

DEPARTMENT OF WATER RESOURCES

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September 2, 2016

Colusa County Board of Supervisors
547 Market Street, Suite 102
Colusa, California 95932

Colusa County Water Commission
Colusa County Water Resources Department
100 Sunrise Boulevard
Colusa, California 95932

Dear Supervisors and Commission members:

The purpose of this letter is to provide you with a summary of the recent Global Positioning System (GPS) land surface survey performed by the Department of Water Resources (DWR) with assistance from Colusa County Public Works staff. The majority of the work took place on June 20-23, June 28, and August 4.

History

An initial Sacramento Valley GPS subsidence network was created and surveyed in 2008 by DWR with assistance from local agencies to establish baseline elevations that would be used to determine change in land surface elevation over time. Unfortunately, there has not been any follow up surveys in Colusa County since the initial baseline measurements of 2008.

In spring 2014, Glenn County requested that DWR resurvey two areas of their county after preliminary results from the analysis of a 2004 Glenn County survey and the 2008 Sacramento Valley survey showed subsidence may be occurring. From the results of these two surveys, DWR determined that a small amount of land subsidence was detected southwest of Orland and potential subsidence west of Hamilton City.

In the fall 2015, National Aeronautics and Space Administration Jet Propulsion Laboratory (NASA/JPL) released a report that showed how remote sensing using Interferometric Synthetic Aperture Radar (INSAR) can be used to detect land subsidence in California's Central Valley; this is the catalyst that led to the recent GPS resurvey in Colusa County. The NASA/JPL report identified subsidence that had occurred in the area surrounding the town of Arbuckle on the west side of the Sacramento Valley. Two different Nasa/JPL analyses, during different time periods, with different satellites showed land subsidence.

The first analysis by NASA/JPL covered a time period from 2006 to 2010. It showed approximately 2 to 4 inches of subsidence in the area surrounding Arbuckle, and slightly more around the town of Colusa. This analysis showed the amount of subsidence as minor and at least 6 years old. However, by combining this information with a recent report of a City of Colusa public supply well that had several inches of vertical compression, supports the possibility that subsidence has occurred recently, or did not stop in 2010.

The second NASA/JPL analysis covered the period between May and November 2014. This analysis considered the amount of subsidence significant and stated the following: "The small area of intense subsidence evident near Arbuckle in 2014 shows an uneven subsidence about 5 inches for the last half of 2014." Both of these analyses were considered a remote sensing proof-of-concept and historical images were used for comparison. DWR did not perform a GPS survey during this time period, thus preventing results from being verifying.

The County and the rest of the Sacramento Valley counties had hoped to conduct a GPS resurvey of the entire 2008 Sacramento Valley GPS subsidence network this past spring, but funding and resources prevented it from occurring. DWR is currently planning on conducting a full resurvey of the northern Sacramento Valley in spring 2017 and will be coordinating soon with each county and other agencies to establish the schedule and identify resources to assist DWR with the effort. In the interim, DWR was able to secure resources to do a partial GPS resurvey in the area of Arbuckle, and it is this resurvey that is being summarized below.

The primary goal of the resurvey was to determine if inelastic subsidence had occurred since the 2008 baseline elevations were determined and to what extent. It was expected that if inelastic subsidence had been occurring, or occurred since 2008 in the Arbuckle area as NASA/JPL indicated, the results of this resurvey would be a change in elevation equal to or greater than the amount reported by NASA/JPL.

Methods

In an effort to minimize the impacts of small seasonal or annual changes in the surface elevation due to simple soil compaction and expansion, also known as elastic subsidence, the resurvey was performed at approximately the same time of year (spring) as the original 2008 survey to obtain comparable results. If there is a measured change in elevation then it is considered inelastic subsidence.

To determine the land surface change in elevation, two monuments (P208 and SUTB) were considered to be "fixed" or "held" meaning they are stable and are not expected to change in elevation. Typically, these monuments are usually located in the hard rock areas of the valley or on the Sutter Buttes. Using these monuments and extremely long GPS measurements of five-hour durations, a third monument at the southern end of the area of interest (point BIRD) was determined to have possibly subsided 0.12 feet (1.5 inches). Although this difference is within the possible estimated error of GPS measurements, we decided to use the newly computed ellipsoid height for point BIRD. Point BIRD, P208, and SUTB were then held as fixed control for the network. The remaining 18 monuments were assumed to be able to move vertically, and each was referenced against the fixed points to determine elevation change for these monuments.

Results

The accuracy of GPS vertical elevation surveys are affected by errors or "noise." This noise can influence survey results by as much as 0.13 to 0.16 feet (1.5 to 1.9 inches).

When working with small changes that might not individually exceed this error margin, trends were looked at over time to help identify potential subsidence. For the spring 2017 survey, changes in ground surface elevation greater than 1.9 inches are considered as “statistically significant,” while differences greater than 1.5 inches, but less than 1.9 inches, are considered as “potentially statistically significant.” The results of each individual monument’s change in elevation for the Arbuckle area resurvey are summarized in Table 1, Figure 1, and in the paragraphs that follow. Please be aware that the numbers shown are ellipsoid heights which are what is measured by GPS. Changes in ellipsoid heights can be considered equivalent to changes in elevation.

Table 1: Results of spring 2016 GPS resurvey of area around the City of Arbuckle

Monument	Ellipsoid Height 2008 (Ft.)	GS Ellipsoid Height 2016 (Ft.)	Change 2016 v 2008 (Ft.)*	Change 2016 v 2008 (In)*	Rate of Change (In/yr.)*	Notes
SECO	29.380	27.299	-2.08	-24.97	-3.12	
HAHN	-9.583	-11.226	-1.64	-19.72	-2.50	
WAYN	-51.978	-53.080	-1.10	-13.22	-1.65	
DRAI	-56.188	-57.049	-0.86	-10.33	-1.29	
GRNO	-64.983	-65.624	-0.64	-7.69	-0.96	
HERS	-53.441	-53.994	-0.55	-6.64	-0.83	
WHEA	-29.757	-30.289	-0.53	-6.38	-0.80	
NLD6	-58.980	-59.468	-0.49	-5.86	-0.73	
LUSA	53.730	53.241	-0.49	-5.87	-0.73	
TARK	-34.678	-35.146	-0.47	-5.62	-0.70	
1075	-50.843	-51.305	-0.46	-5.54	-0.70	
X200	-1.257	-1.708	-0.45	-5.41	-0.68	
0304	-54.895	-55.200	-0.31	-3.66	-0.46	
PASS	6.043	5.738	-0.31	-3.66	-0.46	
COLI	-48.100	-48.374	-0.27	-3.29	-0.41	
T644	-8.209	-8.460	-0.25	-3.01	-0.38	
P272	-37.913	-38.152	-0.24	-2.87	-0.36	
D850	23.743	23.692	-0.05	-0.61	-0.08	
P208	245.393	245.393	-	-	-	HELD
SUTB	2,024.419	2,024.410	-	-	-	HELD
BIRD	208.963	208.841	-0.12	-1.46	-0.18	HELD
TC23	-	89.585	-	-	-	NEW
TC22	-	94.220	-	-	-	NEW

Notes:

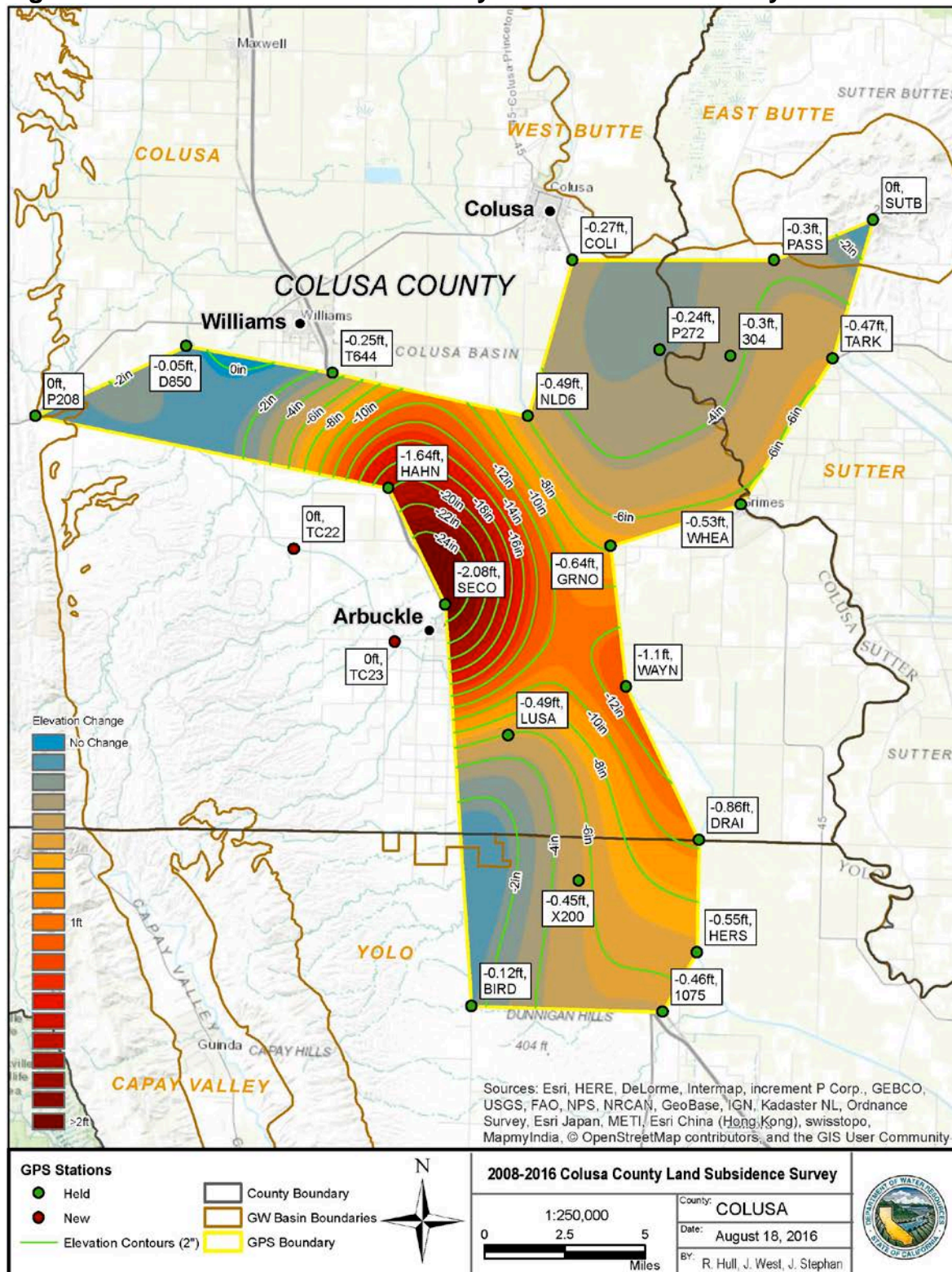
1 – Monument held fixed

2 – Held or Fixed - refers to monuments that do not have changes or significant changes in elevation during the analysis period

3 – New – Monuments that were added and measured during this resurvey and were not used in this current analysis

* - rounded to hundredths

Figure 1: Results of 2016 GPS resurvey of area around the City of Arbuckle



Note: Contours presented on this map (Figure 1) are interpolated and are for illustration only. Because of the limited number of data points they may not represent the actual location of vertical change.

The results from the resurvey indicate that between 2008 and 2016, the area in and around Arbuckle subsided by a maximum of 2.08 feet (approximately 2 feet 1 inch) as measured at monument SECO located approximately 1 mile north of Arbuckle. This amount represents a rate of slightly more than 3 inches per year since 2008. There are two other points in the resurvey that show changes in elevation that exceeded 1 foot. There are 1.64 feet (approximately 1 foot 8 inches) of change at monument HAHN, which is located approximately 5 miles northwest of Arbuckle, and 1.1 feet (approximately 1 foot 1 inch) of change at the GRNO monument, located approximately 6 miles east of Arbuckle. There are several other points in this resurvey that also show significant changes and can be referenced in Table 1 and Figure 1.

It also should be noted that between the City of Williams and south into Yolo County, the western edge of the survey area coincides approximately with the Interstate 5. Additional points need to be added to the network to expand the detection and monitoring area to the west. As part of this resurvey, DWR did add two additional points that are located along the Tehama-Colusa Canal. Both of the new points and any additional points that may be added cannot be compared back to 2008 since they were not surveyed at that time. The points can only provide reference of change to surveys performed in the future.

The conclusion of this analysis indicates the area in and around Arbuckle has subsided by as much as 2.08 feet (approximately 2 feet 1 inch) since 2008. It can also be reported that this amount of change far exceeded the 5 inches (0.4 ft.) detected in 2014 over a 6-month time period as reported by the NASA/JPL and mentioned above. It is also important that the amount of change detected is not equal in all areas surveyed and could be caused by one or both of the following:

- The amount of change could be influenced by differences in subsurface geology (i.e. the amount of fine sediment present).
- Not all of the locations are experiencing the same amount of groundwater level declines.

Sustainable Groundwater Management Act of 2014

The Sustainable Groundwater Management Act of 2014 identifies “inelastic subsidence” as one of the six undesirable results that can occur if groundwater is not managed sustainably in the basin. It is recommended that additional, more in-depth analyses of this undesirable result need to be conducted to ensure that current basin conditions and appropriate management actions are adequately addressed in the up-coming Colusa Subbasin Groundwater Sustainability Plan(s). The plan(s) are due to DWR in 2022.

To assist in data gathering and analysis, DWR will be coordinating the GPS resurvey of the Sacramento Valley to take place in spring 2017. This will encompass the entire Sacramento valley including areas of known and unknown subsidence has occurred since 2008. From that data, we will be able to determine the amount, the extent (as much as possible), and the annual rate of change of land subsidence.

Additionally, the continued adaption of remote sensing mapping of elevation changes will enable more frequent analysis of this basin and all other basins throughout the State. A formal presentation of the results will be provided by DWR to the Colusa County Board of Supervisors as early as September 20, 2016. Prior to the presentation, DWR will be presenting the results at the Colusa County Water Commission meeting on September 8, 2016.

If you have any questions or need additional information, please contact me at (530) 528-7403, or Roy Hull, Engineering Geologist, at (530) 529-7337.

Sincerely,

A handwritten signature in blue ink, appearing to read 'W. Ehorn', with a stylized flourish at the end.

William Ehorn, Chief
Regional Planning Branch