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January 28, 2011

Attn: Delta Stewardship Council

Re: Delta Plan EIR Notice of Preparation

Alternative for EIR analysis: Watershed restoration for baseflow augmentation

Attch: Figures 2.12-2.23 from Jigour 2010 dissertation; summary submitted to NRC committee; December 9, 2010 additional comments to NRC

Dear Delta Stewardship Council,

Please accept my sincere appreciation for the enormous effort expended to date by many organizations and individuals to help bring clarity and resolution to the complexity of interplaying issues and demands challenging the greater Delta human ecosystem. Fully respecting the work completed to date, the current Delta Plan overlooks an enormous opportunity that must be considered in the EIR alternatives analysis, especially given that public funds will ultimately be sought to implement the plan.

The vast areas of nonnative annual grasslands literally ringing the central valley represent lands with degraded watershed functions—detention storage functions have been degraded with the historic loss of native woody and other perennial vegetation, and their associated soil ecosystems. Restoration of these degraded lands offers thus far overlooked opportunities for subsurface detention storage on a scale quite comparable to that provided by surface reservoirs, while simultaneously providing the most efficient form of flood amelioration—at the source. While these nonnative annual grasslands, otherwise known as rangelands and hardwood rangelands, constitute the greatest area of overlooked opportunities, another even more surprising error of omission has been the disconnect with the seemingly obvious storage functions afforded through the widening of riparian zone buffers and reparation of functional floodplain connections—not just on lands in and surrounding the Delta, but all the way upstream to headwaters, on all the contributing watersheds. While it may be argued that riparian zones have received ample attention, virtually all of it has been focused on the habitat and water quality functions of riparian zones while their water storage functions have been ignored in the search for solutions, except perhaps within the immediate vicinity of the Delta.

Despite the recognition that past engineering solutions have addicted us to a seemingly endless spiral of more engineering fixes to address the problems wrought by past engineering fixes, the current impetus toward yet one more set of costly engineering solutions without considering an integrative, ecosystem/watershed approach seems so 20th century. At the very least, the stakeholders and the citizens of California deserve analysis of an alternative approach that harnesses the aid of countless biological allies in self-organizing, synergistic systems that, once restored, can become self-sustaining, with appropriate management, and thus may be far less costly .

I submitted a summary of this approach, based on my interdisciplinary doctoral dissertation, to the National Research Council committee on the Bay-Delta late last July. When I offered brief comments to the committee during the open mic segment at the end of their December 8th meeting in San Francisco, I learned that none had yet seen my summary, but was assured I had succeeded in bringing it to their attention that day. That document remains the most convenient summary so I have attached it, including the accompanying dissertation figures, to this letter.

A few additional remarks on that subject are appropriate. As noted in that summary, the GIS analysis presented in Part 3 of my dissertation concerned the historical steelhead watersheds from San Francisco Bay southward through San Diego County, so I necessarily adapted comparabledata from other reports to work up estimates of the additional detention storage possible with the watershed restoration approach. I did not have enough information to be able to make specific geographic estimates, but the analysis I envision would seek to evaluate whether restoration of detention storage functions on the watersheds feeding the Delta from the south could potentially alleviate the need for additional north-south conveyance. In other words, the question is whether restoration of detention functions on watersheds south of the Delta could provide enough additional water to users south of the Delta that the need for additional conveyance might be eliminated. It seems certain that such an approach would result in improved water quality, but it would also address the significant flooding threats brought to mind by the recent flooding in the southern central valley, as well as the recent attention on the potential emergency ramifications of a meteorological event like the one that inundated much of the valley in 1862.

The vast majority of the vast acreage on which I propose watershed restoration is in private ownership, thus incentives would be necessary to implement such an approach. It would mean a more distributed application of funds—to land owners and their contractors rather than to point source monolith structures. But in the context of ecological economics, this approach makes sense and is hardly novel. Among the best examples is the New York City water supply, noted in my dissertation and, fortuitously, in a recent news article, "Mapping the value of watershed services"(Kett 2011), which is available online. This article and the related documents offer an example of how the concept is applied to forested watershed east of the Rockies. Following the initial restorative actions, long term management of watershed lands could be partly supported through carbon offsets, since subsurface carbon stores are the least labile.

The accompanying summary and figures should suffice to get this alternative considered in the DEIR. I am presently in the process of developing the www.BaseflowAugmentation.net site, so it is not operative as I submit this. But soon that will become the place to learn the status of the eBooks I intend to publish based on the dissertation. The eBooks should be available from Amazon.com well within the time frame allotted for DEIR development, so I trust the DEIR preparers will use them as a resource in addressing this proposed alternative. I will be happy to provide pertinent information upon request.

Additionally, my attached Dec. 9th followup comments to the NRC committee summarize the evidence of staggering overdrafts of central valley groundwater determined through the GRACE satellite mission. I request that the DEIR evaluate how these overdrafts impact the delta plan and ecosystem.

Respectfully,

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Citation

Kett, H. 2011. Mapping the value of watershed services. *Ecosystem Marketplace*. January 24, 2011. Available from: http://www.ecosystemmarketplace.com/pages/dynamic/article.page.php?page_id=7970&section=news_articles&eod=1

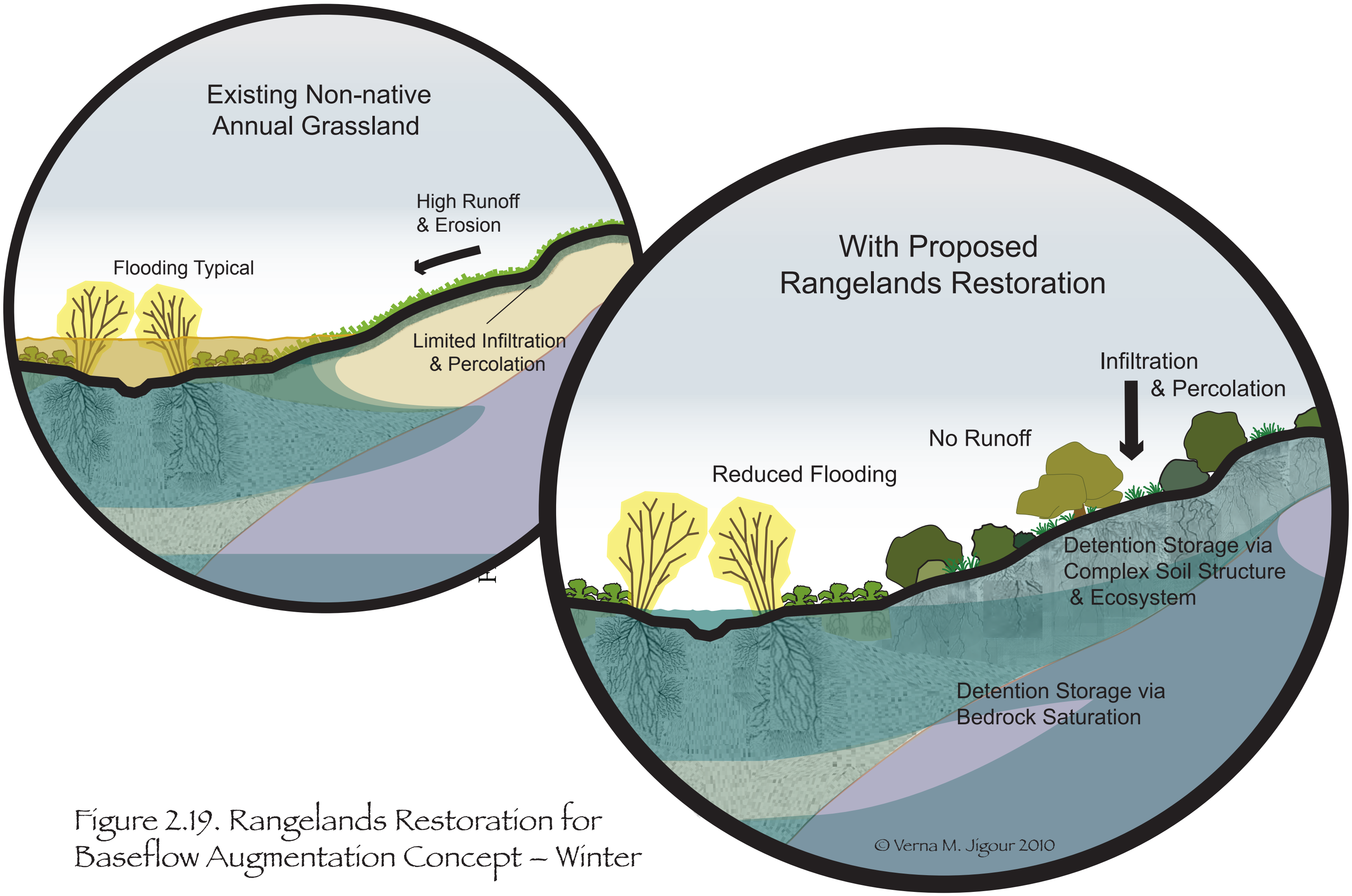

Figure 2.19. Rangelands Restoration for
Baseflow Augmentation Concept – Winter

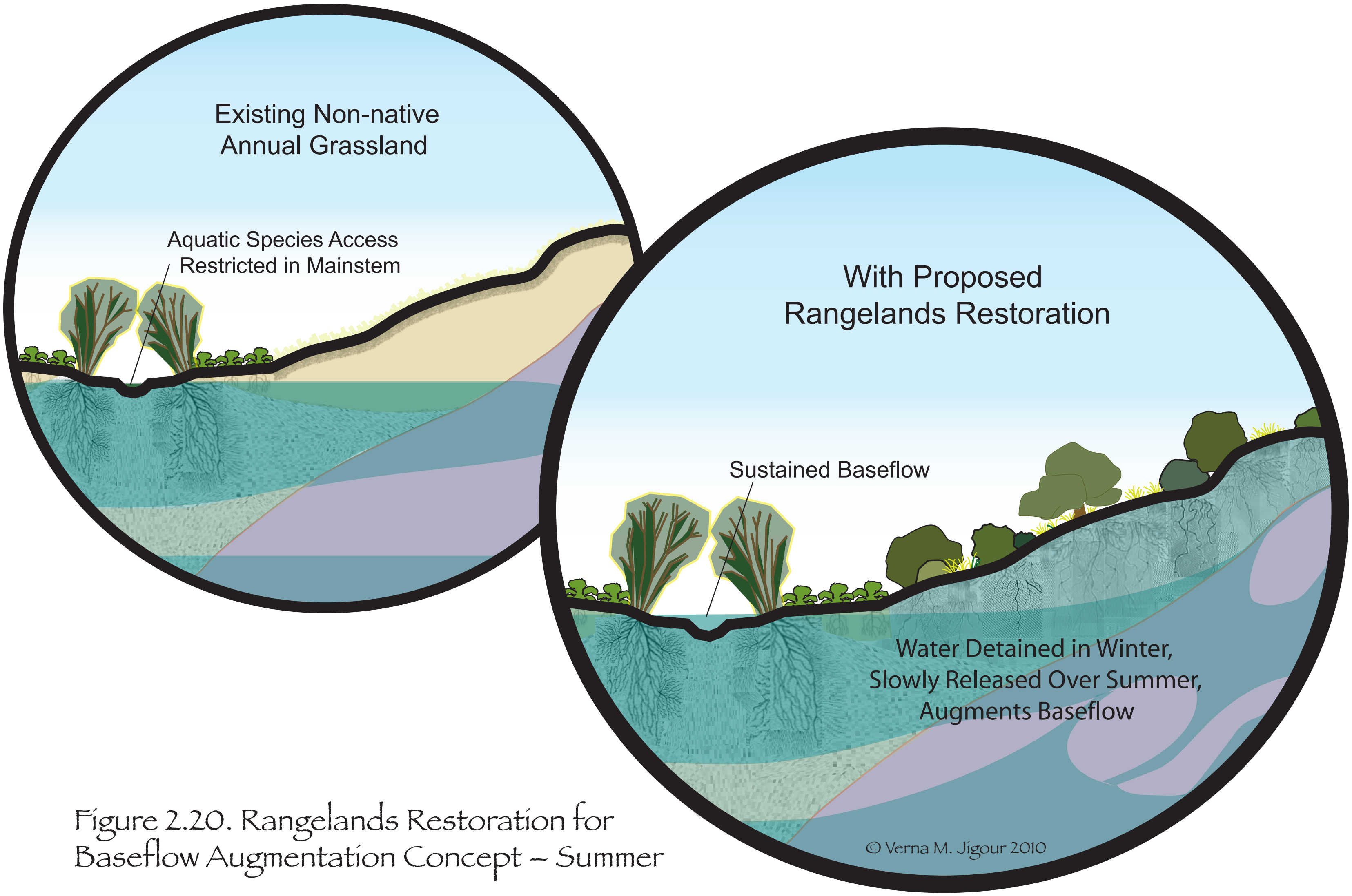

Figure 2.20. Rangelands Restoration for Baseflow Augmentation Concept – Summer

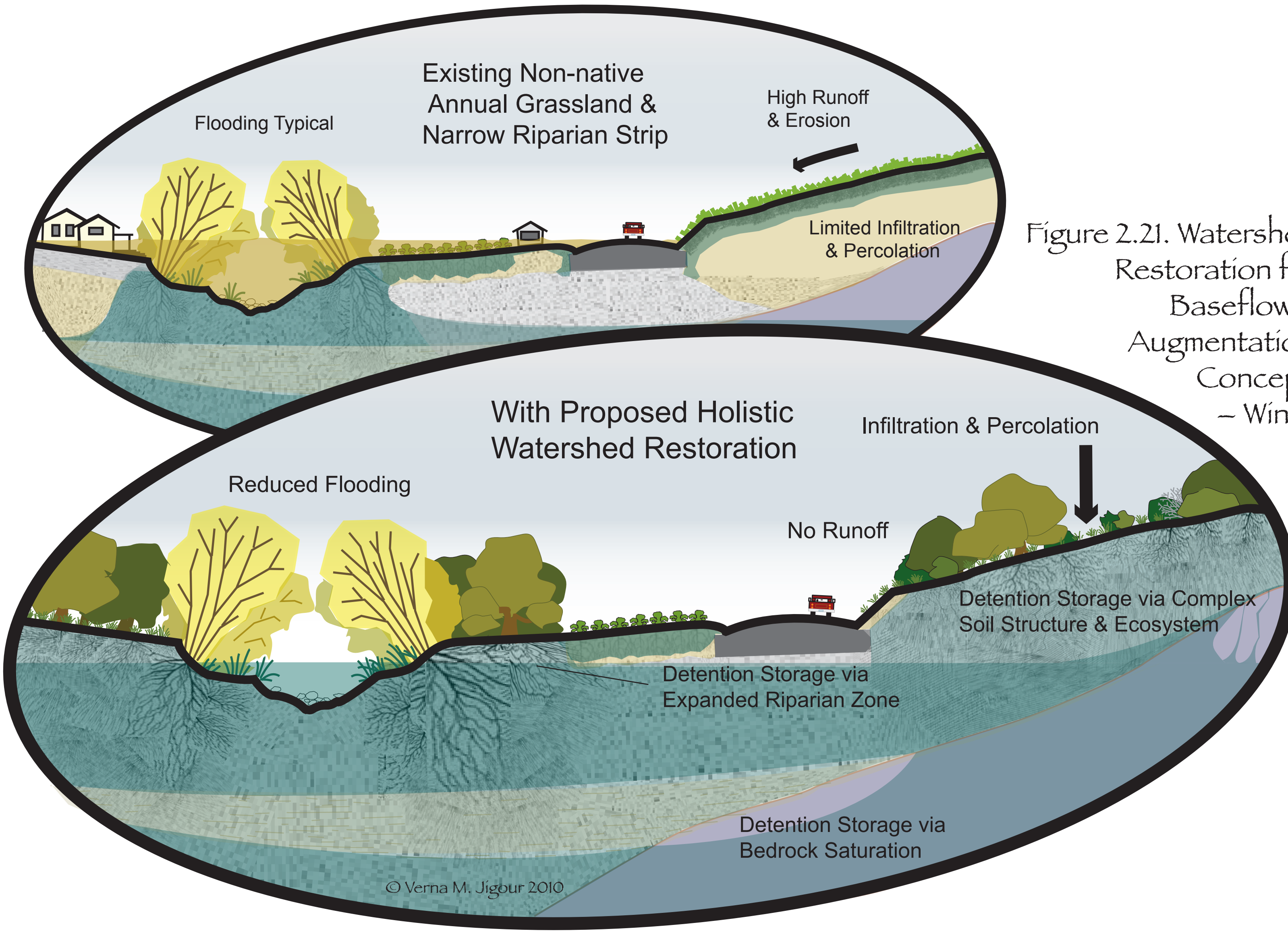

Figure 2.21. Watershed Restoration for Baseflow Augmentation Concept – Winter

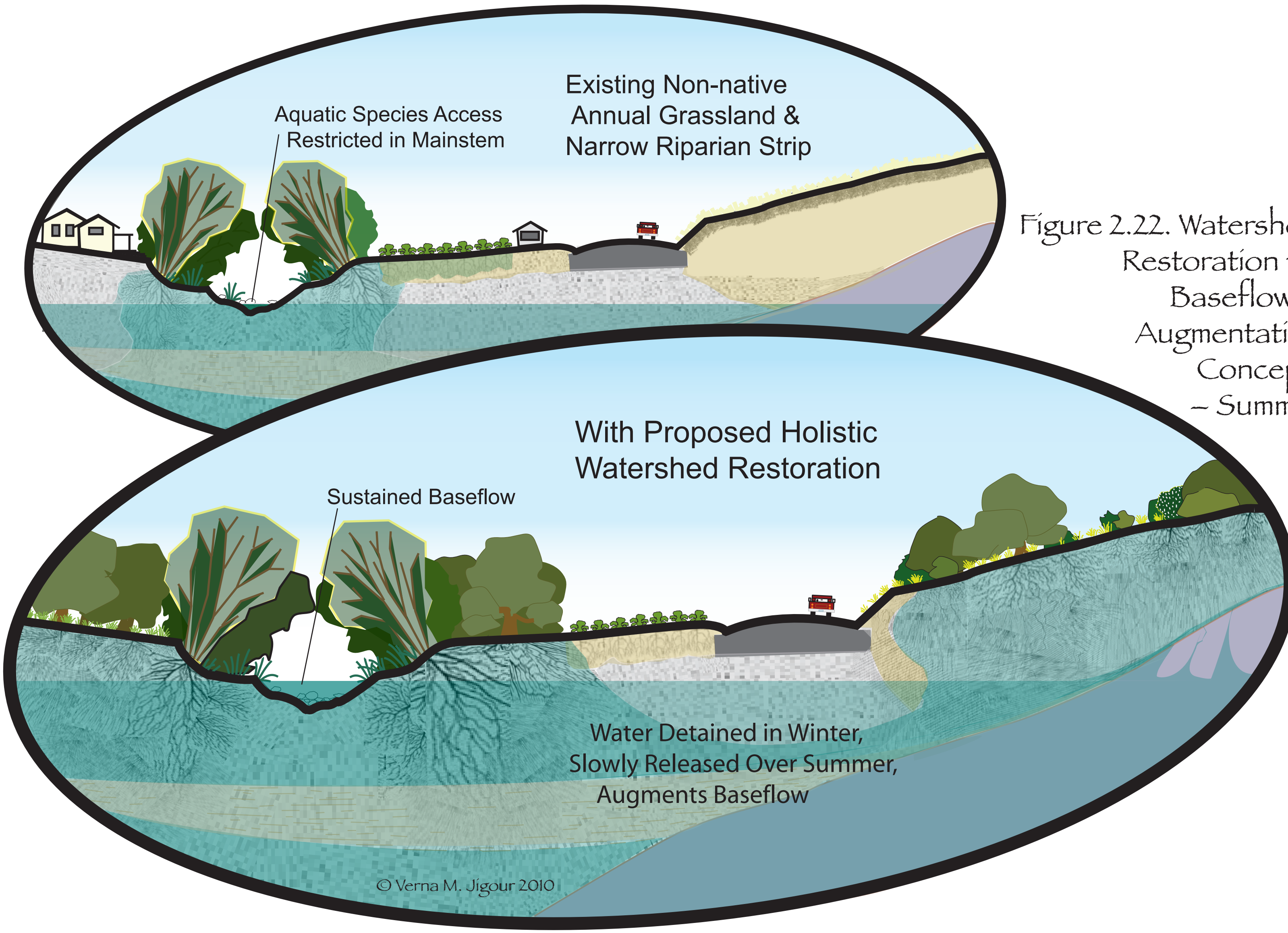

Figure 2.22. Watershed Restoration for Baseflow Augmentation Concept – Summer

Figure 2.23.
"Bathtub ring" of high-albedo nonnative annual grasslands around California's Central Valley: Opportunities for watershed restoration for baseflow augmentation

Attn: National Research Council Committee Members July 30, 2010

Via emailed pdfs to SRO David Policansky;
Attachment: Jigour (2010) Figures 2.19-2.23

Project: Sustainable Water and Environmental Management in the California Bay-Delta
PIN: DELS-WSTB-09-09

Subject: Holistic Strategy: Watershed Restoration for Baseflow Augmentation

Dear National Research Council Committee Members,

In response to my inquiry last January, SRO David Policansky kindly advised me to provide the committee with a summary of the input I offer. Since my input concerns the bigger picture issues of the committee's second report, and partly because of my own timing issues, this is the most opportune time for my summary. I regret that I was unable to attend the Sacramento committee meeting earlier this month, but I trust that since the committee is just beginning its second report, this input remains timely. I seek to call the committee's attention to a holistic strategy for restoring Delta flows that has been wholly overlooked to date by those charged with shepherding the mission through the CALFED phase into the present—despite my efforts to bring it to their attention. My short-hand encapsulation of this strategy is the title of my doctoral dissertation, Watershed Restoration for Baseflow Augmentation, currently moving through the Union Institute & University's Dean's Review process. Essentially what I propose, applicable to the NRC concerns, is the restoration of catchment detention storage functions in the watersheds feeding the San Francisco Bay-Delta, emphasizing opportunities to enhance storage functions over vast expanses of degraded uplands, specifically nonnative annual grasslands, as well as in restored streambanks and floodplains.

Fundamental Concepts

My title takes its cue from "Baseflow augmentation by streambank storage" (Ponce 1989) and my dissertation is essentially an expansion upon Ponce's (1989) foundation. Despite that the 1989 piece was followed by more broadly accessible versions (Ponce and Lindquist 1990b, Ponce and Lindquist 1990a, Ponce and Lindquist 1990c), the message seems to have fallen on deaf ears among water resources interests in California and beyond. Since Ponce (1989) is freely available online[1], I encourage interested committee members to consult the original. To encapsulate the hydraulic dimension, for which Ponce (1989) provides equations, baseflow augmentation by streambank storage involves increasing the width of the aquifer by increasing the space available for streambank storage; in other words, widening the riparian and/or floodplain zone—a strategy that has apparently seen little to no conscious application to water storage in California or elsewhere, even over the more than a decade of CALFED activity, despite that this strategy seems obvious to an observer with an integrative worldview. I elaborate on that subject in a following section.

1 http://ponce.sdsu.edu/baseflow_augmentation_0803050.html

Among the gems in Ponce (1989) is the quote from Alexander von Humboldt, on the cusp of the 19th century, that exemplifies the integrative perspective embodied by this summary; one apparently shared, or at least expressed, by few today, to the detriment of watershed integrity. If the veil of perception could be lifted enough to share such understandings more broadly among the community of San Francisco Bay-Delta stakeholders, at least some might begin to see the enormous opportunity that has eluded them. This elusiveness seems primarily due to a problem of perception, rigidified by the long dominance of the natural sciences, especially hydrology, by the proponents of deterministic reductionism. This is the worldview that gave us 60+ years of research biased by what I refer to in shorthand as the "water yield" paradigm, that is, vegetation removal for water yield. Note the contrast in goals between *water yield* and *baseflow augmentation*. This is also the worldview that seeks to solve Delta flow problems with yet more engineering solutions—dams and conveyance—further locking us into an endless spiral of plumbing projects that degrade affected ecosystems. And much of this infrastructure is called for to support irrigated agriculture in the southern San Joaquin Valley where ongoing soil salt accumulation arising from irrigated agriculture is already taking some farmlands out of commission, with more on the horizon.

Von Humboldt's example demonstrates that (self-interested) watershed consciousness has been around for at least a couple centuries, but for various reasons it remains to be fully actualized. The Clean Water Act has worked well to magnetize attention to water quality. But the corresponding water ***quantity*** issues were left behind in the dust. Furthermore, while the shift in focus from point-source to nonpoint source water pollution does represent remarkable social progress, we are collectively still far from making the leap to true watershed consciousness with respect to recognizing the significance of upland contributions to the quantitative aspects of watershed function. My observation is that there is a widespread figure/ground perceptual problem, akin to the iconic images—"Do you see the vase or the profiles?" If one's gaze is fixated on the vase, it can be exceedingly difficult to even perceive the profiles. For example, while many watershed groups arose in California during the 1990s, catalyzed by corresponding language in the multi-agency Memorandum on Biodiversity, the vast majority of such organizations, including academic groups, focused their attention on the drainages, considering uplands, if at all, only in their nonpoint source pollution context. Yet, if one stops to consider the percentage of land occupied by drainages relative to that occupied by uplands, one realizes that the drainages constitute by far the smaller proportion of any catchment. Since precipitation does not favor drainages over uplands, the relative opportunities for infiltration and percolation over the more expansive area of uplands should be apparent. Some of our historical perceptual problem likely arose with the choice of words—*watershed* conveys drainage, where *catchment* conveys storage.

But deep U.S. political roots date to 1824, when "Congress instructed the U.S. Army Corps of Engineers to improve the navigable streams" (Hays 1959 (1975)). Ever since, the predominant regulatory and infrastructural focus has been on ***surface*** waters. However, in the semiarid western U.S., many drainages themselves flow below ground for much of the year, their presence indicated by only phreatophytic vegetation. This long history of focus on surface waters has essentially ignored interflow, or subsurface flows that route precipitation to catchment storage, providing the sources for springs, as well as sustained baseflow.

The uplands opportunity so seemingly obvious yet flying below the prevailing radar is the enormous expanse of nonnative annual grasslands ringing California's great Central Valley, thus constituting the flanks of its watersheds/catchments. The nomenclature of California vegetation associations has been evolving, but I use *nonnative annual grasslands* to refer to "Non-Native Grassland", the original term in the vegetation description system (Holland 1986) used in the California Gap Analysis (Davis et al. 1998), which served as source data for the geographic information system (GIS) modeling I documented as part of my doctoral dissertation. But the nonnative annual grassland term also conveys the truly degraded condition of this land-cover type, which is apparently unique to California (Corbin et al. 2007), owing to our Mediterranean-type climate, and manifested in landscape dominance by annual grass species of Mediterranean heritage that apparently do not form such dominant associations in their lands of origin (Jackson 1985). Yet in California they constitute a significant percentage of the state's land cover, and thus its watersheds. According to the California Gap Analysis, Non-Native Grasslands comprise 27,483 square kilometers and 6.7% of the state's land cover (Davis et al. 1998), second only to (cumulative) Agricultural Types, which cover 52,426 square kilometers, 12.9% of the state's lands (ibid.). Corbin et al. (2007) estimate that grasslands in total comprise over 10% of California's land cover (Corbin et al. 2007), but only a small portion of that represents native perennial grasslands. Clearly this vegetation type has arisen through anthropogenic disturbance of the valley-to-foothill gradients most amenable to human occupation and industry. Favored by anthropogenic burning, which is increasing in wildlands-urban interface areas (Keeley 2007), nonnative annual grasslands are likely only expanding their range, except where focused restoration efforts are ongoing.

The impacts of the expansion of this nonnative cover-type on watershed function arise not so much from the plants themselves, which are mere indicators, but from the loss of the woody and other perennial vegetation, and especially their associated soil ecosystems that held vital roles in watershed function. While degradation is commonly thought of as beginning with the introduction of European life-ways to California, there is much evidence to suggest that, despite their relatively small numbers, aboriginal Californians had a disproportionate effect on their landscapes through their use of fire as a land management tool, and that the scattered trees dotting existing oak savannas along the Sierra Nevada foothills were originally thinned through burning (Lewis 1993 (1973)) that, in many cases, favored disturbance-adapted plant species like chia (*Salvia columbariae*), a relationship that Kat Anderson refers to as a "regional food complex" (Anderson 2005). Thus, while the European cultures had their own impacts, their early observations do not document a "pristine" landscape, but rather a landscape from which woody vegetation had already been reduced. Successive waves of immigrating Europeans concentrated their burning activities on different vegetation types (Greenlee and Langenheim 1990), following up with dryland farming of especially wheat over much of the state; leaving us with the vast expanses of nonnative annual grasslands we have today. Observing such patterns in other parts of the world we recognize it as desertification, yet we have been collectively blind to its impacts closer to home.

Loss of the complex soil ecosystems engendered by interrelations of tree and perennial root systems, their symbionts and countless other interactions, constitutes the most obvious impact on watershed functions. Among the earliest documentations of water channeling by tree roots appeared in "Nature and extent of macropores in forest soils and their influence on subsurface water movement" (Aubertin 1971). There are now more examples than are appropriate to cite in this summary[2], but a corollary issue revealed little more than a decade ago is the water-insoluble glomalin protein class produced by mycorrhizal fungi associated with perennial vegetation—first identified through research led by USDA Agricultural Research Service (ARS) scientist Sara F. Wright (Wright et al. 1996, Wright and Upadhyaya 1996). Not only does glomalin appear to be a primary constituent (Wright and Upadhyaya 1998) in the formation of water stable soil aggregates (Tisdall and Oades 1982), which provide space for interflow and vadose zone water storage, but it also plays a significant role in carbon sequestration, with glomalin accounting for nearly one third of the world's soil carbon stocks (Nichols et al. 2002, USDA/ Agricultural Research Service 2002, Nichols 2007, USDA/Agricultural Research Service 2008)—a relationship apparently being overlooked in current carbon market schemes that account only for above-ground carbon stocks, which can be more subject to ready depletion, even through natural events.

Contrast that complexity with the seasonal life cycle of the dominant players in nonnative annual grasslands—most of which aren't around long enough to support mycorrhizal relationships. Furthermore, their root systems are much shallower than any suitable native vegetation types. Cognizant of the potential impacts of the ongoing land conversion through burning in the Sierra Nevada foothill belt, between 700 and 3,000 feet, early 20th century researchers set up an experiment to examine the effects. P.B. Rowe's report, "Influence of woodland chaparral on water and soil in central California"(Rowe 1948), documents results of land management experiments initiated by the U.S. Forest Service apparently long before Rowe became involved, at the California Forest and Range Experiment Station's North Fork experimental area in the foothills of the San Joaquin drainage. I have included many of the figures from that report in the Part 2 Synthesis of my dissertation, but this particular report by Rowe seems to have been overlooked by most others. The results indicate a diminishment of infiltration and percolation observable after just a couple of burns in close succession, with more dramatic results affected by repeated annual burns over six years. Given that aboriginal burning likely occurred frequently, if not annually, Rowe's (1948) results convey a sense of the likely prehistoric impacts of vegetation conversion through burning, as well documenting the prevailing early 20th century land management the experiment was intended to elucidate.

Even more subtle and thus insidious may be the effect such vegetation conversion has on watershed topology, which affects drainage function. Nonnative (aggressive perennial species) grassland was shown to engender a more concave pedogenic topography, hastening runoff to drainages, compared with chaparral cover that affects a more convex topography, encouraging infiltration and percolation (Williamson et al. 2006).

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2 I'll be happy to provide additional information upon request.

Viewed within the context of global energy balance (Budyko 1961, 1970b, a, 1974, 1986, MacCracken et al. 1990, Budyko 2001), it must be recognized that reduction of vegetation, that is, localized reduction of the energy of transpiration, combined with increased albedo and orographic effects, impacts not just global, but also local and regional climate (Pielke and Avissar 1990, Ponce and Lohani 1997, Ponce et al. 1997, Ponce et al. 2000, Pielke 2001, Ponce 2003, Xue 2006, Cotton and Pielke Sr. 2007). The net effect is typified by increasing aridity with vegetation removal—again, the effects we associate with desertification. While annual grasslands are a type of vegetation, their annual death at the end of the rainy season leaves a summertime land cover that approaches the transpiration rates, albedos and orography of unvegetated lands.

Fundamental Misconceptions & Historical Perspective

In addition to the figure/ground issue that precludes most Bay-Delta stakeholders from seeing the watershed for [fixation on] the delta, two fundamental misconceptions have forestalled a holistic apprehension of watershed functions that could be restored to support baseflows to the Delta. The first is the aforementioned six-plus decades of research interest in vegetation removal for water yield. I completed my own summary of this historical research as my dissertation Appendix A prior to publication of the NRC summary (Committee on Hydrologic Impacts of Forest Management and National Research Council 2008), thus I have not reviewed that work. However, I understand that the conclusions may be similar to my own, based on a comment in Wilcox and Huang (2010). My observation is that essentially all such studies focus only on the E (evapotranspiration) part of any water balance equation, ignoring the other components. Illustrating that this skewed perception of the relationship between vegetation and water balance is not simply an artifact of the past, this same focus on evapotranspiration, to the exclusion of other factors in a water balance equation, is expressed in the report on research comparing soil-water use by exotic annual versus California native perennial grasses (Holmes and Rice 1996), as well as in the chapter, Water Relations (Reever Morghan et al. 2007) in *California Grasslands: Ecology and Management* (Stromberg et al. 2007). More realistic water balance equations include some interflow and, ideally, baseflow component[3]. Vegetation serves not only to transpire water but also to route it to subsurface storage through above-and below-ground entrainment of flows along vegetative and other biologically-derived surfaces.

The second basic misconception, that shrub "encroachment" is a manifestation of rangeland degradation, seems like old common knowledge, but has apparently been with us for less than a century. Considering the committee's task at hand, I trust it is an appropriate indulgence to share with you the following dissertation excerpt, itself an historical excerpt from the statement prepared by H. A. Jastro, President of the American National Live Stock Association, and read at the Conference of Governors in the White House, Washington, D.C., May 13-15, 1908 (McGee 1909), convened by President Theodore Roosevelt to consider the national security implications of the country's conservation needs.

> Residing in Kern county, in the State of California, where the entire flowage of the Kern river is applied to agricultural lands on what is known as the Kern River

[3] For one example see: http://ponce.sdsu.edu/catchment_wetting_and_water_balance.html

delta, to a large extent under my personal supervision, I can state as a fact that a very perceptible effect is observed upon the low-water flow of the river since the exclusion of sheep[4] from the forest reserves covering the river's watershed. **I need not go into a process of reasoning to account for a fact that is so obvious and so well-known. It is not claimed that the aggregate discharge of a river is increased by the growth of timber or vegetation, but it is demonstrated that the run-off is more gradual and is prolonged through a greater length of time. That is to say, the forests and vegetation serve the same purpose as artificial reservoirs, made by dams or otherwise.** Also it is evident that if the ground surface is protected by timber or vegetation from erosion, artificial reservoirs are protected from being quickly filled up by silt from the mountain slopes, and disastrous torrents are prevented.

According to daily measurements of Kern river, during the period of seven years **from 1899 to 1906, after the establishment of the national forests, we find an increase of minimum flow from 86.22 feet to 222.06 feet—an increase of over 50% taking place in the seventh year.** Through this steady and gradual increase, the area of lands under irrigation was increased from 130,000 acres in 1899 to over 180,000 acres in 1906.

Also, according to the statement of Elwood Mead, in his report of irrigation investigations in California in 1901[5], there seems to be a conclusive demonstration of the favorable effect of forests on the watershed of a river on the low-water run-off. A case in point is the difference between the run-off of the two branches of the Yuba river. The North Fork, being heavily timbered, furnishes 75% of the low-water flow, which is supplied from only one-tenth of the total drainage area—the watershed of the South Fork being comparatively bare of timber. Mr. Mead summarizes his conclusion on this subject in the following language:

> It appears that the solution of the problem of a storage of flood waters is not in the retention of a small percentage of the storm waters behind dams, but in applying storage over the entire watershed by the systematic extension of forest and brush-covered areas. …
>
> [Statement by H. A. Jastro in McGee (1909), emphases added]

The likelihood of finding a livestock association representative with a similar perspective on watershed storage today is slim to nil, illustrating a paradigm shift over the past century. That same perspective was beautifully expressed by U.S. Forest Service

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4 Sheep were known to have a greater impact on watersheds, in that they will eat the vegetation down so closely to the ground as to kill most perennial plants, hastening the degradation of watershed functions, a phenomenon I've observed myself. This became one of the chief issues for cattlemen versus shepherds. Hays (1959) points out that another political undercurrent of the tension arose from the "exotic" character of the many Basque shepherds of the time, along with their nomadic ways, moving from state to state.

5 "In 1898 Mead became Chief of a new Office of Irrigation Investigations in the Office of Experiment Stations of the Department of Agriculture" [Hays 1959 (1975)] p. 243.

researchers in "The soil profile as a natural reservoir" (Hursh and Fletcher 1942), just as deterministic reductionism, promoted by hydraulic engineers, began to assume political dominance over research agendas and funding.

Recent "Paradoxical" Evidence for Watershed Restoration

Only after embarking on late refinements to my dissertation this past spring, in the midst of the Dean's Review process, did I come upon the most convincing evidence to date in support of watershed restoration for baseflow augmentation. Had I known of this sooner I might have cut back on the heft of my literature review, which spans a century of pertinent research, but the piece was only published last March. The title, "Woody plant encroachment paradox: Rivers rebound as degraded grasslands convert to woodlands" (Wilcox and Huang 2010), conveys the unexpectedness of the researchers' results. Following is the abstract, which will hopefully help power light bulbs going off in your head as you read, with respect to holistic approaches to restoring Delta flows.

> The related phenomena of degradation and woody plant encroachment have transformed huge tracts of rangelands. Woody encroachment is assumed to reduce groundwater recharge and streamflow. We analyzed the long-term (85 years) trends of four major river basins in the Edwards Plateau region of Texas. This region, in which springs are abundant because of the karst geology, has undergone degradation and woody encroachment. We found that, contrary to widespread perceptions, streamflows have not been declining. The contribution of baseflow has doubled—even though woody cover has expanded and rainfall amounts have remained constant. We attribute this increase in springflow to a landscape recovery that has taken place concurrently with woody expansion—a recovery brought about by lower grazing pressure. Our results indicate that for drylands where the geology supports springs, it is degradation and not woody encroachment that leads to regional-scale declines in groundwater recharge and streamflows.
>
> (Wilcox and Huang 2010)

I now state in the introduction to my dissertation that if one reads it, one should understand why Wilcox and Huang's (2010) results do not actually represent a paradox. Again, the issue is a problem of perception and perspective. The specifics of geologic formations associated with the various watersheds feeding the Bay-Delta remain to be correlated through applicable analysis. But virtually all rock types permit entry, flow and storage of water (McGee 1913, Meinzer 1923) as sources for springs (Meinzer 1923), and any geologic map reveals abundant historical springs throughout the California foothill regions of concern.

Empirical Insights on Subsurface Flows & Catchment Storage

A recent *Hydrology and Earth Systems Science* (HESS) Opinions piece, "On the use of laboratory experimentation . . ." (Kleinhans et al. 2010), lauds the empirical approach of

Peter Black[6], who (in my opinion), took the rising limb of the deterministic era by the horns, using iconic laboratory watershed models and rainfall simulators to illuminate catchment behavior (Black 1970, 1972, Black and Cronn 1975). Despite the intervening four decades, Kleinhans et al. (2010) hailed Black's 1970s works as among their rare good examples. Another condition that has changed little in the intervening decades is the dominance of hydrology by the determinism applied with such skill to flows through built structures by hydraulic engineers, but it nearly always fails to capture the actual flow dynamics through natural systems. As Black (1970) commented, "virtually all the physical models made and tested so far have been designed to verify mathematical models, not to study runoff." With his precisely constructed laboratory models he showed that under less than saturated conditions the storage effect of soil depth was clear, as was a "considerable separation of the decay time" (ibid.). He demonstrated similar results for soil depth in the second set of experiments, including a study of "channel storage" wherein he removed portions of the simulated "soil" depth determined by dry weight, in the vicinity of the channel. "Removal of 4 per cent of the soil layer caused an 18 per cent increase in maximum peak, a 15 per cent decrease in time of concentration, and a 5.9 per cent decrease in the per cent of runoff occurring prior to the peak" (Black 1972). He reported several other insights among the three publications based on his model experiments. The third set of experiments found close similitude between model and real watershed functions (Black and Cronn 1975). More current perspectives of ***watershed*** hydrology from Black may be found in his summary, "Watershed functions"(Black 1997), along with his book, *Watershed Hydrology* (Black 1996).

Isotopic tracers have shown that groundwater constitutes a surprisingly high percentage of the initial stormwater runoff (Sklash and Farvolden 1979). The "groundwater ridging hypothesis" proposed by Sklash and Farvolden has been observed by others though described in different language. Researchers in the Bavarian Alps found that 70-80% of total catchment outflow was through indirect, or subsurface flows, using a more general description of the phenomenon as, "the spontaneous response of the groundwater reservoir to an input impulse by rain or meltwater . . . due to a rapid dislocation of the subsurface pressure head" (Herrmann and Strichler 1980). U.S. Geological Survey researchers subsequently proposed that some of the "groundwater" observed in previous isotopic studies may have actually been vadose zone (soil) water, undifferentiated from the groundwater per se due to research methodology (Kennedy et al. 1986). They reported on a more comprehensive analytical procedure in "Determination of the components of stormflow using water chemistry and environmental isotopes, Mattole River Basin, California" (ibid.). Their results indicated "large-scale interaction with soils occurring rapidly, as well as subsurface stormflow over much of the catchment" (Kennedy et al. 1986). To quote the German researchers, "The experimental results from environmental isotope studies in small catchment areas lead to the opinion that the traditional concept of runoff generated chiefly by the surface flow should be revised" (Herrmann and Strichler 1980).

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[6] http://www.watershedhydrology.com/index.html
http://www.esf.edu/fnrm/faculty/black.htm

Following is a pertinent quote from "New Strategies for America's Watersheds", pages 270 (bottom)-271.

> Floodplains act as storage sites for floodwater, and the ability of floodplains to store and moderate high flows is strongly influenced by the width of the floodplain, the development of an overflow channel system, and the condition of riparian vegetation. . . .
> (Committee on Watershed Management and National Research Council 1999)

Again, I wish that awareness had seen broader implementation.

Several contemporaries have zeroed in on another problem with the state of hydrological models that is summarized by the following quote, "We continue to develop more and more complex 'linear' models, even after recognizing that almost all hydrologic (and climatic) processes are inherently non-linear in nature." (Sivakumar 2008). A few hydrologists have generated nonlinear models that better describe catchment behavior (Wittenberg 1994, 1999, Wittenberg and Sivapalan 1999, Kirchner 2009). These models necessarily derive their insights from actual catchment water balance and all employ the fundamental assumption of catchment (subsurface) storage as a significant feature and even controller of water balance. Kirchner's elegant model describes "catchments . . . in which discharge is determined by the volume of water in storage" (Kirchner 2009), which applies to most catchments. As indicated in his title, Kirchner derived his portrayal of "catchments as simple dynamical systems … [by] doing hydrology backwards" (ibid.), that is, basing his model on actual field data, rather than imposing a deterministic model on the natural system, then tweaking it to make it work, as has been common. Thus, while his approach does not directly consider biological and ecological components of the catchments, their dynamical influences are captured by accounting for storage in the model.

Jigour (2010) & Link to Ponce (1989)

Ponce (1989) mentions, but does not elaborate on uplands and rangelands vegetation management for baseflow augmentation, so my work picks up where he left off on. I had actually already completed my GIS study several years before finding Ponce (1989), but after reading that and some of his others works, in 2005 I asked and he consented to become Adjunct Professor on my doctoral committee. To this day, he remains the only individual I've found out to have published on both of the major emphases of my dissertation—baseflow augmentation and biospheric feedbacks with local and regional climate. Ponce's ability to transcend disciplinary boundaries made him a perfect mentor for my interdisciplinary quest. Perusal of his ever-burgeoning web site[7] will net several articles representing ecohydrological thinking, though not necessarily labeled as such.

The GIS analysis documented in my dissertation Part 3 encompassed the watersheds historically hosting steelhead (*Oncorhynchus mykiss* ssp. *irideus*) populations around, and south of the San Francisco Bay, thus extending through California's Central Coast to San Diego County. I conceived and created the GIS, with technical support, over a decade ago

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7 http://ponce.sdsu.edu/

at U.C. Santa Cruz GIS Lab, as part of a regional conservation analysis. The foundation for the database was the then-current version of "Table 4. Status summary of California steelhead in coastal drainages south of San Francisco Bay" from *History and status of steelhead in California coastal drainages south of San Francisco Bay* (Titus et al. 1999 in preparation). Essentially, the data in that table became the attribute data, which I, with some assistance, linked to the geospatial data in the GIS, using the maps in that document as guides. This gave me the ability to correlate steelhead status and other factors in historical steelhead watersheds with land cover/vegetation, for which the California Gap Analysis (Davis et al. 1998) served as source, among other geographic data. I had observed many apparently degraded rangelands, but working with the GIS heightened my awareness of the vast proportions of some watersheds clothed in nonnative annual grasslands. I developed several geographic models correlating steelhead status with land cover/vegetation. The most pertinent of these correlations is with nonnative (annual) grassland.

Having begun with a modest estimated increase of one inch of additional detention storage with vegetative restoration, my extensive literature review prompted at least a ten-fold increase. Partly for simplicity, I ultimately applied an average estimated one-foot increase in detention storage per acre, so that acres of nonnative grassland equals acre-feet of increased detention storage. Without elaborating the litany of support for this figure here, consider that this figure represents an amount at some unknown future point in time; that as detention storage, this space may be refilled many times over a season; and that part of that increase represents the routing of infiltrated and percolated water through vadose zones into bedrock storage that it may not currently reach, given moribund, compacted soils under especially overgrazed annual grasslands. The most striking result was the estimated increased detention storage on Salinas River tributary watersheds not obstructed by dams, including the Estrella River subwatershed that indistinguishably, in terms of land-cover, borders western San Joaquin Valley subdrainages. The estimated potential increased detention storage exceeds the combined capacity of the two largest reservoirs on the Salinas River drainage. For the Pájaro River, where flooding of agricultural fields on the coastal plain in 1995 provoked brutal decimation of the riparian vegetation along that reach, the combined detention storage possible with restoration of upstream floodplains (Curry et al. 2003) and tributary uplands clothed in nonnative grasslands (Jigour 2010 in press) could significantly alleviate downstream flooding, ideally allowing restoration of riparian features that were not the cause of flooding in the first place. In other cases, significant areas of nonnative grassland occur on watersheds above reservoirs; with vegetative restoration the effective storage capacity of those reservoirs could be increased.

The bulk of my dissertation is in the Part 1 Literature Review, with the Part 2 Synthesis focusing on California's nonnative annual grasslands. Recognizing the obvious application of my subject to the watersheds feeding the Bay-Delta, I proposed a presentation for the 2008 CALFED Biennial Science Conference. My request to present was denied, but I was offered a poster slot, which I accepted (Jigour and Ponce 2008b). Despite its large size and colorful layout, my poster was a virtual wallflower, as most attention was seemingly on the CALFED-funded projects. I did give a presentation earlier that year to a much more receptive audience at the SERCAL annual conference (Jigour and Ponce 2008a), though I concede it felt a bit like "preaching to the choir", while the concepts and information I presented were new to all. Recognizing that it was apparently a mistake to expect the CALFED audience to apply the lessons of Central Coast steelhead watersheds to the salmon watersheds of the Bay-Delta, I subsequently added text to my Part 2 synthesis offering preliminary estimates of increased detention storage with vegetative restoration of nonnative annual grasslands on watersheds feeding the Bay-Delta, using GIS data compiled by others, but also based on the California Gap Analysis (Davis et al. 1998). Additionally, I developed a set of section/elevation illustrations originally drawn from elements in the CALFED poster.

Having missed the Bay Delta Conservation Plan CEQA input process while ensconced in these and other dissertation refinements, I attempted to alert the California Department of Water Resources (DWR) to this watershed restoration for baseflow augmentation option by providing written input, including earlier versions of the figures included in the accompanying attachment, to the California Water Plan Draft 2009 Update public comment page. In full knowledge that my proposed strategy has been articulated nowhere else to date, with the exception of Ponce (1989) and his related publications, my comments invited DWR to request additional information from me but I never received a hint of curiosity about it. Perhaps the problem was the flaw in my earlier drawings. Perhaps those focusing on the Bay-Delta only looked for pertinent comments in the Bay-Delta regional report—again, not seeing the watershed for the Delta. In any case, it left me with the impression that my comments were not taken seriously. That impression was only heightened when my separate attempts in July, August and September 2009 to get some of my information before the Bay Delta Conservation Plan Steering Committee were quite blatantly ignored (I documented those efforts).

It seems there is no escaping the influence of politics on science—among the historical reasons the strategy I propose has been overlooked for so long. Indeed, the involvement of the NRC is a direct result of political influences, as the committee well understands. But the committee's scientific orientation, as well as the emphasis on finding holistic solutions, gives me some hope that my proposed strategy will at least receive some serious consideration.

Application to Watersheds Feeding the Bay-Delta

I presented a synopsis of my proposed watershed restoration for baseflow augmentation strategy in my overall comments on the California Water Plan Draft 2009 Update, Resource Management Strategies, submitting a separate comment letter on the Central Coast regional report. In an early section of that Resource Management Strategies comment letter I noted the lack of attention to streambank and floodplain detention storage, based on my review of past CALFED Science Conference abstracts. My observation, based on perusal of years of CALFED abstracts, as well as the delineations made in funding opportunities and conference breakouts, is that CALFED has considered riparian areas solely from an ecological standpoint, rather than in the context of water quantity or storage. The same is essentially true for watersheds.

Following, in dark blue, are the excerpts from my dissertation section 2.4.4. Foothill Rangelands to Floodplains: Regional Applications, that I included in those comments on the California Water Plan Draft 2009 Update.

The regional GIS analyses described in Part 3 illuminated opportunities for watershed restoration for baseflow augmentation on extant Non-Native Grassland in the central and south coastal regions of California, but the principle is clearly applicable to other regions of the state. The foothill landscapes ringing California's great Central Valley exemplify the now-subtle evidence of prehistoric, as well as historic land management patterns. It's actually not subtle at all if you understand what you're looking at – it stands out vividly, for example, in Figure 2.23.

A report documenting the process of biologically prioritizing rangelands for conservation, prepared for the California Rangeland Conservation Coalition (The Nature Conservancy 2007a) identifies a total 7,928,141 acres of annual grassland[8] in their study area, which encompasses the lands featured in Figure 2.23. These lands, highlighted in the coalition's map of priority areas (The Nature Conservancy 2007b), comprise the most significant opportunities for watershed restoration for baseflow augmentation in California. However, since that analysis excluded degraded areas, the priorities identified in the map do not represent the highest priorities for watershed restoration, and areas shown there as green, indicating "public and privately protected land" of lesser priority in that analysis, are of equivalent interest with respect to restoration for baseflow augmentation. Nevertheless, the map provides a helpful reference to the majority of the specific lands of interest for watershed restoration and the analysis provides fundamental knowledge of biological sensitivities on those lands that is prerequisite to region-wide planning for watershed restoration.

Applying the estimating standard used in Part 3 – an average 12 inches of increased subsurface storage depth, so that acres equal acre-feet – to the total annual grasslands identified in table 4 of that report (The Nature Conservancy 2007a) suggests a potential approximately 7,928,141 acre-feet of additional subsurface water storage with restoration on existing annual grasslands in the central portion of the state. Combining that figure with the potential storage likely available with restoration of floodplains and riparian zones, well over 8 million acre-feet of additional storage is possible without building new dams and in a manner that will only increase in effectiveness over time, in contrast with the declining value of reservoirs over time. …

2.4.4.2.2. Restoration on Nonnative Annual Grasslands & Hardwood Rangelands

The following is from the SNEP, "Assessment Summaries and Management Strategies, Chapter 7. Rangelands" (SNEP (Science) Team 1997):

> Major conversions from 1945 through 1973 were from rangeland clearing for enhancement of forage production. Since 1973, major losses have been from conversions to residential and industrial developments.
>
> Introductions of domestic livestock and exotic annuals have led to dramatic changes in hardwood rangeland ecosystems. The herbaceous layer has changed from a perennial layer to an annual layer. . . . Soil moisture late in the growing season has

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8 The coalition's GIS study used the same vegetation data source (Davis et al. 1998) used in the Part 3 GIS analysis, wherein the term Non-Native Grasslands identifies annual grasslands.

> decreased, and soil bulk density has increased due to compaction from higher herbivore densities. . . .
>
> **Ironically, factors that cause livestock operations in hardwood rangelands to suffer low profitability and high risk are leading indirectly to conversion of these lands from extensively managed private ranches to suburban developments.** . . .
> [SNEP (Science) Team 1997, emphasis added]

This observation gets at the heart of why it is so critical that we begin to place monetary value on the ecosystem, including watershed, services of privately managed lands, and, as water users, collectively pay for those services.

Figure 2.23 suggests significant opportunities with respect to nonnative annual grasslands in the foothills lining California's great Central Valley. Some of the light-colored areas in Figure 2.23 may represent oak woodlands or savannas with limited canopy area. While it is not among the most expansive land covers in the region, the gap analysis of Sierran vegetation (Davis and Stoms 1997) tabulated 1,923 square kilometers (1,930 square miles, or 1,235,456 acres) of Non-Native Grassland in the Sierra region. Applying the same estimate applied to the central and south coastal analysis in Part 3 to that figure – an average 12 inches of increased subsurface storage depth, so that acres equal acre-feet – the **potential storage possibilities with watershed restoration on Non-Native Grassland in the Sierras total over 1 million acre-feet.**

"Hardwood rangelands" is a utilitarian term that may be more recognizable to many landowners than oak woodlands and savannas, but it's also a convenient catch-all term for an economically functional land-cover type comprised of several different plant association categories in the California Natural Diversity Database (CNDDB) codes used for the GIS analyses. In order to discern the proportion of those rangelands with Non-Native Grassland understories it would be necessary to perform an analysis similar to the one I did to arrive at Tables S-9 and S-10, whose results are summarized in 2.3.4. The SNEP Chapter 7, Rangelands, provides the following figure for hardwood rangelands, which may overlap some of the area attributed to Non-Native Grassland:

> There are 4.7 million acres of hardwood rangelands (also known as oak woodlands) in the Sierra Nevada region. … These lands are concentrated in the western foothills (85% on private land) in a belt 20-30 miles wide from 450 to 4,500 feet in elevation. Nearly 800,000 acres of hardwood rangelands habitat in the Sierra Nevada were converted to other land uses and vegetation types over the last forty years, an overall decline of almost 16% and highlighted by individual county losses as high as 42% [represented in a table]. Major conversions from 1945 through 1973 were from rangeland clearing for enhancement of forage production. Since 1973, major losses have been from conversions to residential and industrial developments.
> (SNEP (Science) Team 1997)

The SNEP Science Team considers the ongoing "Conversion of Hardwood Rangelands" among its "Critical Findings".

> Human settlement patterns represent the largest threat to continued sustainability of ecological functions on hardwood rangelands
> (SNEP (Science) Team 1997)

Part 1 [of Jigour (2010)] presents ample evidence to support the protection of oak woodlands throughout the state for their watershed services, whose sustainability the water-using beneficiaries must be willing to pay for. **Protection and ecological restoration of oak woodlands and their understories should be considered of highest priority to realize the greatest subsurface water storage capacity soonest**. Some yet-to-be-determined portion of the 4.7 million acres of hardwood rangeland can be restored to enhance subsurface storage capacity. Basing the estimate on the known total of Non-Native Grasslands and some portion of the hardwood rangelands, it appears that, **with watershed restoration, at least an additional 1 to 2 million acre-feet of detention storage may be realized in the Sierra Nevada foothills**.

And that doesn't even consider the possibilities with inclusion of rangelands on other watersheds feeding the Bay-Delta system. Figure 2.23 suggests opportunities in the western Sacramento River Valley, as well as the Sierran foothills that fall into the nearly 8 million acres identified in the 2.4.4. introduction. Watershed restoration on all these lands, along with restoration of whatever additional streambank and floodplain storage may be available, could be a highly cost-effective way of protecting Sacramento from flooding. As urban stormwater quality protection educational materials have touted, the objective is to **start at the source**, where watershed protection is least costly and most effective.

Another watershed consideration applicable to ongoing concerns over the greater Sacramento and San Joaquin River drainages is the impacts on watershed functions of a variety of fuel modification procedures implemented by private landowners in the Sierra foothills and other catchments feeding into the Bay-Delta ecosystem and state water project.

Following is an excerpt from earlier in that comment letter that summarizes my concept of how this strategy would be most equitably funded:

Once one understands the potentially profound implications of this strategy for California's near-and long-term water resources, the applicability of ecological economics should become clear. The current draft plan discusses "willingness to pay" in terms of local residents paying to restore their own local watersheds. But for watersheds that feed into the state water project, it makes far more sense to have **water users pay for watershed restoration and long-term management in exchange for those watershed services**. Watershed restoration will be far less costly than structural storage strategies and the benefits will only increase over time – a potential return on investment unmatched by conventional investment strategies, as we've seen so clearly in our recent economic downturn. Furthermore, this approach has the potential to generate far more "green jobs", distributed over a far broader geographic area than centralized structural storage options.

I trust the NRC committee to integrate this input as appropriate to the report it is currently entrusted with. As I offered the California Department of Water Resources, I will gladly provide my dissertation and/or the book manuscript I am deriving from it, to the committee upon request. I place no expectations on any recipients of the document to read the whole thing. It is long, though really not much longer than a longish book, once taken out of its double-space dissertation format. But considering the extraordinarily extensive literature review I've compiled, I would think that, at the very least, those links to pertinent literature spanning a century could support the committee's work. Because I've received no outside funding for the lion's share of my dissertation efforts, I cannot afford to make much of it freely available to the public, hoping to recoup some of my enormous expenses through publication of a couple books based on it. So this is "a limited time offer".

Since yours is a federal project, permit me to end with a quote from our 32nd U.S. President.

> Our disastrous floods, our sometimes almost equally disastrous periods of low water, and our major problems of erosion … do not come full grown into being. They originate, in a small way, in a multitude of farms, ranches, and pastures.
> [President Franklin D. Roosevelt 1936, in Transmitting the Little Waters report to Congress per (Schiff 1962) p. 140, footnote 68 p 211]

Thank you for your consideration of this summary.

Respectfully,

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Attn: **National Research Council Committee Members** **December 9, 2010**
via emailed pdf to RSO David Policansky;

Project: **Sustainable Water and Environmental Management in the California Bay-Delta**
PIN: DELS-WSTB-09-09

Subject: **1. BDCP vs. central valley groundwater overdrafts identified through GRACE?**
2. Carbon offsets to help fund long-term watershed conservation

Dear National Research Council Committee Members,

Comments made by Jerry Johns in response to your excellent questions at the December 8th meeting, as well what didn't come up, suggest that there is a likely disconnect of the BDCP process from the news last December of staggering California central valley groundwater overdrafts in recent years, identified through the GRACE satellite mission. It seems reasonable to question how the Bay Delta system would not be impacted by such overdrafts and how this information should be correlated with BDCP. I'm guessing that at least some committee members may already be aware of this news, but it can't hurt to (try to) bring this to your attention. Below is another excerpt from my refined dissertation (Jigour 2010 in press) to which I added a summary and links to the original 2009 information. Following the quotations, I also provide my conversions of the principle numbers into acre-feet.

1. How can/should this news from GRACE be applied to the BDCP process?

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2.4.3.1. Water Rights & Groundwater Regulation. . .

2.4.3.1.2. Need for Regional or Statewide Regulatory Oversight

Existing hydraulic models applied to surface waters differ mathematically from those applied to groundwater and this difference is among the reasons systemic, or integrative approaches addressing their interrelationships, have been lacking. But an intriguing application of satellite technology to study changes in the gravimetric weight of water among the components of large hydrologic systems has offered the first startling evidence of systemic overdrafts from the watersheds feeding the Sacramento/San Joaquin Rivers Delta, including especially large groundwater overdrafts from the San Joaquin River basin.

University of California Irvine, NASA and other institutional collaborators reported their initial findings from the GRACE (Gravity Recovery and Climate Experiment) twin satellite mission at the fall 2009 meeting of the American Geophysical Union in San Francisco. The abstracts for "Total water storage change over the San Joaquin and Sacramento River Basins comparing GRACE and observational data" (Ho and others 2009) and "Water storage change in the Sacramento and San Joaquin River Basins since 2003, including Central Valley groundwater depletion" (Bethune and others 2009) are available from the AGU web site. A *ScienceDaily* article, "California's troubled waters: satellite-based findings reveal significant groundwater loss in Central Valley" (University of California Irvine 2009) offers additional detail.

> GRACE monitors tiny month-to-month differences in Earth's gravity field primarily caused by the movement of water in the planet's land, ocean, ice and atmosphere. Its ability to "weigh" changes in water content provides new insights into how climate change is affecting Earth's water cycle.
>
> Combined, California's Sacramento and San Joaquin drainage basins have shed more than 30 cubic kilometers of water since late 2003, said Jay Famiglietti, UCI Earth system science professor and director of the UC Center for Hydrologic Modeling. A cubic kilometer is about 264.2 billion gallons, enough to fill 400,000 Olympic-size pools. The bulk of the loss occurred in the state's agricultural Central Valley. The Central Valley depends on irrigation from both groundwater wells and diverted surface water.
>
> "GRACE data reveal groundwater in these basins is being pumped for irrigation at rates that are not sustainable if current trends continue," Famiglietti said. "This is leading to declining water tables, water shortages, decreasing crop sizes and continued land subsidence. The findings have major implications for the U.S. economy, as California's Central Valley is home to one-sixth of all U.S. irrigated land and the state leads the nation in agricultural production and exports."
>
> "By providing data on large-scale groundwater depletion rates, GRACE can help California water managers make informed decisions about allocating water resources," said project scientist Michael Watkins of NASA's Jet Propulsion Laboratory.
>
> Preliminary studies show most of the water loss is coming from the more southerly located San Joaquin basin, which gets less precipitation than the Sacramento River basin farther north. Initial results indicate the Sacramento River basin is losing about 2 cubic kilometers of water a year. Surface water losses account for half of this, while groundwater losses in the northern Central Valley add another 0.6 cubic kilometers annually. The San Joaquin basin is losing 3.5 cubic kilometers a year. More than 75 percent of this is due to groundwater pumping in the southern Central Valley, primarily to irrigate crops.
>
> Famiglietti said recent California legislation decreasing the allocation of surface water to the San Joaquin basin is likely to further increase the region's reliance on groundwater for irrigation. "This suggests the decreasing groundwater storage trends seen by GRACE will continue for the foreseeable future," he said. …
>
> (University of California Irvine 2009)
>
> Our results show that the Sacramento river basin is losing 30 mm of water a year, half of which is lost from surface water, while an additional 8 mm/yr are lost from groundwater. The San Joaquin basin is losing 42 mm/yr, over 75% of which

(32 mm/yr) we calculate to be lost from groundwater.

(Bethune and others 2009)

Converting these figures into the traditional water resource denomination of acre-feet used herein, the total loss of 30 cubic kilometers among the two basins since 2003 corresponds to 729,164,154 acre-feet. The annual loss of 3.5 cubic kilometers from the San Joaquin basin corresponds to a loss of 85,069,151 acre-feet per year. The enormous scale of overdrafts calculated through these analyses dwarfs the potential estimated benefits of watershed restoration discussed herein, as well as those of other conservation strategies. Some systemic regulation of groundwater appears inevitable in the face of such unsustainable extraction. However, the need for groundwater regulation does not negate the cumulative value of the integrative watershed restoration approach described herein. The application of GRACE to regional water balance analysis appears an exciting step toward more systemic approaches that may better accommodate the role of vadose zone hydrology than was previously possible.

Especially in the case of multiple watersheds feeding a single ecosystem, like that of the San Francisco Bay-Delta ecosystem, it seems that ultimately, the applicable laws will have to evolve to accommodate our 21st century, systemic understandings of the nonlinear path of water—through atmospheric flows, through our watersheds, including vadose zone and groundwater flows, through the oceans' flows, and back again. Considering how the interests of those with the most money can easily dominate over the best interests of the greater public in local agency CEQA and other regulatory processes, it does appear that some regional or statewide regulatory oversight is needed to ensure implementation of watershed restoration for baseflow augmentation.

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2. Regarding the summary I submitted to the committee July 30, 2010 on Watershed Restoration for Baseflow Augmentation, I realize that I implied but did not specifically point out that, given a flourishing and expansion of the carbon market beyond above-ground stocks, long-term management of private lands for watershed functions could be at least partially supported through carbon offsets. I trust it doesn't hurt to mention what may be obvious in the context of a likely diminishing responsibility of water agencies to fund such watershed services once they've been established. That ecological economics context helps to frame initial expenditures for watershed restoration as truly sound investments.

Respectfully,

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