Collaborators:

Funding Agencies:

October 22, 2021

Fillmore and Piru Basins Groundwater Sustainability Agency
PO Box 1110
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Submitted via email: evai@unitedwater.org

Re: Public Comment Letter for the Piru Basin Draft GSP

Dear Eva Ibarra,

We appreciate the opportunity to comment on the Draft Groundwater Sustainability Plan (GSP) for the Piru Basin being prepared under the Sustainable Groundwater Management Act (SGMA). We are a group of academic scientists conducting research on the Santa Clara River (SCR) to understand groundwater dependent ecosystem responses to groundwater elevations and drought. This research is part of a $2.5 million suite of projects that we currently have funded to develop water stress indicators (WSIs) for dryland riparian forest ecosystems threatened by climate change and increasing human water demand.

Based on our review of the Piru Basin Draft GSP, we would like to share some of our key research findings to help improve with the identification and consideration of groundwater-dependent ecosystems (GDEs) in the Piru Basin. The findings below are based on investigation of water stress responses of riparian woodlands during and after the exceptional drought of 2012–2019, as a set of studies focused on different spatial and temporal scales. We coupled tree-ring studies from riparian stands along the Santa Clara River with a basin-scale remote sensing investigation to compare the timing and severity among WSIs, and to explore ecosystem resilience to drought. Below we describe our recent key research findings and their relevance to the Piru Basin Draft GSP.

Key Research Findings

1. **Riparian vegetation die-off during the 2012-2016 drought is linked to groundwater decline.** At the landscape scale, remote sensing of the riparian vegetation showed decreased canopy greenness and increased die-back progressing from 2012 to 2016 as a "brown wave" from the Ventura/Los Angeles county line downstream to the City of Santa Paula. This is shown in the panels in Figure 1 as processed aerial images for individual years between 2011 and 2016, during which swaths of dead vegetation (shown in red) increased in area and progressed downstream. This die-back (loss of green vegetation) is correlated with groundwater table decline across all of the study sites (Figure 2), emphasizing the importance of groundwater support to native deep-rooted riparian trees. This research capturing the landscape-scale impacts of drought on riparian vegetation in this basin has been published as Kibler et al., 2021 in the journal *Environmental Research Letters*

2. **Groundwater decline causes more water stress to riparian vegetation than climatic variables.** Tree-ring analyses confirmed strong reductions in radial growth and in carbon isotope discrimination, which represents prolonged closure of stomata (leaf pores) due to water stress (Figure 3). Together, these responses indicate that severe drought stress occurred within this GDE. We also found that these stress responses in riparian trees were driven more by the rate of groundwater decline than by meteorological variables (e.g., precipitation, air temperature). This analysis also showed that immediately after the drought, during which many trees died in the areas of greatest groundwater decline, the surviving trees showed strong recovery of both growth and leaf function (open stomata) where the groundwater level rose again and stayed within several meters of the surface during the subsequent growing seasons (Figure 3). This suggests a degree of resilience to water stress when groundwater decline is less severe, except at sites subjected to the greatest water stress. This research, led by PhD student Jared Williams and academics at SUNY-ESF and UC Santa Barbara, is currently in preparation for submission to a scientific journal (Williams et al., in prep.).

3. **Native cottonwood and willow trees are groundwater-dependent species that rely on constant root access to groundwater for survival and growth, especially during dry summer months and in drought years.** These trees comprise the greatest proportion of vegetative cover in riparian forests along the SCR. Research on the same species in other dryland regions suggests that groundwater is also used for evaporative cooling of the tree canopy to mitigate heat stress. Native cottonwood and willow trees are also essential for maintaining healthy river ecology by maintaining good water quality in stream, and supplying forage and habitat for critical status species such as steelhead (*Oncorhynchus mykiss)* and Least Bell's Vireo (*Vireo bellii pusillus)*. During the summer months, when this access to a perennial water source is most critical, groundwater levels are in decline in the SCR, which poses the risk of tree rooting systems becoming disconnected from groundwater-derived moisture. As a result, ***groundwater pumping during the summer can exacerbate the existing seasonal drought stress experienced by these Mediterranean-climate woodlands.***

4. **The rate of groundwater level decline is as important to riparian vegetation as the absolute depth below which their roots completely lose access to the water table ("critical water depth").** Our research shows that both the absolute groundwater level and the rate of groundwater table decline have a strong effect on the function, health and survival of GDE tree species. Both Kibler et al. (2021) and Williams et al. (in prep) indicate that ***when the water table declines below a depth of 4-6 m***

below the surface, riparian trees demonstrate pronounced reductions in canopy greenness and growth, and increases in dead vegetation (Figures 1 and 2). Prior to that point however, a high rate of groundwater decline reduces the physiological functioning of the trees (Figure 3), imposing strong physiological stress that makes them vulnerable to cavitation (formation of air bubbles in the xylem, which kills them) and to attack by insects, pests and other risk factors. Often the reported maximum rooting depth for species is not realized under field conditions, because mature trees are adapted to the local groundwater depth and dynamic hydrological regime under which they developed. Even shallowly-rooted trees can become stressed when the groundwater drops more quickly than they have the capacity to adapt to, and it typically takes years -- if it is possible at all -- for trees to grow deeper roots, even for highly adaptable species. ***Therefore these two factors, absolute groundwater depth and groundwater decline rate, should be factored into GSP guidelines to support groundwater-dependent tree species.***

5. **The installation of more shallow monitoring wells is needed to support ongoing efforts to understand the ecohydrological links between groundwater and riparian forests along the SCR.** There is substantial spatial and temporal variability in groundwater elevations across both space and time; groundwater conditions are not homogenous across the basin. It is therefore important to select wells carefully to monitor the groundwater conditions within any GDE of interest, because nearby wells may not accurately capture local groundwater dynamics. Shallow groundwater wells are much less numerous currently within the SCR corridor and in the location of important GDEs than are deep production wells.

Thank you for considering our latest research findings and comments as you finalize the GSP.

Sincerely,

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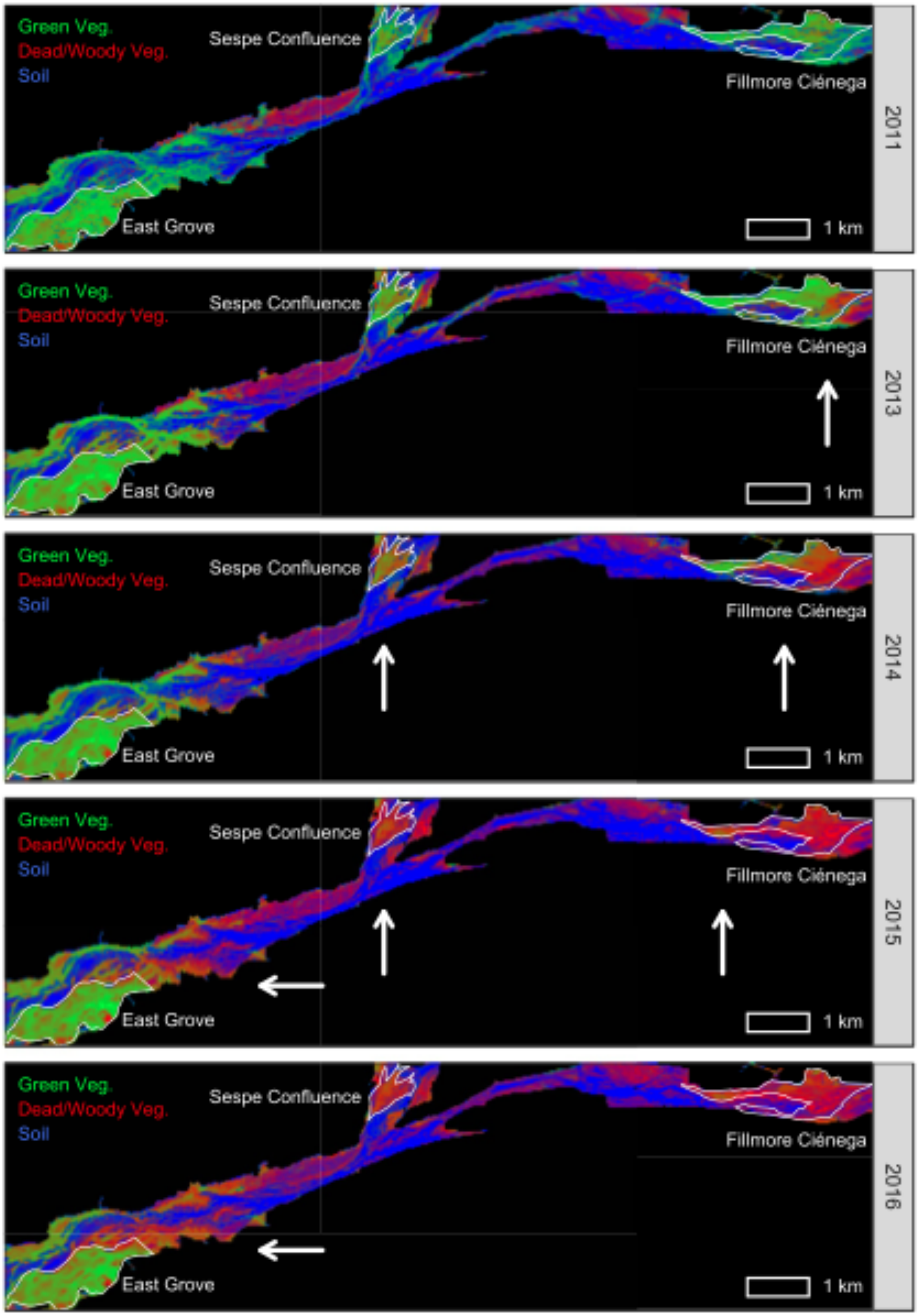

Figure 1. Processed remote imagery in part A (from [Kibler et al., 2021]) shows a "brown wave" of vegetation mortality during the drought progressing right to left, from Fillmore Cienaga downstream to East Grove (figure). Stacked panels show individual years from 2011 to 2016. Live and dead vegetation fractions are shown in green and red, respectively.

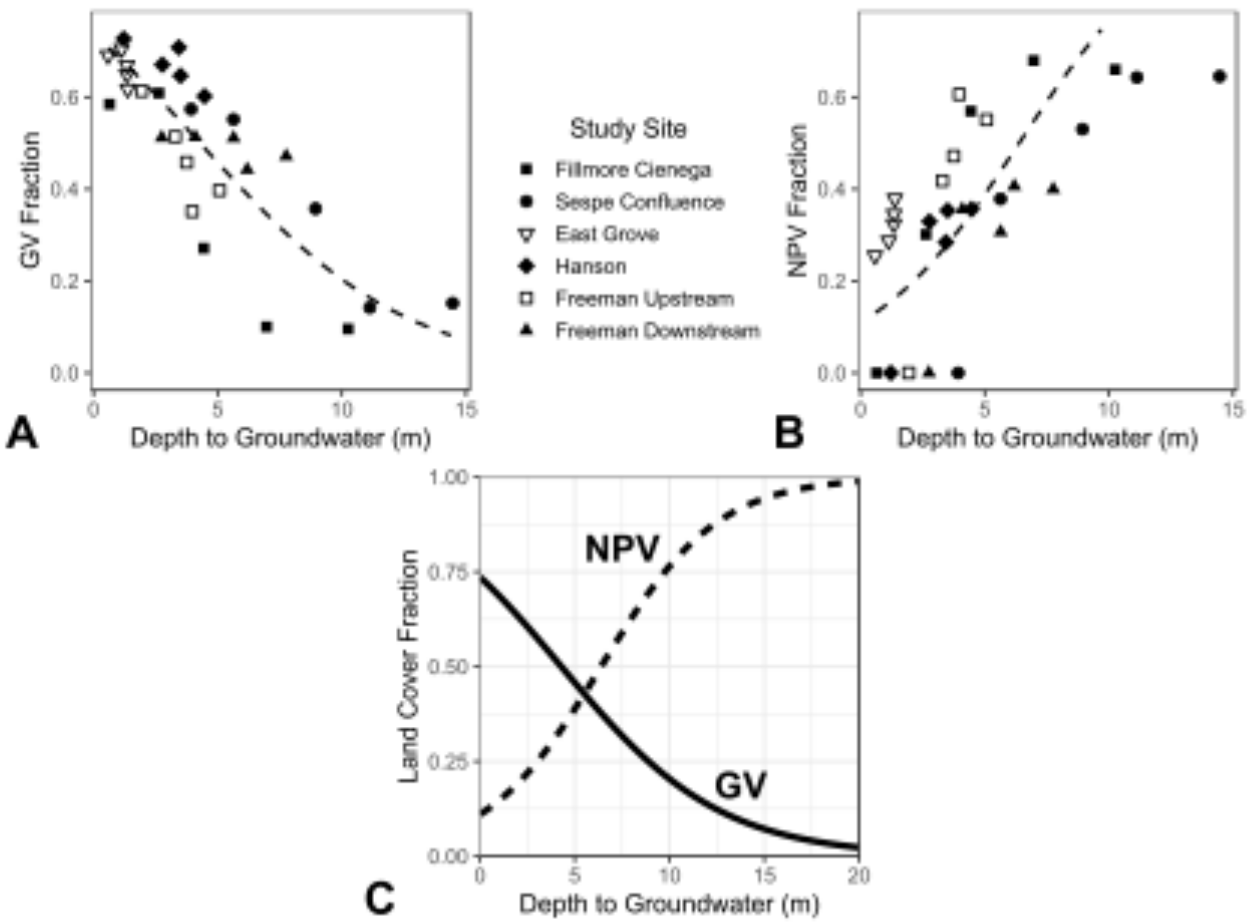

Figure 2. Plots showing the influence of groundwater depth on riparian woodland canopy health along the Santa Clara River before and during the 2012-2019 drought. The data are from Kibler et al., 2021 in the journal *Environmental Research Letters*. Panel A shows the land area fractions of healthy green vegetation (GV) as a function of groundwater depth across six sites along the SCR. Panel B shows the fraction of non-photosynthetic vegetation (NPV) with groundwater depth at the same sites, indicating that the amount of canopy die-back increased as the groundwater level dropped. Panel C shows statistical models for GV and NPV based on the same data.

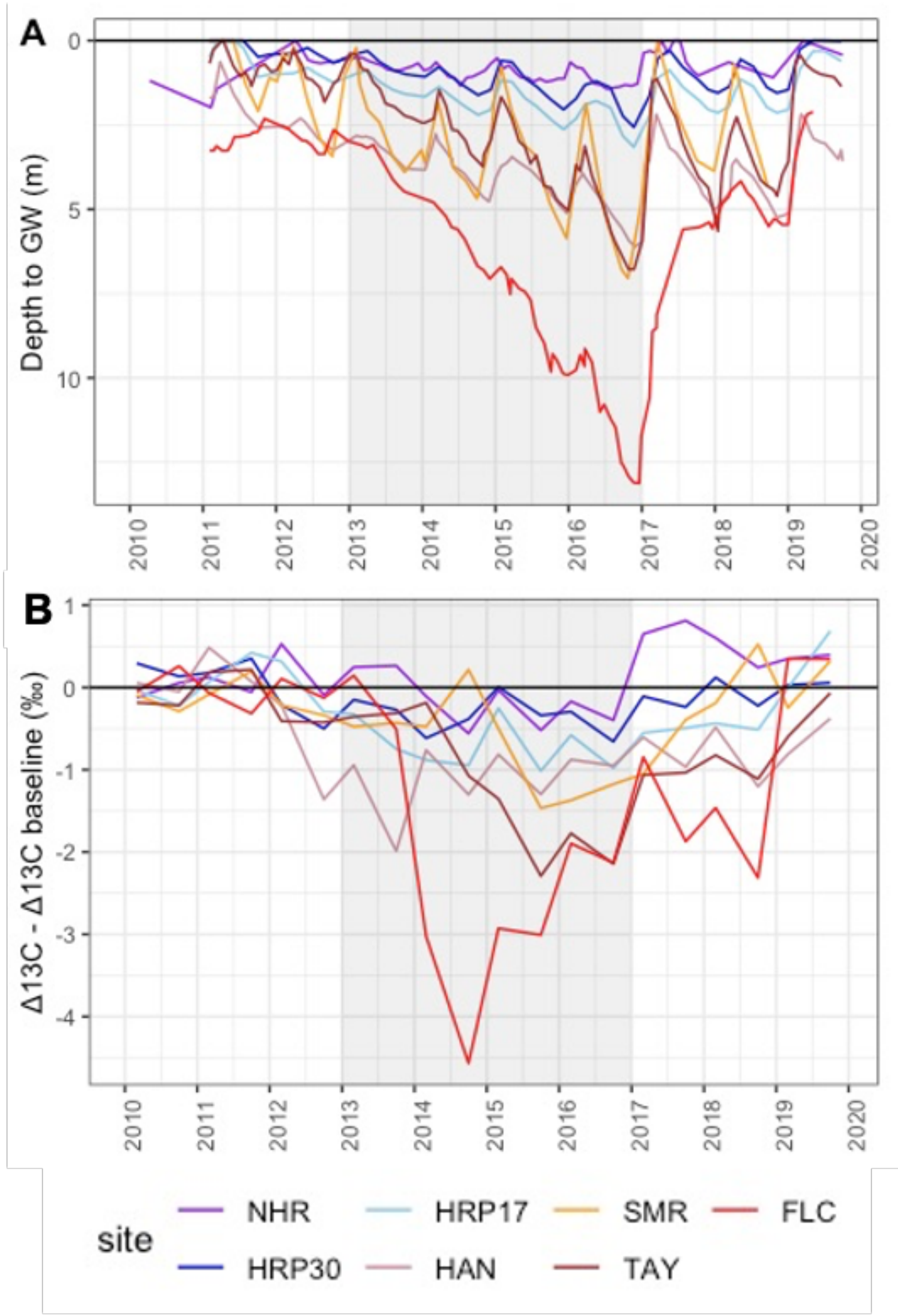

Figure 3. Line graphs from J. Williams, in prep.) showing the change in depth to groundwater at seven sites along the river (Panel A), and the change in physiological function of the trees over the same period based on tree ring stable isotopes of carbon (Panel B). More negative changes in the isotope values reflect greater water stress and a stronger response by trees. Shaded areas in both panels indicate the peak drought period of 2013-2016. Sites listed in downstream order are as follows: Newhall Ranch (NHR), Fillmore Cienaga (FLC), Taylor (TAY), South Mountain Road (DMR), Hedrick Range Lower (HRL), Hedrick Range Upper (HRU), and Hanson (HAN).