KG16-0313

January 29, 2020

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Re: Mapping of latitudinal limits of Ventura River flow, Upper Ventura River Groundwater Basin, Ventura County, California

Greetings Bryan:

Kear Groundwater (KG) has prepared this summary of surface water-groundwater interface mapping activities in the Upper Ventura River in accordance with our Master Service Agreement (MSA) with the Upper Ventura River Groundwater Agency (UVRGA) and Work Order No. 6. The monitoring activities described in this letter contribute to Sustainable Groundwater Planning Grant (Grant) Task 3 (Surface Water – Groundwater Interface Monitoring), with the objective to fill data gaps, including improved characterization of the hydrogeologic conditions to serve groundwater planning and management activities.

As with many watersheds in arid and tectonically active regions, the Ventura River Watershed exhibits a very dynamic and mobile, ephemeral and intermittent network of streams. Surface flow from most streams exit the headwaters and infiltrate into the subsurface as the streams enter the groundwater basins, namely the Ojai Basin and the Upper Ventura River Groundwater Basin. Given the cobbly and bouldery substrate of the river beds, gauging the flow is difficult except for where bridges or impoundments exist and have created an engineered river bottom of planar concrete. A network of gages exists at many bridge locations, but these are at areas where flow is often absent while the live/continuous reaches flow over areas where measuring the flow can be difficult and inaccurate due to the mobile river bed gravels.

To accommodate this phenomenon, KG and other researchers have been monitoring the southern edges of surface flow on the losing reaches and the northern edges of surface flow on the gaining reaches, as well as limits of intermittent flow, in this generally north-to-south flowing system. Since the spring of 2018, KG has conducted this mapping on as frequently as a weekly basis using GPS tools, developing a long-term database (data are summarized in Table 1). By correlating the latitudes of the daylighting groundwater with measured flow, the latitudes can be used as a rating-shifted proxy for river and stream flow, without the uncertainty of measurements in the mobile substrate. Unique to each stream system, such a network can be used to graph the relationship between flow components and simplify the flow model of the stream system and interacting groundwater.

Table 1: Summary of Observed Latitudinal Limits of Ventura River Flow, 2018 - 2019				
Observation Date	**South End of Northern/Upper Continuous Flow (Latitude, N)**	**North End of Intermittent Flow (Latitude, N)**	**North End of Southern/Lower Continuous Flow (Latitude, N)**	**Notes**
1/1/18				continuous flow
5/16/18				continuous flow
5/28/18	*34.41200*	*34.41000*	*34.40900*	first intermittent observed
6/5/18	34.42662	34.39000	34.38412	intermittent
7/9/18	34.44300	*34.38800*	*34.38350*	intermittent
8/4/18	*34.45000*	*34.38600*	*34.38300*	intermittent assumed
8/10/18	***34.45687***	*34.38500*	*34.38200*	intermittent
8/17/18	*34.45500*	34.38411	34.38156	intermittent
8/20/18	***34.45463***	*34.38400*	*34.38150*	intermittent assumed
8/24/18	***34.45548***	34.38397	34.38147	intermittent
9/10/18	***34.45520***	*34.38280*	*34.38100*	intermittent assumed
9/28/18	***34.45922***	*34.38110*	*34.38000*	intermittent assumed
10/13/18	*34.44000*	34.38082	34.37986	intermittent
11/9/18	*34.43000*	34.38070	34.37988	intermittent
12/8/18	34.42662	34.38086	34.37986	intermittent
1/7/19	34.42662	*34.38000*	*34.38000*	no intermittent
1/8/19				USGS data indicate continuous
1/30/19				first continuous flow observed
3/15/19				continuous flow
4/18/19				continuous flow
7/5/19				continuous flow
7/19/19				continuous flow
8/22/19				continuous flow
9/4/19	34.41468	34.39900	34.39300	first intermittent
9/13/19	34.41600	34.39297	34.39297	no intermittent
9/21/19	*34.41800*	34.39296	34.39296	no intermittent
9/27/19	34.41691	34.39428	34.39428	no intermittent
10/4/19	*34.41900*	34.39148	34.39148	no intermittent
10/12/19	34.42255	34.39172	34.39103	intermittent
10/18/19	34.41687	34.39168	34.38752	intermittent
10/25/19	34.42525	*34.38990*	34.38748	intermittent assumed
10/31/19	34.42345	*34.38800*	34.38430	intermittent assumed
11/8/19	34.42061	34.38743	34.38429	intermittent
11/15/19	34.42061	34.38721	34.38402	intermittent
11/22/19	34.42024	34.38723	34.38408	intermittent
11/29/19	34.41177	34.40059	34.38395	intermittent
12/6/19				first continuous flow
12/20/19				continuous flow

All data points collected by Kear Groundwater staff, except:

- ***Bold and italics: Data from Meiners Oaks Water District;***
- *Italicized (absent bold) indicates data calculated or inferred*

Flow Mapping Methods

From project inception in spring 2018, KG has mapped the latitude and longitude of as many as four points on the weekly (generally) reconnaissance visits to the Ventura River:

1. **South End of Northern Continuous/Losing Flow Latitude:** The point of complete infiltration of the surface flow at the south end of the northern reach, flow is continuous but losing (recharges groundwater) from the headwaters to this point at any given time.

2. **North End of Intermittent Flow Latitude:** The northernmost first point of intermittent surface flow, typically approaching the southern continuous reach area. This is typically daylighting groundwater (generally summer and fall periods) or shorter-lived ponded surface flow remnant from previous continuous flow regimes (generally late winter to early summer periods).

3. The south end of intermittent flow (if present, not tabulated above).

4. **North End of Southern Continuous/Gaining Flow Latitude:** The north end of continuous and gaining (discharging groundwater) flow in the southern reach, flow typically continues southward from this point beyond the basin boundaries and to the estuary at the Ventura River delta/the Pacific Ocean.

While all latitude and longitude of each of these four points are mapped and digitally recorded, only the latitude is reported in Table 1 for simplicity and the general north-south trend of the Ventura River resulting in a similar longitude for most data points. Additionally, the south end of intermittent flow is omitted from reporting herein due to the general proximity of said data point to north end of continuous flow and the often-overlapping margins of mapping errors (up to approximately 16 ft, depending on GPS hardware and satellite positioning).

KG staff mapped all points using handheld GPS devices, and frequently photographed the points of flow and measured field water quality parameters such as temperature and conductivity. KG collected data in accordance with the UVRGA's Monitoring and Data Collection Protocols (UVRGA, 2018).

Data from other sources, such as MOWD staff mapping (M. Hollebrands, personal communication, 2020), have been incorporated to augment the dataset for 2018.

During and after adequate rains, when the Ventura River flows continuously, KG personnel spot-checked flow at bridges across the reach. Since project inception, continuous flow of the river across the Upper Ventura River Basin has occurred from (1) early January 2018 to late May 2018, (2) early January 2019 to late August 2019, and (3) early December 2019 to present (end January 2020). As flow wanes during the dry seasons, KG increases observation frequency to weekly.

Dawn-to-Dusk Survey

On August 22, 2018, KG personnel stationed markers, GPS points, and temperature and level recording devices in the first pool at the northernmost extent of the southern continuous/gaining reach. Observations of the high-frequency survey indicated nearly imperceptible change in the latitude of the point of daylighting groundwater on the observation date.

Between 7:00 am and 8:15 pm on August 22, 2018, KG personnel visually monitored the daylighting surface water at ten-minute intervals, and used a stationary, bottom-set Solinst Levelogger device to record the water level in a pool immediately downstream of the daylighting location. Water level data from the Levelogger are a raw pressure reading combining atmospheric and hydrostatic pressure above the logger. KG corrected the data with hourly barometric data from the Oxnard KOXR weather station. Barometric pressure varied by only 0.1 inch during the observation period, so corrected and uncorrected data are similar. The data are presented as a water level relative to the mean value for the measurement period (Figure 1). KG collected two sets of temperature data: the high frequency measurements taken by the Levelogger, and manual measurements at the point of surface water daylighting.

KG observed a very minor yet perceptible decline in water level over the course of the day, but the areal extent of surface water did not perceptibly change. The location of daylighting surface water changed by less than 0.10 ft during the day, which is far smaller than civilian GPS accuracy (up to 16 ft, depending on GPS hardware and satellite positioning).

During the survey, the water level as recorded by the Levelogger varied by less than 0.16 ft. The water level reached a minimum at approximately 6pm, and then began to increase, generally varying inversely with water temperature. Two processes linked to ambient temperature and solar radiation drive this inverse relationship between water temperature and water level. Direct evaporation from the surface water reduces surface water, as does transpiration by plants tapping into the shallow groundwater. The lag time between peak ambient temperature and water level is caused by continued transpiration lowering the water level in the warm early evening. There is also a difference between logger temperature, collected at the bottom of the pool, and warmer "observed" shallower surface points. Air temperature and sunlight affect the "observed" measurements more acutely while pool bottom remains more consistent and would have more of a lag time behind diurnal fluctuations.

KG concludes that at the time of the survey in the southern continuous/gaining reach there is a diurnal pattern of temperature and water level, but the latter is only measurable with high precision equipment. The magnitude of diurnal spatial changes in surface water flow extent are less than 0.10 ft, which is much smaller than the theoretical best-resolution of Garmin GPS devices. KG therefore concludes that the time of day is not significant for weekly monitoring site visits to the point of daylighting water in the southern reach.

Flow Mapping Results

KG presents results from mapping activities in Table 1 and Figures 2/2A and 3. We have developed unique graphical methods to represent and interpret flow regime dynamics. Due to the essentially north-south trend of Upper Ventura River, two- and one-dimensional depictions of flow regimes (Figures 2/2A and 3, respectively) can accurately and simply depict the growth of the dry reach and progression of the intermittent stretch throughout the year.

Figures 2 and 2A depict a vertically exaggerated river profile for calendar years 2018 and 2019, respectively. Projected above are profiles color-coded to show flow regimes over time, advancing upward with increasing time. Continuous flow (blue), range of intermittent flow (green), and the dry reach (red) changed positions over repeated observations. Each profile line represents a single observation event, and the stacked profiled are scaled temporally, showing more frequent observations during critical periods. These figures graphically illuminate seasonally variable flow dynamics, for example: the effect of increased precipitation in 2019 vs. 2018, resulting in smaller mapped dry reaches and approximately four months more continuous flow in calendar year 2019 (nine months continuous flow) than in 2018 (five months continuous flow).

Figure 3 depicts a similar time-latitude data presentation, with discrete observations interpolated between points. A vertical line along the y-axis depicts the flow regime from north to south at any point in time (x-axis), with horizontal lines indicating locations of watershed landmarks (*e.g.,* bridges). Figure 3 also includes the recorded rainfall (as daily inches) at the Meiners Oaks County Fire Station gage over the same time duration (plotted on secondary y-axis), located about centrally within the basin. KG was not authorized to monitor the south edge of surface flow and therefore did not regularly measure the southernmost surface flow location in the losing reach until November 2018; however, data available from MOWD staff were used in preparation of the 2018 calendar year data set. At times, thick brush and debris prevented personnel from assessing the exact location of intermittent flow; KG used professional judgment to estimate and record field points when these conditions existed.

Closing

KG welcomes the opportunity to continue developing this valuable dataset. Please do no hesitate to contact us with any questions.

Best Regards,

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Professional Geologist No. 6960
California Certified Hydrogeologist No. 749

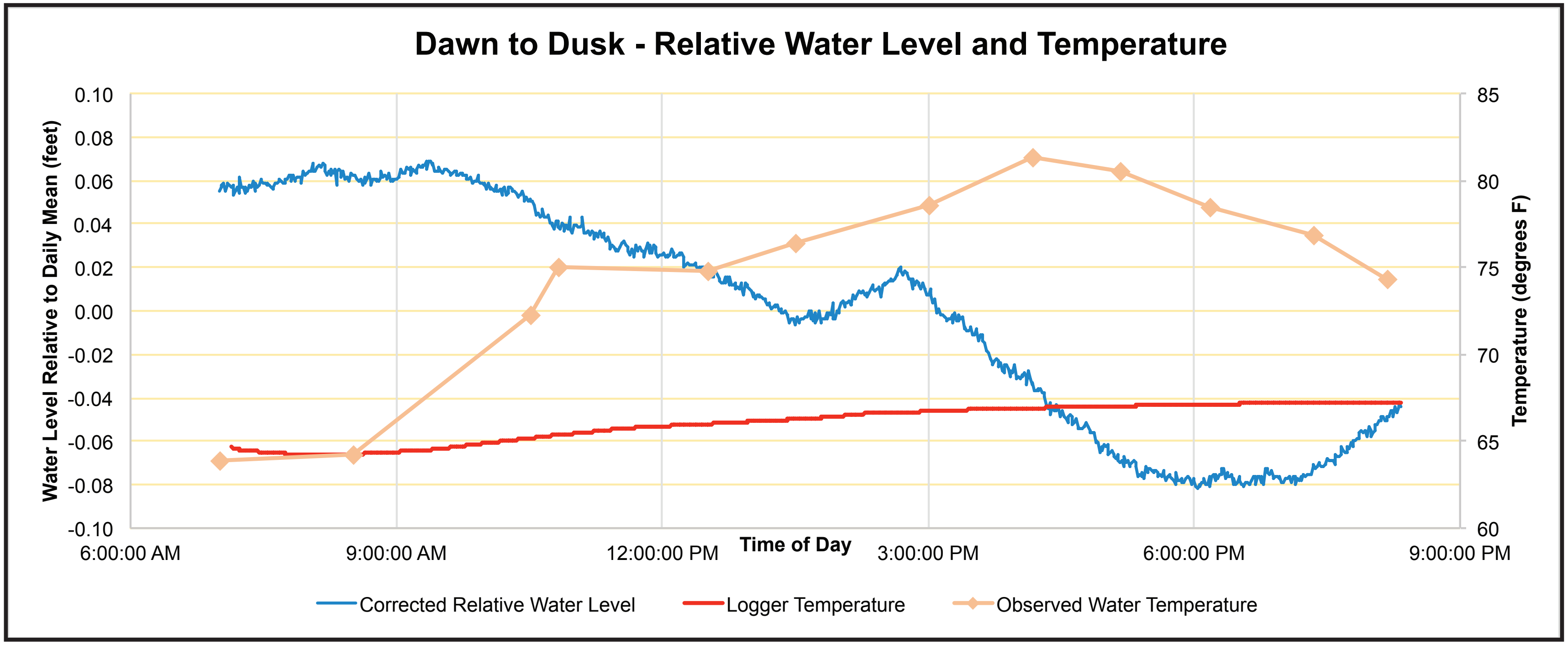
References

Hollebrands, M., 2020. Personal Communication. Leading edge of river 2013 to present. MS Excel file transmitted via email to J. Kear, January 10, 2020.

US Geological Survey, 2020. USGS 11118500 Ventura R near Ventura, available at https://waterdata.usgs.gov/nwis/uv?site_no=11118500 accessed December 11, 2019.

UVRGA, 2018. Monitoring and data collection protocols - Final Draft 5-3-18.

Figure 1. Dawn to dusk survey observations and logger data.



Note: The observed water temperature represents the shallower/first observed daylighted water, but the logger temperature represents that deeper/nearest pool, where cooler and less diurnally-variable temperatures are expected.

Figure 2A. Latitude-elevation time series representation of changes in Ventura River surface flow, 2019 calendar year.

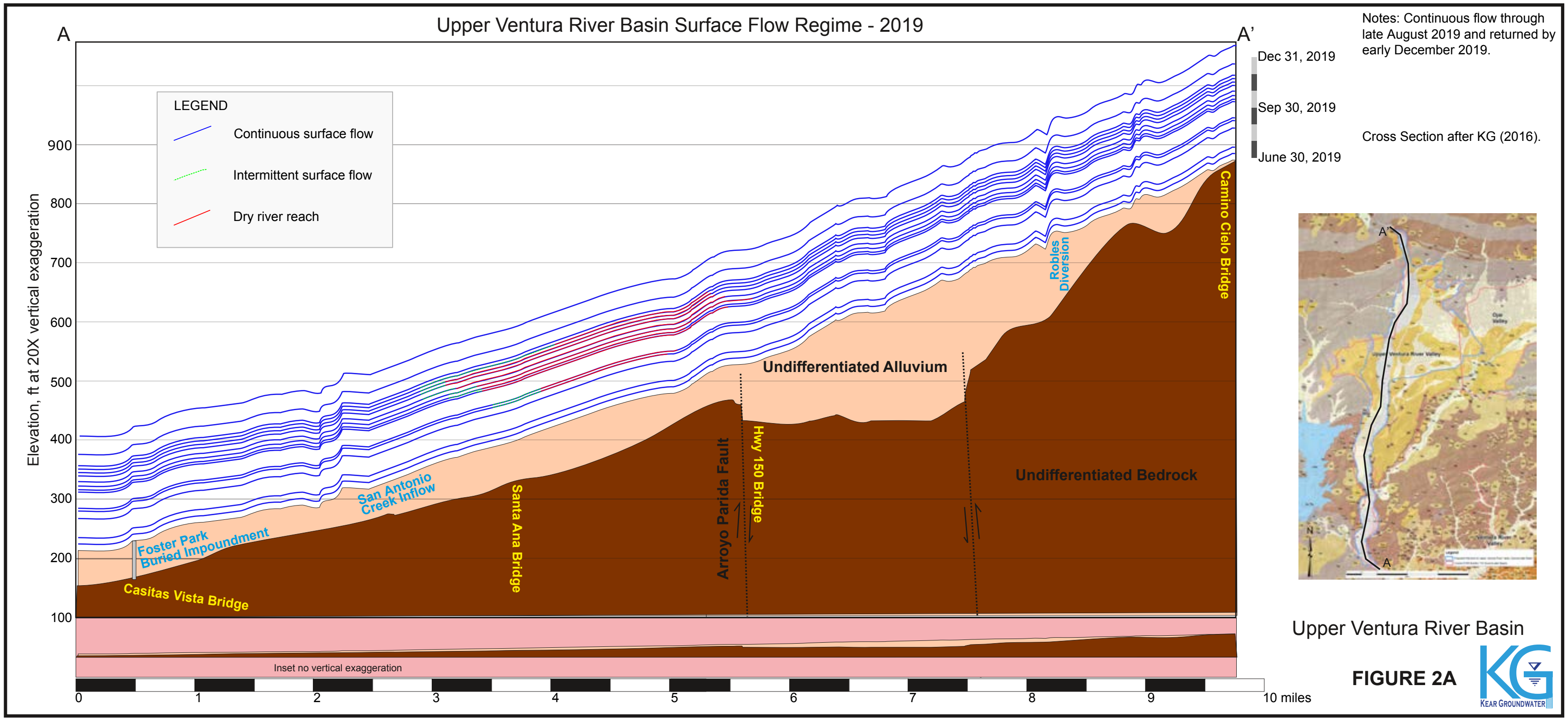


Figure 2. Latitude-elevation time series representation of changes in Ventura River surface flow, 2018 calendar year.

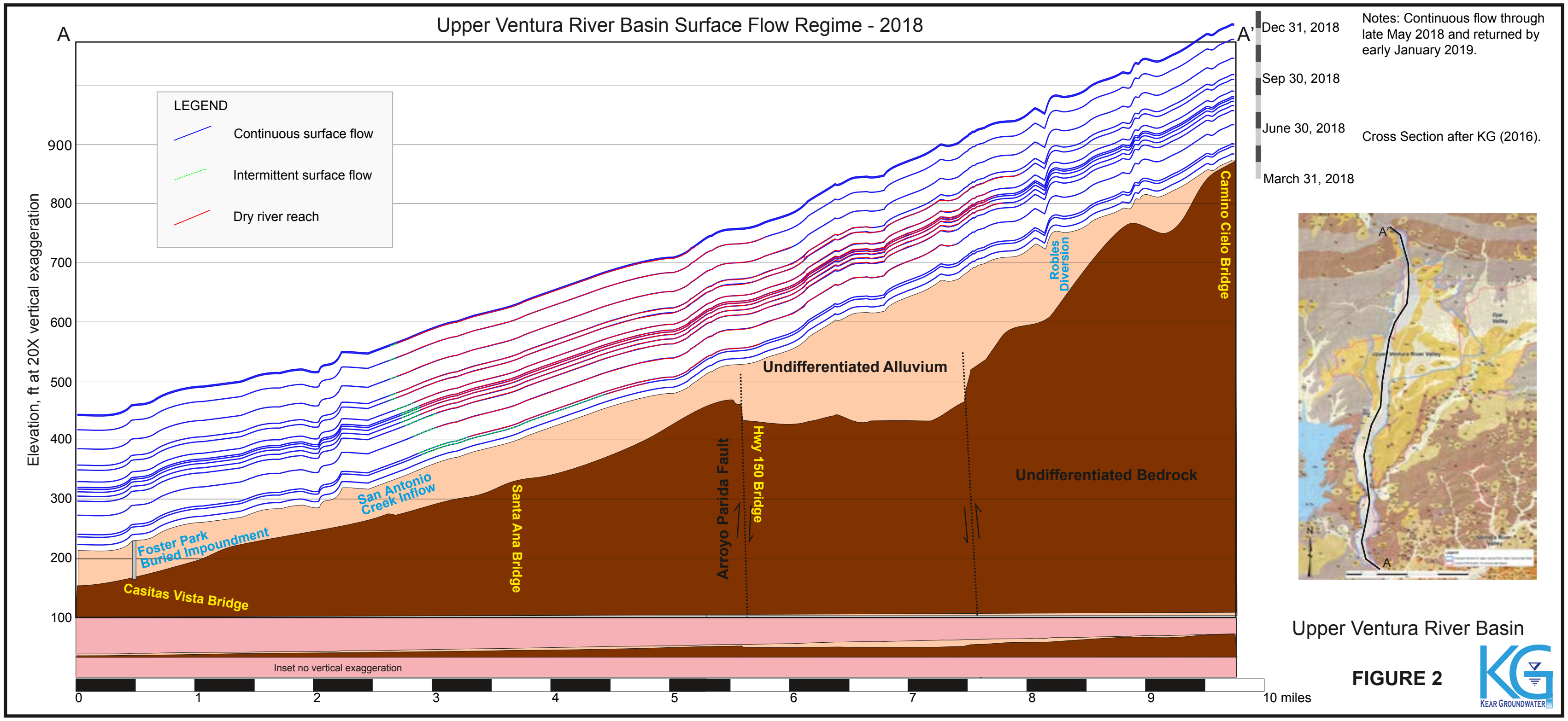


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Figure 3. Time-latitude representation of changes in Ventura River flow regime over 2018 and 2019 vs. daily rainfall at Meiners Oaks County Fire Station gage.