Rainfall to Groundwater

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Santa Clara Valley Water District (Valley Water)
transmitted via email to: PachecoExpansion@valleywater.org

Comments re: Pacheco Reservoir Expansion Project Draft Environmental Impact Report (DEIR); State Clearinghouse # 2017082020

Dear Valley Water representatives,

I sincerely invite Santa Clara Valley Water District to **consider an alternative** to the proposed project and proposed alternatives that is not under your current consideration. In fact, I've been inviting Valley Water to consider this alternative for four years now, in that your GSA contact person has been on my Rainfall to Groundwater email list since I began it in January 2018. I added to my list all GSA contact persons for GSAs that would most likely benefit from the Rainfall to Groundwater approach. I send alerts to those on my email list each time I post a new blog entry. My first post was Jan. 26, 2018 and there have been twelve posts to date.

I perhaps foolishly imagined that Groundwater Sustainability Agencies (GSAs) would want to learn about an approach to **natural recharge** that has the potential to **recharge far more groundwater at far less cost** than can ever be done by the various Managed Aquifer Recharge (MAR) schemes, which I know Valley Water has been doing for many decades now. Furthermore, it is an approach that will yield increasingly greater benefits, while requiring increasingly fewer human inputs, over time.

Your GSA contact person was also among a baker's dozen GSA contact persons I selected to send hard copy letters to by U.S. Mail, thinking that might be a better way to reach y'all I retain a copy of that letter, dated April 12, 2018, and will share it with you upon your request (since it contains my email address I prefer not to have that be revealed in a public document). An excerpt from that letter:

> Given that it serves a region of innovation, I hope that SCVWD will extend that innovation to an as yet novel approach to recharge. That is, restoring detention functions to watershed areas that have been degraded through historical land uses. These are areas now dominated by nonnative annual grasslands – the rangelands, including many that lie within state and county parks in Santa Clara County.

Let that excerpt serve as an introduction to my proposed alternative Rainfall to Groundwater approach – one that you could have considered and evaluated four years ago. I regret that I did not interact with Valley Water earlier in your DEIR process to propose that alternative sooner, but since I no longer live in your service area and furthermore, greatly prefer staying in proactive, rather than reactive mode, I just haven't had the "bandwidth" to cover public processes like this. But it does appear that commenting here may be the best, if not only, way to get your attention to my proposed alternative approach.

I offer a summary introduction to the Rainfall to Groundwater approach on my website and you may download the Rainfall to Groundwater Executive Summary at that link. An email address is required to download the executive summary, but you already have a person on staff who remains on my email list so you actually don't even need to get another on my email list in order to download, as you may choose. The R2G Executive Summary offers an overview, including contextual links to pertinent topics on the website and I consider that and my entire website incorporated by reference into my comments herein.

As noted in my letter excerpt above, Rainfall to Groundwater is about restoring catchment (a.k.a. watershed) functions to permit greater natural infiltration and percolation, or recharge to groundwater, than is rendered where catchment functions have been degraded through historical land uses dating back at least to European colonization, if not before with certain indigenous land management practices. The central recognition is that, throughout human history and over most of the world, there has been an unwitting tendency to degrade catchment functions in the process of procuring our livelihoods.

Also essential is recognizing that retention is not the only viable form of water storage, as suggested by my page, Retention vs Detention Storage.

With currently increasing awareness of how catchments function, along with the emergence of ecohydrology coincident with this new century and millennium, and with the stark evidence of ongoing anthropogenic climate change smacking us in the face anew with each new year, doesn't it seem time to begin considering new, nature based solutions to our water resources challenges?

The most spatially expansive focus of Rainfall to Groundwater consists of the nonnative annual grasslands that predominate on low to mid- elevation lands in Central and Northern California. With relatively shallow root systems compared with native counterparts and moreover, given their annual lifeways – soaking up lots of water during the wet season, then dying as it ends – they necessarily support less complex soil ecosystems than do native perennial plant species.

But along with the displacement of native biodiversity in general by these alien invaders, there has been an overall loss of woody species, including native oaks and shrub species whose rooting habits, dead and alive, confer significant hydrological connectivity between the land surface and fractured bedrock aquifers, along with the vadose (unsaturated) soil zone through which they course.

The combination of such woody root systems along with the metabolic products of soil microbial ecosystems serves to structure the vadose zone and create pathways for preferential flow from the land surface to those bedrock aquifers, as well as laterally through the vadose zone to feed streams, vernal pools and other wetlands.

I wish I could count on not needing to inform Valley Water, How Does Groundwater Get There? but my suspicion is that the District has been doing MAR so long that your agency has either forgotten about or overlooked potential opportunities for enhancing **natural recharge**. I must trust Valley Water to understand that all but approximately 2% of global groundwater is headed toward – that is, drawn by gravity toward – a surface water outlet Thus, especially given California's geology and seismicity, bedrock aquifers are clearly the greatest source of natural recharge draining to the alluvial aquifers that get the most attention regarding water resource concerns.

Continuity of tree roots with bedrock aquifers has been brought to recent attention by the following publication:

McCormick, E. L., D. N. Dralle, W. J. Hahm, A. K. Tune, L. M. Schmidt, K. D. Chadwick, and D. M. Rempe. 2021. Widespread woody plant use of water stored in bedrock. *Nature* 597:225–229. https://doi.org/10.1038/s41586-021-03761-3
https://assets.researchsquare.com/files/rs-138459/v1_stamped.pdf?c=1610662325

[Note that, to facilitate review by all, where applicable I will provide herein URLs for free downloads of literature I'm citing here, as is the case for the second URL, above.]

Presumably because the data was not accessible by McCormick and colleagues, they missed this early source:

Lewis, D. C. and R. H. Burgy. 1964. The relationship between oak tree roots and groundwater in fractured rock as determined by tritium tracing. *Journal of Geophysical Research* 69:2579-2588.
https://doi.org/https://doi.org/10.1029/JZ069i012p02579
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/JZ069i012p02579

In any case, attitudes about human/ plant relationships have changed in the intervening nearly six decades.

A few excerpts from McCormick and colleagues (2021) are appropriate here:

> Abstract [with endnotes omitted]:
>
> In the past several decades, field studies have shown that woody plants can access substantial volumes of water from the pores and fractures of bedrock. If, like soil moisture, bedrock water storage serves as an important source of plant-available water, then conceptual paradigms regarding water and carbon cycling may need to be revised to incorporate bedrock properties and

> processes. Here we present a lower-bound estimate of the contribution of bedrock water storage to transpiration across the continental United States using distributed, publicly available datasets. Temporal and spatial patterns of bedrock water use across the continental United States indicate that woody plants extensively access bedrock water for transpiration. Plants across diverse climates and biomes access bedrock water routinely and not just during extreme drought conditions. On an annual basis in California, the volumes of bedrock water transpiration exceed the volumes of water stored in human-made reservoirs, and woody vegetation that accesses bedrock water accounts for over 50% of the aboveground carbon stocks in the state. Our findings indicate that plants commonly access rock moisture, as opposed to groundwater, from bedrock and that, like soil moisture, rock moisture is a critical component of terrestrial water and carbon cycling.

Other germane excerpts [with endnotes omitted]:

> … The circulation of near-surface water by plant roots has consequences for a large number of Earth-system processes, including landscape evolution, ecosystem carbon storage and nutrient delivery to streams. …
>
> … For example, our deficit analysis suggests that in California alone, 20 km^3 (16.2 million acre-feet) of water can be extracted from bedrock by woody plants annually. This is approximately equal to the volume of water stored in all of the state’s reservoirs combined, and about three times the state’s annual domestic water use. …
>
> Given that the dynamics of rock moisture have the potential to regulate the timing of groundwater recharge and runoff, bedrock water storage may be critical to water resource planning. …
>
> Thus, bedrock water storage dynamics are likely key to understanding the sensitivity of carbon, water and latent heat fluxes to changes in climate.
>
> (McCormick and colleagues 2021)

I can imagine how some readers might respond to this news – perhaps not too dissimilarly to Lewis and Burgy’s (1964) response to the results of their research that showed that blue oaks are absolutely accessing bedrock moisture, in the following excerpt from their Conclusions:

> To the hydrologist, who studies the occurrence and distribution of water, the trees are analogous to a number of pumps spread uniformly over an area, all operating to depress the water table. In the situation which has been studied, soil moisture sampling cannot measure summer transpiration by trees. Furthermore, the analogy helps to explain the mechanism of response to treatment in watershed management programs which include killing or removal of oak trees. When the direct transpiration of groundwater is eliminated (the pumps are permanently removed), groundwater levels will rise and be maintained at higher levels by natural recharge.
>
> (Lewis and Burgy 1964)

That interpretation of their data exemplifies their time – the mid-20th century view of trees as water "thieves". This paradigm inspired a century of "experiments" to show how removing trees would yield more water. It was essentially a case of mass "hallucination" or confirmation bias. And some among us have still not let go of that antiquated perspective.

While it was true that cutting forests in particular would often lead to temporary increases in streamflow, those increases were quite short-lived and furthermore, the increases in water yield often amounted to early-season flooding and related erosional impacts, especially in the western U.S. For more on that Alternate Paradigm, please refer to my page "Water Yield" vs Baseflow Augmentation along with Plants in an Ecohydrology Context.

But the paradigm was extended to southwestern U.S. shrublands, where large expanses were chained, simultaneous with California Division (later Department) of Forestry supported efforts on our state's oak-studded private rangelands, as detailed in my blog post # 6. Ball and Chain & Other Links. For specific acreages treated in Santa Clara and San Benito Counties, please refer to the CDF references I cited there.

It must be recognized that this is among the few instances wherein removal of woody species on California rangelands was even documented at all, especially acreage by county. I have found one earlier documentation of acres subjected to intentional or accidental anthropogenic fire in the state, but in that case it lumps the total statewide acreage.

We know that the Spanish used fire to extend their grazing lands on the Central Coast, based on several references I've seen. Similar practices extended into the Mexican and Anglo periods, as detailed in the following source:

Greenlee, J. M. and J. H. Langenheim. 1990. Historic fire regimes and their relation to vegetation patterns in the Monterey Bay area of California. *American Midland Naturalist* 124:239-253.

And we know that indigenous people in the region of the proposed project used burning as a land management tool, as documented by Fray Crespi in the following text:

Crespí, J. 2001. *A description of distant roads: original journals of the first expedition into California, 1769-1770. Edited and translated by Allan K. Brown.* San Diego State University Press.

I offer a small selection of other sources on indigenous Californian use of fire and other land management tools on my blog post 4. Think Outside the Basin.

Throughout human history on the Central Coast and California in general, native oaks provided fuel – in the form of firewood and charcoal. Oak and madrone remain the prized hot-burning firewood for many in the state. Such incremental consumption only added to the removal of trees through accidental and intentional anthropogenic fire. That we yet have oak woodlands at all is doubtless owed to the fact that they were found mostly unsuitable as lumber.

That this woody plant removal enthusiasm was a temporal paradigm is demonstrated by contrasting viewpoints expressed only a few decades earlier in excerpts from a 1908 statement by H. A. Jastro, President of the American National

Live Stock Association, shared on my blog post 3. How Watersheds Relate to Groundwater.

So what was lost in the process of removing woody plants from rangelands? That hydrological connectivity from land surface to bedrock aquifers. While some of that connectivity may be due to flow along the exterior of roots tapping bedrock moisture, documented instances of preferential flow have been primarily associated with macropores that are typically formed by decomposing root matter and the organochemical byproducts of its microbial decomposition, along with the soil structure itself, which is mediated by the interaction/ ecology of plant roots and soil microorganisms.

One type of microbially derived compound we know about is referred to as glomalin or glomalin-related soil protein, a soil protein class associated with mycorrhizas, that is apparently the primary "glue" responsible for soil aggregation. Encouraging development of this compound in soil may be key to accelerating long-term soil carbon sequestration, as noted on my Ecohydrological Economics page, Carbon Farming & Watershed Restoration. Since glomalin is produced by mycorrhizas, its proliferation is dependent on reestablishing perennial plant species to rangelands and that is among the chief scientific rationales for the California Dept. of Agriculture's Healthy Soils Program, which is supported by cap-and-trade. That program includes incentive funding for silvopasture that could essentially meet the goals of Rainfall to Groundwater.

But the state's Healthy Soils Program is focused on carbon sequestration, not on catchment restoration, so projects are implemented without considering any strategic planning for catchment functions at this point. In order to ensure such benefits, my take is that water users will pay for restoration of catchment functions once they understand the benefits and especially once they understand the cost differential between this nature based approach and hard, engineered retention projects like the proposed Pacheco Reservoir Expansion.

Getting back to macropores and their role in preferential flow I will note that I amassed the support of numerous scientific literature references with respect to both preferential flow and macropores in my doctoral dissertation, abstract attached to this comment letter:

Jigour, V. M. 2008 (2011). *Watershed restoration for baseflow augmentation*. Doctoral dissertation. Interdisciplinary Studies: Arts & Sciences: Conservation Ecology. Union Institute & University.

Since completing that dissertation significantly more literature support has been published and I keep track of it all to the best of my ability. But here I'll just cite two references by the same seminal authors, one included in my dissertation and one that came after.

Beven, K. and P. Germann. 1982. Macropores and water flow in soils. *Water Resources Research* 18 (5):1311-1325.

Beven, K. and P. Germann. 2013. Macropores and water flow in soils revisited *Water Resources Research* 49:3071–3092. https://doi.org/10.1002/wrcr.20156

The second article is open access, I believe. I trust that the preceding citations, along with the material on the Rainfall to Groundwater website (many citations included there also) and in the R2G Executive Summary, serve to at least introduce the hydrological aspects of this alternative approach. Of course I will happily share more information with Valley Water upon your request.

As you will see from my dissertation abstract, the original impetus and inspiration for Watershed Restoration for Baseflow Augmentation, now framed as Rainfall to Groundwater, was analyses performed on a GIS database I developed of historical California steelhead streams and watersheds south of San Francisco Bay, extending from the greater SF Bay Area southward to San Diego County. I conceived and developed that database at the UCSC GIS Lab, with technical support and even a bit of volunteer support with the digitizing, based on a table and non-digitized maps in the following document:

Titus, R. G., D. C. Erman, and W. M. Snider. 1999 in preparation. *History and status of steelhead in California coastal drainages south of San Francisco Bay*. California Department of Fish and Game, Sacramento, California, USA.

This was my primary contribution to the local regional Wildlands Project, for which funding was routed through California Wilderness Coalition. I developed the proposal for our Central Coast regional project, which was first in the state to succeed in getting funded. I also served as project fiscal sponsor and manager for the initial round of funding. We did produce interim reports that were not widely circulated, given an expected second round of funding. When that second round of funds became available I could no longer spare time from my doctoral work and professional consulting to do more than complete the work on the steelhead database, analyses and report. Our final report, below, included some maps from the steelhead database and corresponding discussion, but the results of the analyses were only reported in my dissertation.

Thorne, J., D. Cameron, and V. Jigour. 2002. *A guide to wildlands conservation in the central coast region of California*. California Wilderness Coalition, Davis, California, USA.
http://www.elkhornsloughctp.org/uploads/1161026607Central%20Coast%20Report.pdf

So I want to share some of those analysis results that are pertinent to my proposed alternative approach to Valley Water's proposed Pacheco Reservoir Expansion. But first it is appropriate to summarize the benefits to steelhead of this approach.

I was looking for a means to support steelhead habitat connectivity on especially the challenging inland streams like Salinas and Pajaro Rivers. I include among that cohort all the inner Coast Range steelhead streams north of Pajaro, including Coyote and Alameda Creeks, as well as smaller tributaries to the southeastern San Francisco Bay. I realized that, whereas most of the streams with prime steelhead habitat had been obstructed by dams or other constructed barriers, restoring catchment/ detention functions on undammed tributaries could help support hydrological connectivity. Moreover, groundwater contributions to streams bring influxes of naturally cold groundwater – required by all salmonid species to complete their life histories.

While that was the original impetus, I also realized that this is one instance where actions to restore habitat functions for steelhead would also serve water detention functions for human needs – specifically groundwater recharge and reduced flooding, as noted in my dissertation abstract. This reasoning predated SGMA by many years and was clearly, perhaps, still remains ahead of its time.

At the time I conceived the approach, the memory was still fresh in my mind of the decimation of the lower Pajaro River riparian zone prescribed by responsible public agencies as their (ill-suited, IMO) reaction to the 1995 extensive flooding that impacted both the Pajaro and Salinas River valleys. A quick overview of that situation and link to pertinent video documentation of the decimation, after the fact, appears about halfway down this page, Plants in an Ecohydrology Context, below the three illustrations there.

Now I understand that the U.S. Army Corp of Engineers is embarking on its levee project through the Pajaro Valley and I can only sigh that the potential for reducing downstream flood risks by restoring upper watershed/ catchment functions has not been evaluated to date as a cost-effective alternative to costly hard infrastructure.

But, while that example in particular suggests that Rainfall to Groundwater remains ahead of its time, given the water resource challenges that face a growing population under the increasingly evident impacts of anthropogenic climate change, let alone those challenges facing steelhead and other salmonids in California, I feel responsible to keep promoting Rainfall to Groundwater until at least some of you water agencies finally recognize the enormous overlooked opportunities here (or I die, whichever come first).

So, some specifics are in order from one of the tables I created based on the analyses I performed on the steelhead database. Since I don't currently have access to GIS my ability to specify is limited, but the tables do offer some spatial insights. The data I wish to share concerns the spatial extent of nonnative annual grassland in the pertinent counties. FYI, in this analysis I correlated watershed land cover with the conservation status of steelhead on the associated stream/ tributary. While not all status classes appear in the data I'm sharing here, I include them all for context on the next page.

Steelhead Status (adapted from Titus and colleagues 1999):

P Steelhead present currently, any significant change in production from historical levels not discernible based on available information

P- Steelhead present currently, but production reduced or likely so

? Steelhead present historically but current presence/absence not known.

O Obstructed: Given current habitat conditions, the steelhead life history of coastal rainbow trout is no longer supported in the stream. In all cases, viable trout habitat still exists in the system, typically in headwaters areas. These areas support the resident life history of coastal rainbow trout. However, the lack of connectivity between the ocean and these viable spawning and rearing areas, as a result of habitat alterations, no longer allows anadromy to occur and noticeably persist.

N/A Steelhead not present within recent geological history, e.g. due to impassable barrier at stream mouth.

U The historical and contemporary presence of an anadromous steelhead population is unknown to date (this status class added by Matt Stoecker)

Note the areal extent of nonnative annual grasslands, that is, area of lands with anthropogenically degraded catchment functions. Note that these figures are based on the California Natural Diversity Database (CNDDB) land cover classes, as articulated by the following project:

Davis, F. W., D. M. Stoms, A. D. Hollander, K. A. Thomas, P. A. Stine, D. Odion, M. I. Borchert, J. H. Thorne, M. V. Gray, R. E. Walker, K. Warner, and J. Graae. 1998. *The California Gap Analysis Project--Final Report*. University of California, Santa Barbara, California, USA. http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html

Santa Clara County

P- 83,740 acres

? 22,573 acres

o 25,297 acres
131,610 Total acres nonnative annual grassland in Santa Clara County

San Benito County, Pajaro R. watershed

P- 66,696 acres

? 167,258 acres
233,954 Total acres nonnative annual grassland in San Benito County

Stanislaus County, Pajaro R. watershed

P- 3.93 Total acres nonnative annual grassland in Stanislaus County

Merced County, Pajaro R. watershed

P- 5.8 acres

? 11.87 acres
17.67 Total acres nonnative annual grassland in Merced County

So, how may we interpret that in the context of water resources? Realizing that a solid answer to that question might be years in the quest, I opted for the Keep it Simple (Stupid) KISS or Occum's razor approach and estimated a potential increase of one foot of additional detention storage capacity per unit area, so that the number of acres of nonnative annual grassland is equivalent to the number of acre-feet of potential detention storage.

Since we know, especially now, that many woody plant roots and their mycorrhizal associates reach all the way to bedrock aquifers, the potential additional detention storage capacity is much vaster than one might guess intuitively, even with a known depth of the vadose zone. Compare that kind of hydrological connectivity with the depauperate vadose zones beneath nonnative annual grasslands. I offer a graphic depiction of the contrast in the two slides atop the Rainfall to Groundwater Front Page. Those two images also appear in the R2G Executive Summary as Figure 4. Holistic Restoration Concept, on page 14.

Getting back to the spatial extent of nonnative annual grasslands, understand that, in Santa Clara County, the steelhead P- status may apply to watersheds feeding either Coyote Creek or Pajaro River and, without the GIS for reference, they are thus necessarily lumped together. Note that some very small extents of nonnative annual grassland may be associated with P- status San Francisquito Creek, but such instances would be very small in extent, especially compared with the expanses in the Coyote Creek and Pajaro River drainages.

The acreages associated with the “?” steelhead status class are primarily associated with the smaller streams draining through Santa Clara County to the SF Bay, from Matadero Creek southeastward around the bay to Saratoga Creek. The Guadalupe River tributaries, Los Gatos and Alamitos Creeks, are included in the ? status class.

Acreages associated with the o steelhead status class occur primarily upstream of dams, on the Coyote Creek tributaries of San Felipe Creek and the East and Middle Forks of Coyote Creek. One good reason to point out this presence of nonnative annual grasslands upstream of dams is the potential to Expand existing reservoir capacity non-structurally, the topic of my second blog post.

It is much easier to discern geographic locations of the nonnative annual grasslands in San Benito County by steelhead status class. In the original document by Titus and colleagues (1999) San Benito River was assigned a status of N/A. But, given the analyses of land cover correlations I had in mind, I changed it to “?” and, as a matter of fact, several years ago I learned from a solid authority that there is evidence of historical/ prehistoric steelhead presence on lands now occupied by Hollister Hills State Vehicular Recreation Area, which drains to San Benito River. So the acreage of nonnative annual grasslands in the “?” status class in San Benito County lies primarily within the San Benito River watershed/ catchment.

Given the potential detention storage within the San Benito River catchment, there is ample opportunity to support cold flows for steelhead that might venture as far upstream as the state park someday, as well as to detain at least some portion of potential floodwaters and recharge groundwater storage in the process.

If you consider the quite modest estimate of one foot of additional detention storage capacity, applying the Rainfall to Groundwater approach to nonnative annual grasslands in Santa Clara and San Benito Counties the total would exceed the surface storage objectives proposed by all of Valley Water's alternatives.

The Rainfall to Groundwater approach was designed to support steelhead and it is a much more cost effective, moreover reliable, means to achieve all steelhead objectives than the mechanistic scheme proposed by Valley Water.

A Disneyland-Style Steelhead Stream?

Forgive me for repeating the comparison I used in my comments to the California Water Commission on this project, but the comparison is so apt, how can I now use it? I understand that the objective is to operate the dam so as to provide "cold" flows for steelhead at key times during their life history, while reducing overall flows on Pacheco Creek. According to Valley Water's Feasibility Documentation, "under the Project, the expanded reservoir allows for greater controlled releases and optimized reoperation to provide flows to meet SCCC steelhead needs". In other words, this is a Disneyland-style approach to habitat restoration – 'looks good on the surface but is based on a wholly mechanistic, artificial infrastructure that is not to be trusted..

Please just name a reservoir that is truly helping to restore any salmonids in California. They offer big promises but if they had actually delivered on those promises, salmonids would not be in the poor shape they are in today. For a current example, please refer to this paper, published in August:

Willis, A. D., R. A. Peek, and A. L. Rypel. 2021. Classifying California's stream thermal regimes for cold-water conservation. *PLOS One* 16:e0256286. https://doi.org/10.1371/journal.pone.0256286 Please consider the following excerpt from the abstract:

> … Several salient findings emerge from this study. Groundwater-dominated streams are a ubiquitous, but as yet, poorly explored class of thermal regimes. Further, flow regulation below dams imposes serial discontinuities, including artificial thermal regimes on downstream ecosystems. Finally, and contrary to what is often assumed, California reservoirs do not contain sufficient cold-water storage to replicate desirable, reach-scale thermal regimes. …

Those findings are summarized in this blog post:

"Dammed hot: California's regulated streams fail cold-water ecosystems"
Posted on August 29, 2021 by UC Davis Center for Watershed Sciences
by Ann Willis, Ryan Peek, and Andrew L. Rypel
https://californiawaterblog.com/2021/08/29/dammed-hot-californias-regulated-streams-fail-cold-water-ecosystems/

If those much larger dams are incapable of providing the cold flows needed by salmonids, what makes Valley Water assume they can achieve that objective with this significantly smaller reservoir?

Rainfall to Groundwater is the only approach to water resources I've seen to date that addresses the ubiquitous groundwater-dominated streams that the above abstract refers to as a "poorly explored class of thermal regime". Not by me. That's what Rainfall to Groundwater is all about.

And then, consider the history of aquatic species biodiversity in Santa Clara County under the historical management of Valley Water. Your agency has no qualifications to recommend you as "stewards of steelhead". That is why the historical steelhead population on Coyote Creek has apparently met its demise. Witness:

Smith, J. 2018. Fish population sampling In 2017 on Coyote Creek. Pages 48-86 in Comment Letters Received subsequent to the Workshop for the 2018 Triennial Review of the San Francisco Bay Basin Water Quality Control Plan (Basin Plan). Water Boards, CA.

https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/planningtmdls/basinplan/web/docs/Triennial_Review/2018%20Triennial%20Review%20Workshop%20Comments%20Package%205-21-18.pdf

Impacts of Increasing Evaporative Demand on Proposed Project Benefits

Recent evidence indicates that evaporative demand (a.k.a. vapor pressure deficit) is increasing with anthropogenic climate change, as we witnessed to the surprise of all paying attention this year.

California Department of Water Resources (DWR) was caught off guard in overestimating the quantity of snowmelt runoff this year, based on historical correlations. I understand that DWR is working with USGS California Water Science Center on Improving Forecasting for California's Snow Melt Water Supply, but at this point, all bets would appear to be off.

Here's an encapsulation of my understanding of what happened during the first half of 2021. Sierran snowmelt runoff was significantly overestimated this year, based on ***past experience that no longer applies under climate change***. The extra hot air apparently sucked up far more moisture this year than has ever been known. Sure, some of it likely soaked into the parched ground, but there are indications that much evaporated right off the snow surface, including some likely via sublimation, wherein the snow goes directly from a solid into a vaporous state, bypassing the liquid water state.

Following are a few examples of informed observations on this remarkable year that's coming to a close:

Water Year 2021: An Extreme Year – DWR
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Water-Basics/Drought/Files/Publications-And-Reports/091521-Water-Year-2021-broch_v2.pdf

Pertinent excerpts:
p 3:

> It becomes increasingly difficult to rely on historical observations to predict water supply conditions, as was observed this spring when DWR's snowmelt runoff forecasts substantially over-estimated the runoff that occurred. DWR's median April 1st runoff forecasts for the Sacramento River Hydrologic Region, San Joaquin River Hydrologic Region, and Tulare Lake Hydrologic Region were overestimated by 68 percent, 45 percent, and 46 percent, respectively. …
>
> … Impacts of warmer and dryer conditions include not only the obvious water supply impacts of reduced streamflow and water storage but also increasingly observed watershed impacts such as increased wildfire damage and more prevalent harmful algal blooms.

p 10-11:

> … It was observed during California's 2012-2016 drought that harmful algal blooms, such as the one illustrated in the San Luis Reservoir photograph [p 1], are being more commonly observed (Figure 12) and that wildfire damage is increasing.

"California's Missing Forecast Flows in Spring 2021 – Challenges for seasonal flow forecasting". California Water Blog [UCD] (Posted on July 18, 2021 by jaylund) by John Abatzoglou, Anna Rallings, Leigh Bernacchi, Joshua Viers, Josué Medellín-Azuara
https://californiawaterblog.com/2021/07/18/californias-missing-forecast-flows-in-spring-2021-challenges-for-seasonal-flow-forecasting/
This blog post offers a nuanced view of some of the likely drivers of the 2021 deficit.

Other reports of the overestimate include "685,000 acre-feet" according to DWR's Sean de Guzman, chief of snow surveys and water supply forecasting, as reported by the Mercury News' Paul Rogers in their June 24, 2021 e-edition piece, "A lot of our forecasts were off".

Following is an excerpt from the Los Angeles Times enewspaper story, "Urgent water cuts for farmers", dated Aug. 4, 2021:

> “The simplest terms are the snow was kind of there and then it wasn’t,” said David Rizzardo, chief of the hydrology branch at the state’s Department of Water Resources.
>
> According to Rizzardo, it’s not uncommon to lose 10% to 20% of the snowpack to normal hydrological processes, particularly after a dry year. But losing just under 80% — let alone in such a short period?
>
> “It’s beyond unprecedented,” Rizzardo said. The hydrologic conditions witnessed this year have been forecast in climate change models, but according to Rizzardo, such scenarios were expected to come to bear decades from now.

While the first half of this year stood out palpably to anyone paying attention, it is merely the most recent culmination of a pattern in progress for the past nearly two decades, as documented in the following paper, whose abstract is appropriate here.

Pascolini-Campbell, M., J. T. Reager, H. A. Chandanpurkar, and M. Rodell. 2021. A 10 per cent increase in global land evapotranspiration from 2003 to 2019. *Nature* 593:543–547. https://doi.org/10.1038/s41586-021-03503-5

> Abstract
> Accurate quantification of global land evapotranspiration is necessary for understanding variability in the global water cycle, which is expected to intensify under climate change. Current global evapotranspiration products are derived from a variety of sources, including models, remote sensing and in situ observations. However, existing approaches contain extensive uncertainties; for example, relating to model structure or the upscaling of observations to a global level. As a result, variability and trends in global evapotranspiration remain unclear. Here we show that global land evapotranspiration increased by 10 ± 2 per cent between 2003 and 2019, and that land precipitation is increasingly partitioned into evapotranspiration rather than runoff. Our results are based on an independent water-balance ensemble time series of global land evapotranspiration and the corresponding uncertainty distribution, using data from the Gravity Recovery and Climate Experiment (GRACE) and

> GRACE-Follow On (GRACE-FO) satellites. Variability in global land evapotranspiration is positively correlated with El Niño–Southern Oscillation. The main driver of the trend, however, is increasing land temperature. Our findings provide an observational constraint on global land evapotranspiration, and are consistent with the hypothesis that global evapotranspiration should increase in a warming climate.

The context of this new awareness, combined with an already deepening understanding that climate change seems to pose increasing "weather whiplash" extremes for California, would seem to call into question the net effectiveness of *any* proposed new surface water storage.

Indeed, in CNRA Secretary Crowfoot's July 13th Speaker's Series discussion, Drought: The Signals of Climate Change, he emphasized the importance of increasing groundwater storage, as did two of his three co-presenters during closing "low hanging fruit" responses. The other panelist, a DWR hydrologist, emphasized the importance of improved runoff forecasting. She surely had a front row seat to the surprises 2021 had in store.

Public Policy Institute of California's recent blog post echos the theme:
"What's Really Important? Putting Recent Water News into Perspective". PPIC Blog, posted December 8, 2021 Sarah Bardeen queried PPIC Senior Fellow Jeff Mount and PPIC Water Policy Director Ellen Hanak on recent news for this post.
https://www.ppic.org/blog/whats-really-important-putting-recent-water-news-into-perspective/

Excerpt from Jeff Mount: "... To adapt to less snow we have got to change the way we store water. This means moving more water underground whenever possible." Ellen Hanak was among Secretary Crowfoot's two July 13th co-presenters who emphasized the importance of storing water in the ground.

These ongoing climate change impacts will surely impact the water quantities proposed by Pacheco Reservoir proponents to be delivered for both water users and the environment. And that surely impacts all previously calculated cost/ benefit ratios.

Valley Water's Supplemental Feasibility Documentation Water Storage Investment Program report, section 5.2.2.1 Water Balance for Pacheco Reservoir, page 5-9 (pdf p 99) indicates in Table 5-5 , under Average Annual Pacheco Reservoir Outputs, Reservoir Evaporation (AF), as 600 acre-feet under current conditions and 4,900 acre-feet "With-Project".

Since Valley Water did not share the formula used to arrive at this 4,900 acre-feet figure, nor the assumptions used for that calculation, it is impossible to verify its accuracy. Estimation of evaporation is not a simple task. Following is an online response to a query regarding evaporation loss formulas, which can be daunting even to hydrological engineers:
https://earthscience.stackexchange.com/questions/5071/evaporation-loss-formulas

Note this encapsulation: "the three main variables: temperature, rate of advective removal of moisture (proportional to surface wind velocity), and difference in vapour pressure (which can be related to humidity)." Clearly, evaporative losses are not set in stone, but are absolutely dependent on ambient weather conditions.

To strike me as a reasonable and earnest figure, the estimated Reservoir Evaporation would have to be a ***range, depending on weather variables***. So the simple statement of 4,900 acre-feet in evaporative losses from the proposed expanded surface reservoir seems suspect in itself, especially as a stand-alone figure without further documentation.

Then, add the complexity of increasing evaporative demand that we are coming to understand as among the impacts of ongoing climate change – not that we have a good enough grasp of that yet to even make sound predictions. Nevertheless, some uncertainty should be built into contemporary evaporative loss equations to account for this "new normal".

But that's not the only problem with this estimation. As the title of section 5.2.2.1 Water Balance for Pacheco Reservoir Project, as well as that for Table 5-5, indicate, the project considers (inasmuch as they apparently have) evaporative losses solely for the existing and proposed expanded Pacheco Reservoir, whereas the nature of this proposed project involves **two other sources of evaporative losses from Central Valley Project water en route to Pacheco Reservoir: 1.) the California Aqueduct and**

2.) San Luis Reservoir. Each of those open surface water bodies is subject to evaporative losses and each has its own inherent range of temperature, vapor pressure and wind velocity variables, which have apparently not been considered in the proposed project's water budget.

On top of the evaporative losses in the proposed project's regional pathway, there is also the impact of these changing conditions on the source of Central Valley Project water, as noted in foregoing observations.

The Sierra Club Loma Prieta Chapter prepared the "Pacheco Reservoir Replacement Project Fact Sheet", including the graph, "San Luis Reservoir Storage for the Past Twenty Years", indicating, as stated there,

> The reservoir has been at capacity at most six times in the past twenty years. This raises questions on whether the San Luis Reservoir will provide enough excess water supplies to make Pacheco a viable option.

Compound the experience of the past two decades with the new realizations of 2021 and project viability becomes even further reduced in terms of cost/benefit for all proposed beneficial uses. And then there is the issue of the increasing tendency for harmful algal blooms that is not restricted to San Luis Reservoir. I understand that Valley Water purports to resolve this problem by moving water to the expanded Pacheco Reservoir, but that reservoir is unlikely to be shielded from such harmful algal blooms. The location is near enough to San Luis Reservoir that ambient temperature is not that different. "Figure 12. Harmful Algal Blooms Reported to Date in 2021" in DWR's previously cited brochure, *Water Year 2021: An Extreme Year*, illustrates numerous mapped examples of surface water bodies subject to this problem in just this past year alone.

Researchers are scrambling to model and understand the interplay of ongoing forces, including those attributable to climate change, and thus far no results have been published that include the exceptional – for California, at least – year of 2021.

But following is selection of relatively recent interpretations:

Donohue, R. J., T. R. McVicar, and M. L. Roderick. 2010. Assessing the ability of potential evaporation formulations to capture the dynamics in evaporative demand within a changing climate. *Journal of Hydrology* 386:186-197. https://doi.org/10.1016/j.jhydrol.2010.03.020

Dettinger, M., B. Udall, and A. Georgakakos. 2015. Western water and climate change. *Ecological Applications* 25:2069-2093. https://doi.org/10.1890/15-0938.1 http://bradudall.com/wp-content/uploads/2018/05/dettinger_et_al-2015-ecological_applications.pdf

Dai, A., T. Zhao, and J. Chen. 2018. Climate change and drought: a precipitation and evaporation perspective. *Current Climate Change Reports* 4 https://drive.google.com/file/d/1OASKUoVOkBZlfMg7f09--faM1prndEvP/view

Wang, R., L. Li, P. Gentine, Y. Zhang, J. Chen, X. Chen, L. Chen, i. Ning, L. Yuan, and G. Lv. 2021. Recent increase in the observation-derived land evapotranspiration due to global warming. *Environmental Research Letters* [Accepted Manuscript] https://iopscience.iop.org/article/10.1088/1748-9326/ac4291/meta

Maurer, T., F. Avanzi, S. D. Glaser, and R. C. Bales. 2021 in review,. Drivers of drought-induced shifts in the water balance through a Budyko approach. *Hydrology and Earth Systems Science* [preprint] https://doi.org/10.5194/hess-2021-55

Since increasing evaporative demand should necessarily impact transpiration, as well as evaporation, it is reasonable for non-botanists to wonder how increasing vapor pressure deficit may impact the native plants proposed to facilitate restoration of catchment functions.

But native plants are preadapted to withstand longer and more intense periods of drought than we have yet to experience in the 21st century. The following is one solid source that demonstrates that native plant species have had to adapt to much more challenging conditions than we've experienced so far in current times.

Williams, A. P., A. P. Williams, E. R. Cook, J. E. Smerdon, B. I. Cook, J. T. Abatzoglou, K. Bolles, S. H. Baek, A. M. Badger, and B. Livneh. 2020. Large contribution from anthropogenic warming to an emerging North American megadrought. *Science* 368:314–318. https://doi.org/10.1126/science.aaz9600

And the following source demonstrates that at least some native western U.S. plant species are up to the challenge:

Kannenberg, S. A., A. W. Driscoll, P. Szejner, W. R. L. Anderegg, and J. R. Ehleringer. 2021. Rapid increases in shrubland and forest intrinsic water-use efficiency during an ongoing megadrought. *PNAS* 118:e2118052118. https://doi.org/10.1073/pnas.2118052118

> Significance
> Photosynthesis involves a tradeoff between the uptake of carbon and the loss of water. Intrinsic water-use efficiency is an indicator of this tradeoff that is pivotal for understanding plant responses to climate change. Global increases in atmospheric CO2 concentration have increased intrinsic water-use efficiency, but this relationship is also modulated by water availability. Here, we have identified that a severe, multidecadal drought in the American Southwest has caused some of the largest increases in plant water-use efficiency ever observed. The increase was particularly large in shrubs, which dominate much of the landscape in the region. Given that water scarcity in the American Southwest is expected to worsen, these relationships have important implications for plant health and carbon and water cycling.
>
> Abstract
> Globally, intrinsic water-use efficiency (iWUE) has risen dramatically over the past century in concert with increases in atmospheric CO2 concentration. This increase could be further accelerated by long-term drought events, such as the ongoing multidecadal “megadrought” in the American Southwest. However, direct measurements of iWUE in this region are rare and largely constrained to trees, which may bias estimates of iWUE trends toward more mesic, high elevation areas and neglect the responses of other key plant functional types such as shrubs that are dominant across much of the region. Here, we found evidence that iWUE is increasing in the Southwest at one of the fastest rates documented due to the recent drying trend. These increases

> were particularly large across three common shrub species, which had a greater iWUE sensitivity to aridity than Pinus ponderosa, a common tree species in the western United States. The sensitivity of both shrub and tree iWUE to variability in atmospheric aridity exceeded their sensitivity to increasing atmospheric [CO2]. The shift to more water-efficient vegetation would be, all else being equal, a net positive for plant health. However, ongoing trends toward lower plant density, diminished growth, and increasing vegetation mortality across the Southwest indicate that this increase in iWUE is unlikely to offset the negative impacts of aridification.

Please also consider the implications of the following study, just published yesterday, on proposed project benefits:

Williams, A. P., B. I. Cook, and J. E. Smerdon. 2022. Rapid intensification of the emerging southwestern North American megadrought in 2020–2021. *Nature Climate Change* https://doi.org/10.1038/s41558-022-01290-z

Rainfall to Groundwater recent blog posts (by post number) with information and citations expanding on the catchment restoration alternative proposed herein, as well as issues of increasing evaporative demand with climate change, include the following, that I consider incorporated by reference:

14. Who Values Catchments More Than CA?
https://rainfalltogroundwater.net/2022/01/31/who-values-catchments-more-than-ca/

15. Catchment Restoration for Biodiversity, Climate Change Resilience
https://rainfalltogroundwater.net/2022/02/07/catchment-restoration-for-biodiversity-climate-change-resilience/

16. Oaks As Threatened Catchment Keystones
https://rainfalltogroundwater.net/2022/02/15/oaks-as-threatened-catchment-keystones/

Again, I consider the entire contents of the Rainfall to Groundwater web site pertinent to conveying this proposed alternative “green” approach to meeting project objectives and much lower cost than the proposed “gray” infrastructure.

Impact Bio-2: Adverse effects on sycamore alluvial woodlands & proposed mitigation

Finally, the proposal that adequate mitigation of these impacts can be achieved through purchase of conservation easements on private lands is false and will result in a **net loss** of this rare association within California.

For one thing, private landowners are unlikely to be considering development proposals on such lands specifically because these woodlands lie within floodplains or streambank zones under the jurisdiction of California Department of Fish and Wildlife. Landowners may happily accept the financial helping hand, but would have been unlikely to develop those zones in any case, so that does not reduce impacts below a level of significance.

Moreover, the proposed alteration of fluvial functions will effectively cease the natural fluvial processes that sustain sycamore alluvial woodlands, as I believe is actually acknowledged within the DEIR documentation.

My perspective is that the District has already denied future generations of wildlife and humans access to sycamore alluvial woodlands and now proposes to stick the knife in even farther.

Can Valley Water ever rise above its historical pattern of long-lasting environmental impacts to collaborate with Nature rather than bending her to your will???

Thank you for your consideration of my comments,

Verna Jigour, PhD

V•Jigour LLC: Rainfall to Groundwater

Watershed Restoration for Baseflow Augmentation

Verna Marie Jigour PhD Dissertation[1] Abstract

California's water problems lie not just in the amount of precipitation but in its timing. The temporal disposition of precipitation is strongly influenced by the vegetation of the watersheds it falls on, but for at least the last five decades that relationship has been largely misunderstood in water resources management. Ponce (1989) succinctly defined the goal as "baseflow augmentation", focusing there on streambank storage, while pointing to the potential for management of uplands and rangelands to contribute.

This dissertation expands on the efficacy of potential upland/rangeland management strategies to augment baseflow, focusing on the existing nonnative grasslands, including hardwood rangelands, that cover expansive areas of California's semi-arid watersheds. Extensive review of little-known scientific and policy literature dating back to the early 20th century demonstrates that a body of knowledge supports the essential watershed functions conferred by native vegetation types, their deep rooting systems, and the soil ecosystems they engender—the soil profile as a natural detention reservoir. Framed within the context of the evolving biosphere per Budyko (1986), biospheric feedbacks on regional and local climate are included in this systems evaluation.

The synthesis considers the impacts of aboriginal burning, along with subsequent land management, on the watershed functions of vast areas of the state, proposing vegetative restoration of lands currently clothed in shallow-rooted, nonnative annual grasses to restore those vital functions and augment baseflow; replacing the existing high albedo landscapes that likely feed back into the regional climate system by reducing precipitation, with mosaics of native cover types.

Analyses performed on a GIS database I developed of historical California steelhead streams and watersheds south of San Francisco Bay provide correlations among steelhead status, land-cover types, stewardship status and counties. Most significant are estimates of the potential new detention storage with watershed restoration. Estimated additional storage possible on Salinas River subwatersheds not obstructed by dams surpasses the total storage capacity of the two largest reservoirs on that drainage. Potential detention storage in uplands of the upper Pájaro River watershed could significantly reduce downstream flooding.

This concept holds even greater potential for the watersheds feeding the troubled San Francisco Bay-Delta ecosystem.

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[1] Union Institute & University Graduate College – submitted in partial fulfillment of the requirements for the degree Doctor of Philosophy in Interdisciplinary Studies: Arts & Sciences: Conservation Ecology; approved by doctoral committee 2008, finalized 2011