Time Series Analysis for San Bernardino National Wildlife Refuge Mitigation Well and Glenn Well Ranch (6/10/2020)

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I developed a time series using data from Glenn Ranch Well and a well located at San Bernardino National Wildlife Refuge (i.e,. Mitigation Well) to determine how on-the-ground effects at the Border Wall are impacting wells at the Refuge (November 2019 – May 2020). We can use time series analyses to detect if there is a relationship between the two wells.

First, water use at Glenn Ranch Well has been reported to us weekly. I calculated the mean pressure readings from Mitigation Well to pair with the cumulative data reported for Glenn Ranch Well. These data are represented in the Table below.

Period	Glenn Ranch Well	Mitigation Well (average)
November 2019	2,731,400	3.54
December 2019	1,510,900	3.64
January 1 – 29 2020	1,805,700	3.63
January 30 – February 8 2020	1713500	3.44
February 9 – 14 2020	427400	3.42
February 15 – 21 2020	901400	3.36
February 22 – 28 2020	NA (944000)	3.29
February 29 – March 3 2020	986600	3.31
March 4 – 16 2020	705000	3.22
March 17 – 23 2020	844000	3.09
March 24 – 30 2020	1430400	2.73
March 31 – April 6 2020	1746200	2.99
April 7 – 14 2020	1506100	2.97
April 15 – 20 2020	2026400	2.95
April 21 – 27 2020	2444300	2.94
April 28 – May 4 2020	2946100	2.83
May 5 – 12 2020	2710700	2.76
May 13 – 18 2020	2857400	2.9
May 19 – June 1 2020	2044500	2.59

This set of analyses focuses on weekly and post January 30th. Based on previous data provided by CBP, it was found that for February 9-14 and 15-21 gallons extracted were 427,400 and 901,400. However, previous CBP documents report for February 28th over 5 million gallons withdrawn. Given that the data reported by CBP for February varies by each report, I decided to remove the 5 million gallons used, retain the previous data provided by them for weeks 9-14 and 15-21, and then replace the 5 million gallons using an NA. I then used linear interpolation to impute what the NA value would be given what we know from the time series that they provided. This allowed me to maintain the structure of the data set rather than remove the 22-28 February observations. The value for the linear interpolation is reported in the parenthesis in the

Table above. Here are the paired time series between weekly gallons pumped and weekly pressure readings at Mitigation Well below.

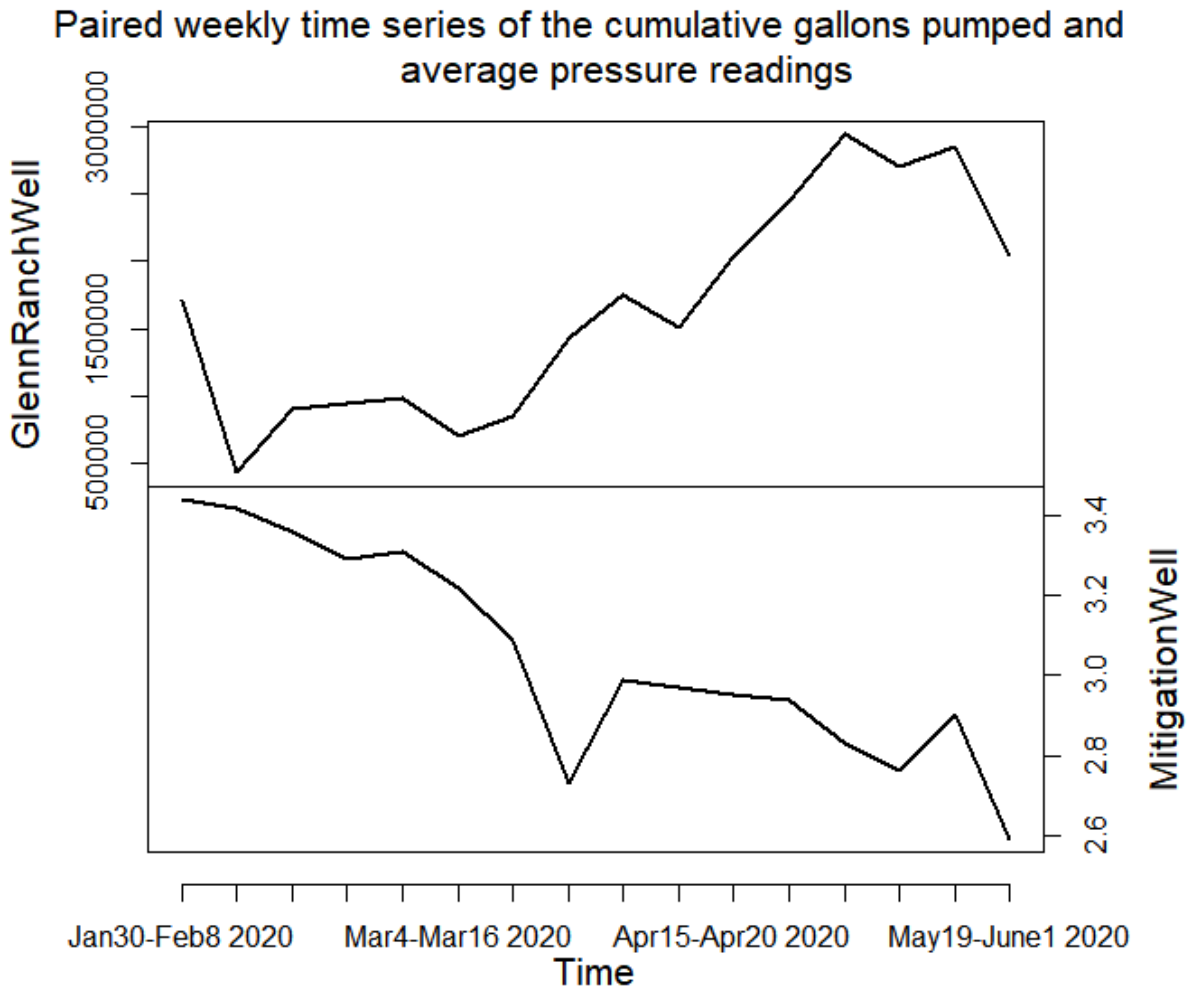

Figure 1: Time series of weekly cumulative gallons pumped at Glenn Ranch Well (top) and the average weekly pressure readings from Mitigation Well located at San Bernardino NWR (bottom) from January 30th to June 1st 2020.

Figure 1 above shows that as the weekly gallons produced increases over time at Glenn Ranch Well, the average weekly pressure readings at Mitigation Well declines significantly. To determine if the relationship is statistically significant, we used a statistical method (i.e,. cross correlation analysis) that tracks the movements between the two wells and allows us to determine if the observed pumping at one well negatively has an impact on the other. In this analysis, we are interested in understanding how pumping at Glenn Ranch Well affects pressure at Mitigation Well. Therefore, I am mostly interested in the cross-correlation at zero to negative lags (i.e., when the weekly cumulative gallons predates inferred weekly pressure readings). This implies a lag effect between them, such that pumping from Glenn Ranch Well affects pressure at Mitigation Well sometime after or within that same week. The cross correlation analysis allows us to determine what lag to use. Given that data is reported on a weekly time step, then the lag will be based on a current week or 1 or 2 week delay. The highest cross correlations between 0 and negative lags occurred at 0 (the same week) and -1 (or 1 week after), and thus indicates that a high producing week at Glenn Ranch Well will lead to a below average value of "pressure" about 1 week after if not that same week at Mitigation Well. This means that our analysis can detect activities from Glenn Ranch Well and we are seeing immediate impacts.

To estimate if the relationship is statistically significant using a lag of one week after (identified from the cross correlation analysis), the two time series were modeled as a dynamic linear model. I also did this for the 0 week after (impacts identified that same week). What this means is that we developed a set of models where we related pumping from the preceding week (e.g., January 30th to February 8th) from Glenn Ranch Well with the next week's average pressure readings at Mitigation Well in accordance to the cross-correlation analysis for lags 0 and -1 (Figure 2). From the statistical model, all coefficients were found to be statistically significant for both models. There is a significantly negatively trend between the previous weeks pumping at Glenn Ranch Well and Mitigation Well, and also a significantly negatively trend between the current weeks pumping at Glenn Ranch Well and Mitigation Well pressure readings. To illustrate the relationship, the lag plot below shows the negative relationship between the two wells (Figure 2).

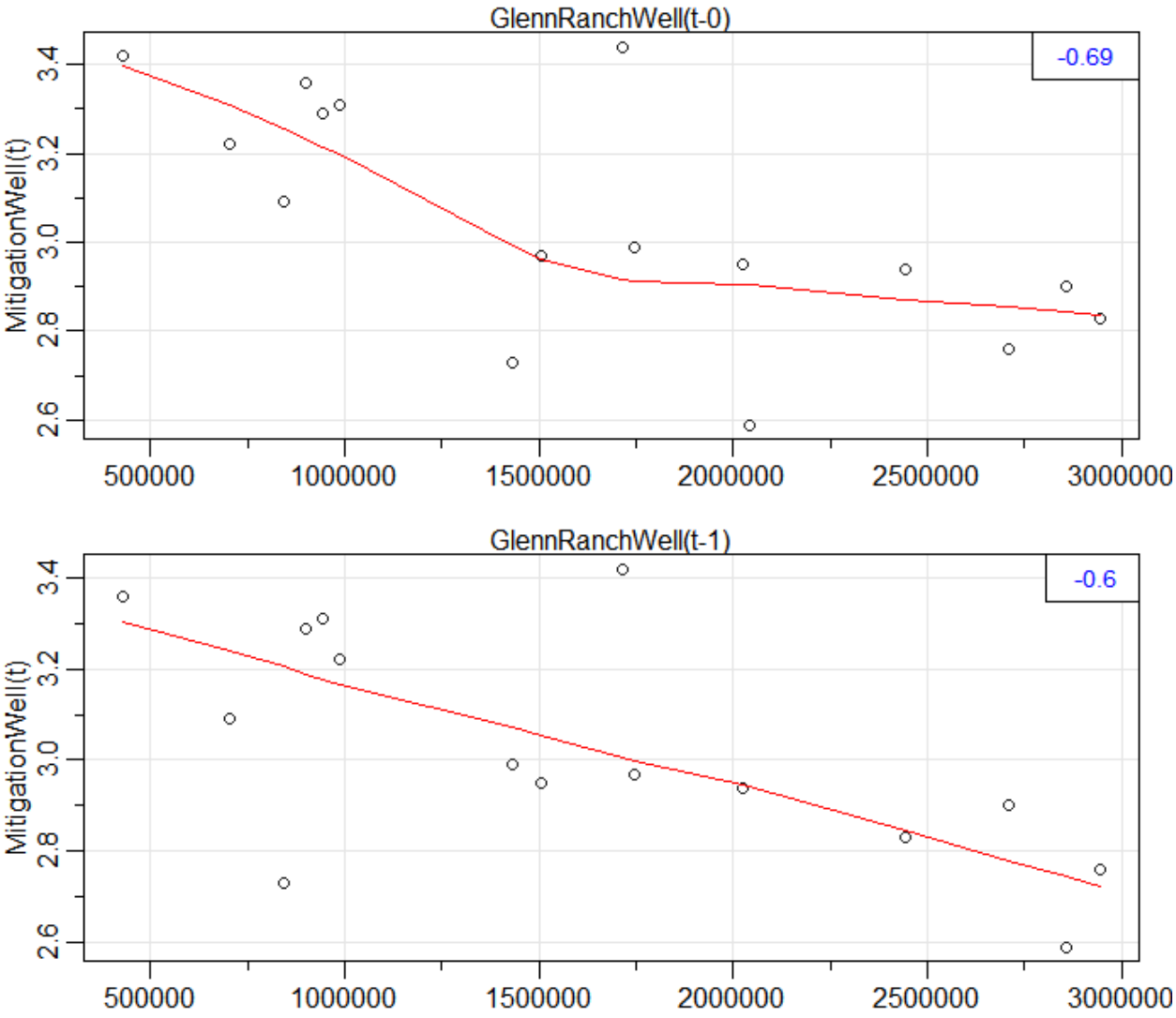

Figure 2. Lag plot between the same (t-0) and preceding (t-1) weeks pumping at Glenn Ranch Well and the same week and following pressure readings at Mitigation Well located at San Bernardino National Wildlife Refuge. The correlations (top right hand corner) are -0.69 and -0.60, meaning that the relationship is significantly negative.

In Figure 2, the correlation value for the time series are -0.69 and -0.60. The $R^2 = 0.47$ from the statistical model (the linear model discussed above) describing the relationship between the same week pumping. The $R^2 = 0.43$ from the statistical model describing the relationship between one week after pumping (lag of one week). This means that about 47% and 43% of the variation observed in pressure readings at Mitigation Well is explained by the same week and previous weeks pumping at Glenn Ranch Well. The results from the two statistical models are presented below.

Lag	Coefficients	Estimate	Standard Error	p-value	R^2
Same week (t-0)	Intercept	3.417	1.149e-01	4.7e-14	0.47
	Slope	-2.242e-07	6.323e-08	0.00323	
One week (t-1)	Intercept	3.344	1.137e-01	2.81e-13	0.43
	Slope	-1.986e-07	6.314e-08	0.00774	

Conclusion: These analyses provides additional evidence that pumping at Glenn Ranch Well is significantly impacting wells located at San Bernardino National Wildlife Refuge, leading to immediate and significant loss in pressure at Mitigation Well within a week. This correlates with why some ponds at the Refuge are void of water, and why it is so difficult to maintain water levels at other ponds that currently have threatened and endangered fish species.