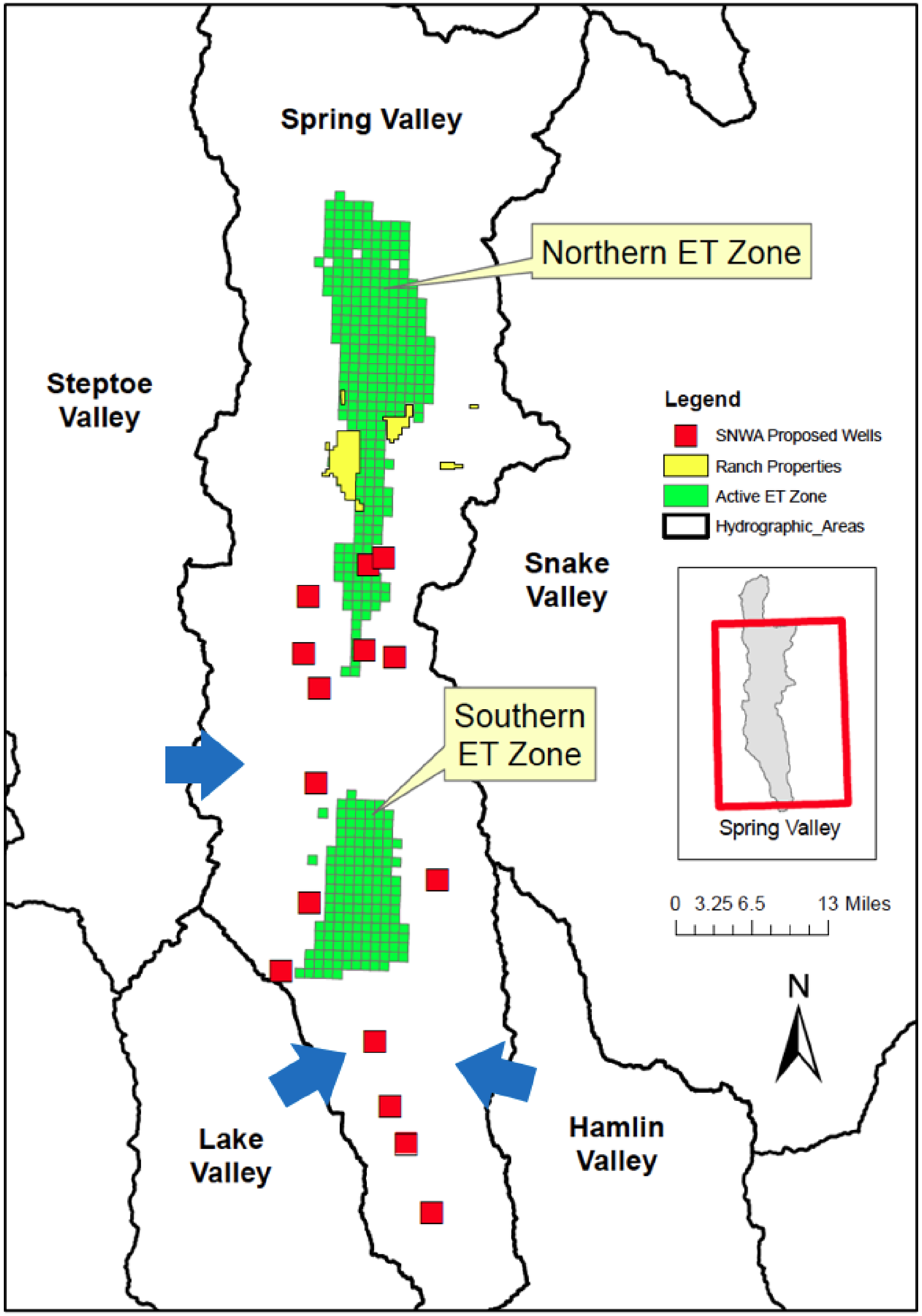
"In summary, the SNWA well system is fundamentally flawed due to the spatial distribution of the wells. The wells are located in the central and southern ends of the valley and are not situated inside the ET discharge zones, much of which is in the northern end of the valley. Accordingly, water is mined from storage and pulled from adjacent valleys regardless of the pumping rate. Therefore, there is no reduced appropriation rate that achieves equilibrium and thereby satisfies the directive in the remand ruling."

CPB Exh 25 - Jones and Mayo, "Response to the June 30, 2017 SNWA Exhibits Related to Spring Valley", Aug 11, 2017. Aquaveo LLC (pg 21)



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