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Applying the Connectivity Approach:

GROUNDWATER MANAGEMENT IN CALIFORNIA'S KINGS BASIN

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Cover: The Consolidated Irrigation District (CID) South and Highland Banking Project. Photo by the CID.

About the California Roundtable on Water and Food Supply (CRWFS)

The California Roundtable on Water and Food Supply (CRWFS) is a multi-sector forum of experts and leaders convened by Ag Innovations to identify obstacles, develop solutions, and take action to enhance water security for agriculture, the public, and the environment in California. The CRWFS has completed a topic-specific module every year since its inception in 2010, and has produced the following three reports in addition to this one: *Agricultural Water Stewardship: Recommendations to Optimize Outcomes for Specialty Crop Growers and the Public in California, From Storage to Retention: Expanding California's Options for Meeting Its Water Needs, and From Crisis to Connectivity: Renewed Thinking About Managing California's Water & Food Supply*. Reports and additional supporting materials can be accessed at: aginnovations.org.

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> STUDYING THE KINGS BASIN REGION HAS REVEALED OPPORTUNITIES FOR IMPROVED CONNECTIVITY IN GROUNDWATER PLANNING AND MANAGEMENT THROUGHOUT CALIFORNIA FOR THE BENEFIT OF AGRICULTURE, THE PUBLIC, AND THE ENVIRONMENT.

PHOTO BY KINGS RIVER CONSERVATION DISTRICT

EXECUTIVE SUMMARY

The California Roundtable on Water and Food Supply (CRWFS) studied the processes used in the Kings Groundwater Subbasin (Kings Basin) of California's San Joaquin Valley to reveal strategies for advancing groundwater sustainability within the context of watershed-scale, integrated water management. This inquiry was guided by the principles of the "connectivity approach"[1]: a framework developed by CRWFS for resource managers, land use planners and policymakers to discover the linkages, strengths, successes, potentials, and disconnects related to their particular resource stewardship issues. A key concept is connected benefits, which refers to achieving multiple benefits across resource and development sectors to respond to California's increasing water management challenges.

Kings Basin Successes

The Kings Basin was chosen as a case study because it is addressing many of the water challenges existing within California, and because notable connected benefit successes have been accomplished from effective multi-stakeholder collaborations and the leadership of several local agencies. Key findings from this case study include:

- Resource managers have achieved an exceptional level of understanding of the Kings Basin water system because of an expansive water monitoring and modeling program. Additionally, basin-wide data are integrated and managed by a single entity, the Kings River Conservation District (KRCD), which is a leading resource management agency for the Kings River region. The KRCD has also taken a leading role in facilitating the efforts of the Kings Basin Water Authority (KBWA).
- Resource managers have completed an array of connected benefit and groundwater-specific projects to address groundwater overdraft. There is a collective recognition that groundwater overdraft is resulting in conflicts among water users, economic losses, and environmental harm, and could also undermine the public trust of this natural resource.
- The KBWA has become a forum where water agencies and land use planning authorities can interact to align goals and coordinate priorities. The Integrated Regional Water Management (IRWM) Plan update process has integrated information, challenges and potential solutions that were first addressed in water management plans and the general plans of land use authorities.
- The KBWA and the KRCD have connected with resource managers in the upper watershed, including the new Southern Sierra IRWM group, and have worked together on interregional projects.
- The KBWA, Community Water Center, and Self-Help Enterprises have engaged and integrated a diverse group of stakeholders into the IRWM planning process. Together they have made great strides to identify the water-related needs of the region's Disadvantaged Communities, and explore a range of possible solutions.

Opportunities for California

This assessment of the Kings Basin region revealed opportunities for improved connectivity in groundwater management planning and implementation in California in the following four areas. These recommendations should be treated as entry points into deeper explorations of policy and implementation strategies by other hydrologic regions.

Upper and lower watershed connectivity

- Improve the scientific understanding of headwater processes and the influence of different mountain forest and meadow restoration and management strategies on the hydrologic cycle through research and monitoring to improve water supply and quality, and flood management.
- The water budgets developed for medium and high priority groundwater basins should consider upper watershed conditions and processes.
- Align and augment institutional cooperation across the watershed scale, either through the development and implementation of joint priorities and projects across regional water management groups (RWMGs), or the formation of unique multi-stakeholder coalitions.

Surface and groundwater storage connectivity

- New water storage efforts should include integration of all hydrological components affecting water availability, movement, and retention to improve supply reliability for evolving needs[2].
- State government should reexamine current policies and regulations to encourage and expand groundwater recharge, especially for medium and high priority groundwater basins.
- State government should regard the recovery of depleted groundwater basins as a public benefit and allocate public funds to incentivize net groundwater recharge.

Alignment of governance structures and tools

- Perform a network analysis of the agencies and governance tools having authority, oversight, or influence on groundwater management; identify inconsistencies and conflicts between them; and assess their alignment with sustainable groundwater management goals.
- Increase coordination between state and federal agencies in support of integrated regional water management and groundwater sustainability.
- Explore opportunities to integrate water and land use planning and management by taking advantage of the requirement of the Sustainable Groundwater Management Act (SGMA) to share information between water supply or management agencies and land use approval agencies.
- Explore opportunities for coordination and consultation between regional water management groups (RWMGs) and emergent groundwater sustainability agencies (GSAs).

Improved public and stakeholder engagement

- Increase financial and technical assistance programs to support the development and endurance of functioning multi-stakeholder collaborations around integrated regional water management.
- Enhance outreach to and engagement of segments of the public that have been inadequately engaged using a combination of traditional and new media outreach strategies.

INTRODUCTION

In this report we present the results of a case study of the application of connectivity principles to groundwater management and decision making in the Kings Groundwater Subbasin (Kings Basin) of California's San Joaquin Valley (Fig. 1). Our aim is to understand how robust solutions to groundwater challenges can emerge from an integrated approach to holistic watershed management through the example of this subbasin, and to extract recommendations with applicability to other regions of California. The connectivity approach, described in detail in the report From Crisis to Connectivity: Renewed Thinking about Managing California's Water and Food Supply [1], provides a framework for assessing water and food supply challenges and developing resilient solutions. Groundwater is an integral part of a larger hydrologic cycle, thus this inquiry considers more than just the focal groundwater subbasin.

Several features of the Kings Basin make it a particularly important case study with lessons for California as a whole. Groundwater overdraft is generally considered the greatest water management challenge for this region, as it is for many other parts of the state, and this challenge has only been exacerbated during recent drought years. The farmers and other water users of this region are reliant on both surface and groundwater, and are influenced by an intricate federal, state, and local water supply system. Much of the Kings Basin region is developed for irrigated agriculture, and a wide variety of crops are produced for domestic and international markets. The region approximates the classic representation of the hydrologic cycle in which water originates as precipitation in the mountains, runs off in

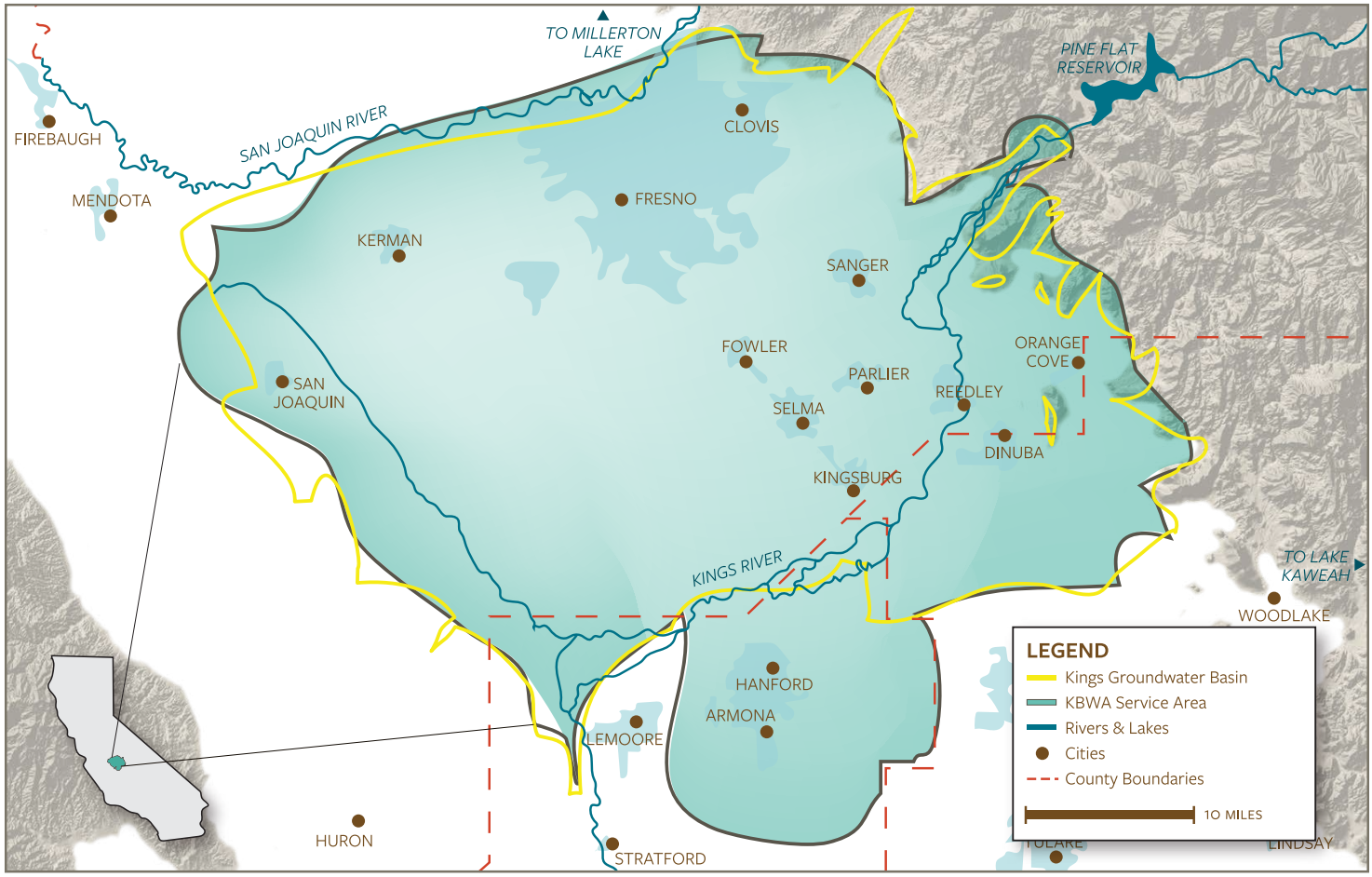

FIGURE 1: MAP OF THE KINGS BASIN REGION [3]

streams and rivers, and feeds alluvial groundwater basins. Lastly, the region has over a decade's worth of experience with integrated regional water management that has resulted in a number of successful connected benefits, and provided a path for further integration between lower and upper watershed management, land- and water-use planning, and surface and groundwater storage strategies.

Managing a groundwater basin for sustained water supply and quality is a long-term and complex task requiring a systemic approach that recognizes human systems as a subset of larger ecosystems, and that promotes alignment between these systems. The California Roundtable on Water and Food Supply (CRWFS) introduced this "connectivity approach" in a previous report[1], and recommends that it be applied to the development of groundwater management strategies within a given watershed. The connectivity approach establishes a number of principles within three areas: connected thinking, socioeconomics and institutional linkages, and public and stakeholder engagement. This approach guides a process of discovery and consensus building on interventions and solutions for the mutual benefit of agriculture, the public, and the environment. The three areas can be treated as separate but interrelated lenses through which an issue can be examined. Guiding principles are most usefully employed in the form of questions to assess how connected approaches have been successful, and where opportunity exists for increased connectivity. Recommendations yielded from this effort should be treated as entry points into deeper explorations of policy and implementation strategies for specific regions, and not a prescriptive roadmap.

KINGS BASIN SUCCESSES

Connected Thinking

Understanding natural systems

Sustainable groundwater management depends on groundwater and surface water supply and quality data that is comprehensively collected and analyzed over time. Good information is the foundation for accurate models of groundwater basin and surface watershed boundaries, hydrology, and interaction dynamics. A recent review of 120 groundwater management plans in California revealed that significant data were lacking in almost all existing groundwater plans [4]. In contrast, the Kings Basin water system is understood fairly well because of an expansive and long-running water monitoring and modeling program, and because one agency, the Kings River Conservation District (KRCD), integrates and manages data from across the entire subbasin (Fig. 4). Local agencies and the Department of Water Resources (DWR) collaborate to collect groundwater data through one of the largest basin monitoring networks in the state. Surface water is monitored at the Kings and San Joaquin rivers, which are hydrologically connected with the underlying groundwater subbasin, as well as along a 1,000-mile long canal network. Regional groundwater withdrawal rates are primarily modeled on semi-annual measurement of groundwater elevation and estimates of crop irrigation requirements.

The KRCD hired a consultant to develop a regional model that simulates surface water and groundwater systems called the Kings Basin Integrated Groundwater and Surface Water Model (Kings IGSM), which at its launch was one of the best available models for the region. The Kings IGSM and its supporting data were made available to the Kings Basin Water Authority (KBWA) to promote consistent modeling across the subbasin. The Kings IGSM includes specific features that allow for the evaluation of Kings River basin water supply and flood management under different scenarios, including climate change[5]. Still, running the model requires a high level of technical expertise, is costly, and has limited transparency due to non-disclosure agreements on the source data. The KRCD and its regional partners have begun a process to modernize and expand the model recognizing that Kings IGSM data is current only through 2004, several important hydrologic boundaries are inadequately modeled, and there is a need to enhance transparency.

The new model is proposed to be more flexible and able to assess future regional impacts and water balance scenarios, thus Kings Basin water agencies will be well positioned to develop groundwater sustainability plans under the 2014

CONNECTIVITY

Connectivity defines the relationships that link the individual parts of a system to form a whole. It recognizes that the actions of one component within a system have an impact, both on the other components of that same system, and upon other, linked systems. The connectivity approach uses this understanding to better align the interactions between human systems (i.e., engineered resource systems, cultural norms, and institutions) and ecosystems (i.e., climatic, chemical and biological systems, and natural resources). This approach proposes that human systems are a central subsystem of the larger ecosystem (Fig. 3), rather than systems that exist apart from and only linked to ecosystems (Fig. 2). The goal of this alignment is to more effectively design for, and simultaneously achieve, benefits for agricultural and urban users, while ensuring environmental restoration, protection, and stewardship. For a more thorough discussion of connectivity and the connectivity approach, see *From Crisis to Connectivity: Renewed Thinking About Managing California's Water & Food Supply* [1].

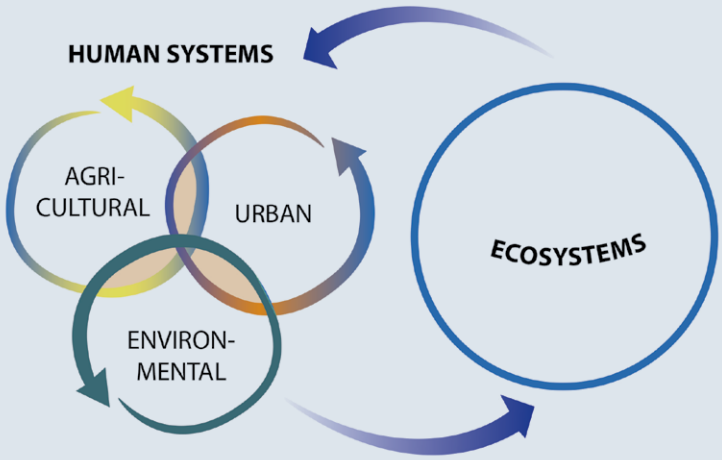

FIGURE 2: COMMON PERCEPTION OF CONNECTIVITY

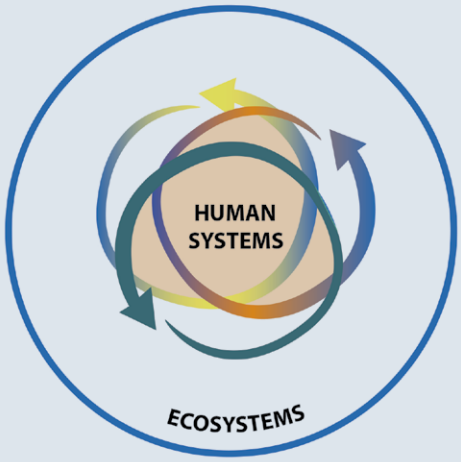

FIGURE 3: NEW VISION OF CONNECTIVITY

CONNECTIVITY PRINCIPLES

CONNECTED THINKING

1. Understand natural systems: Integrated thinking and science-based solutions
2. Recognize that water, farm land, and habitat are finite resources that depend on each other
3. Emphasize connected-benefit projects
4. Recognize that food is water
5. Focus on long-term goals versus short-term fixes
6. Avoid unintended negative consequences of past and emerging approaches

SOCIOECONOMICS & INSTITUTIONAL LINKAGES

1. Move beyond institutional goals and entrenchment
2. Address conflicting policies and regulations
3. Manage political and economic drivers
4. Shift from 'one-size-fits-all' solutions to collaborative, regionally-appropriate, whole systems strategies
5. Assess and manage unintended consequences
6. Design and implement approaches to manage the transition from existing to new practices

PUBLIC & STAKEHOLDER ENGAGEMENT

1. Participate versus consume
2. Public action from the ground up
3. Communicate with the public
4. Increase awareness and effectiveness of educational programs

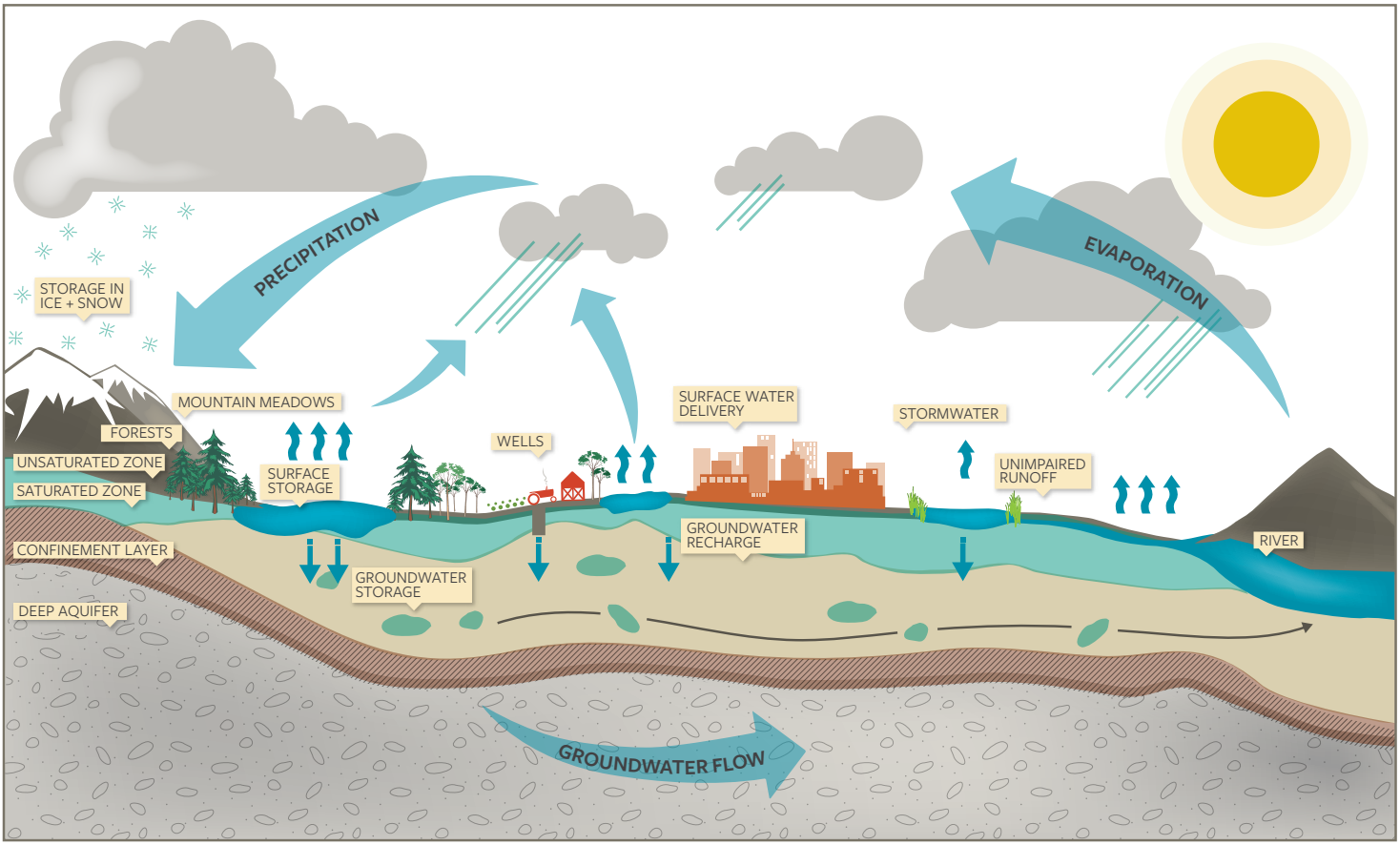

FIGURE 4: THE KINGS BASIN WATERSHED AND HYDROLOGIC CYCLE

Sustainable Groundwater Management Act (SGMA). In addition to constructing an improved in-basin model, there is a possibility to develop a better understanding of the hydrology from the headwaters to the subbasin at the watershed scale, and how different vegetation management and climate change scenarios might influence water supply reliability in the region. Also, analysis could be developed to assess different water management strategies in relation to the region's underlying ecosystem functions and services, so as to build resilience, improve efficiencies, lower costs, and encourage connected benefits.

Recognition that water, farmland, and habitat are finite and interdependent

The KBWA has identified groundwater overdraft as its primary concern, stating in its Integrated Regional Water Management Plan (IRWMP) that this issue "has the greatest potential to result in conflicts between water users, result in economic losses to both urban and agricultural economies, and impacts to the environment." Although individual agencies and landowners have been brought together in a process of regional water management, the KBWA recognizes that groundwater overdraft will only increase under current water management conditions. Thus, the KBWA and the KRCD have initiated and participated in interregional connected benefits projects as part of a strategy to reduce overdraft, improve water supply reliability and water quality, and protect environmental conditions. Toward this overarching goal the KRCD has supported floodwater capture and groundwater recharge projects, as well as ecosystem restoration projects. However, groundwater sustainability also involves reducing net depletions from overdrafted aquifers, in part by reducing groundwater use and extractions.

Emphasizing connected benefit projects

The KRCD and regional partners believe that an opportunity exists for the Kings Basin to advance towards a sustainable water balance by integrating floodwater capture with groundwater recharge and banking. Since 1932, irrigation districts and farmers have worked with the KRCD and partner agencies to develop

recharge strategies and infrastructure, which has resulted in an increase of tens of thousands of acre-feet in average annual water supply. A recent example of an alternative approach is the Terranova Ranch On-Farm Flood Capture and Recharge Project (Fig. 5). This project is being developed to capture flood flows and divert the water to about 15,000 acres of actively farmed land, resulting in improved downstream flood protection and enhanced environmental habitat. An assessment has revealed that one-third of the region's annual overdraft could be replenished with floodwater that can be captured using existing water distribution infrastructure, but there are too few infiltration basins to accommodate the volume (D. Mountjoy, personal communication, November 11, 2014).

Correcting the chronic and severe overdraft in the Kings Basin using flood water capture during wet years will require either many more infiltration basins, or a combination of basins and substantial on-farm flood capture. Numerous farmers would need to be persuaded to integrate in-lieu groundwater recharge into their operations [6]. Several current studies aim to increase farmer awareness and acceptance of on-farm floodwater capture, including an infrastructure cost analysis as well as the development of a model for nitrate and salt leaching. At the same time, major state policy issues about groundwater recharge need to be addressed. Groundwater recharge has generally not been considered a beneficial use, and the recovery of overdrafted basins has not been treated as a public benefit, eligible to receive public funding, for example from the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (hereafter referred to as the Water Bond). Additionally, there needs to be a deeper analysis of the systemic impacts of on-farm water conservation measures, as reducing applied water may have undesirable outcomes. In some cases, the benefits of water applied over and above a crop's needs include availability for on-farm re-use, groundwater recharge, the provision of wildlife habitat, or supply of runoff for possible use downstream[7].

Socioeconomics and Institutional Linkages

Moving beyond institutional goals and entrenchment

Cooperation between land use planning authorities and water agencies is critical to the realization of a sustainable water budget, and the KBWA has become a forum where the two sectors interact. The KBWA is a coalition of 54 public, private and non-governmental organizations which collaborate in managing water resources in an IRWM region encompassing a majority of the Kings Basin, as well as small portions of three other subbasins. Signatories to this IRWMP include many of the local governments exercising land use authority in the Kings Basin, including the County of Fresno, County of Tulare, and nine cities as members, as well as the County of Kings and the City of San Joaquin as interested parties. The recent IRWMP update benefited from this improved cross-agency communication by integrating information, challenges, assets, and potential solutions that were first addressed in general plans and various water management plans. Still, the authority or service boundaries of water agencies, land use planning authorities, and defined groundwater basins do not currently line up, leading to a disconnected approach to groundwater management in many cases. For example, although many of the region's general plans do discuss integrated land use and water supply planning, most do not specifically consider new water supply development or groundwater management. The KRCD and KBWA continue to focus on this challenge, and recently convened a Groundwater Land Use Symposium with other partners to advance the dialogue.

FIGURE 5: VINEYARD BEING FLOODED AS PART OF THE TERRANOVA RANCH ON-FARM FLOOD CAPTURE AND RECHARGE PROJECT. PHOTO BY SUSTAINABLE CONSERVATION.

Moving toward collaborative, regionally appropriate, whole systems strategies

The KBWA and KRCD operate within the lower portions of a watershed that extends into the Sierra Nevada Mountains. Rain and snow that fall in these mountains are the primary sources of surface water for users in the Kings Basin, a region that only receives seven to ten inches of rain annually. In fact, the hydrologic cycle of the region is such that a majority of the groundwater stored in the subbasin originated at one point as precipitation in the Sierra Nevada. Recognizing that the supply and quality of water used by its farms, communities, and habitats is connected to management decisions occurring in the upper watershed, the KRCD and KBWA have been supporting projects and partners upstream of their management area since the 1950s, when cloud seeding efforts were first initiated. An example is the Big Meadows project, which restored the natural flow of water to one of the largest mountain meadow systems in the area, leading to downstream improvements in water supply reliability. Additionally, the IRWM groups representing the lower watershed (KBWA) and the upper watershed (Southern Sierra Regional Water Management Group (SSRWMG)) have explored opportunities for integrated water management activities with benefit to both management areas, including reduction of resource damage to Mill Flat Creek, an important tributary to the Kings River below Pine Flat Dam.

The KBWA has been regularly coordinating efforts with the regional Tulare-Kern Hydrologic Region Group and the statewide Roundtable of Regions. More recently, the KRCD has participated in the nascent Tulare Basin Watershed Connections Workgroup, a multi-agency, intra-regional and inter-jurisdictional collaboration aimed at advancing "collaborative watershed planning and resource management in Tulare Basin based on sound science and mutually identified needs for regional economic and ecological sustainability." There is an opportunity for Kings Basin water agencies to forge fruitful new collaborations with upper watershed resource managers through their continued participation in these regional and statewide groups. While the KRCD and KBWA are not actively engaged in forest management, the lower watershed managers can support these efforts in numerous ways: (a) the development of holistic watershed IRWMP project priorities, (b) the backing of project funding requests put forward by a neighboring RWMG through letters of support, and (c) the development and implementation of multi-RWMG projects directly benefitting each service area.

Public and Stakeholder Engagement

Communicate with the public

The KBWA has engaged and integrated a diverse group of stakeholders in the Integrated Regional Water Management (IRWM) planning process in partnership with the Community Water Center and Self-Help Enterprises. In fact, the KBWA currently involves 11 of the 13 different stakeholder categories identified in the California Water Code. Yet, reaching and involving the over one hundred Disadvantaged Communities (DACs) of the Kings Basin remains a major challenge, as the DACs have limited capacity, including income level, language barriers, and administrative and technical constraints. While DACs are welcome to join the KBWA free of cost as Interested Parties, rates of participation can be improved. Thus, the KBWA has undertaken several studies aimed at developing a comprehensive inventory of DACs and their water-related needs, and exploring a range of possible solutions. Several recommendations for improving DAC involvement in the IRWM process within the Kings Basin have been developed as a result of these studies. They include the funding of a Regional DAC Coordinator to spearhead these efforts, increased collaboration with local non-government or community-based organization to improve outreach penetration, and the development of training opportunities around planning, project development and grant application development.

Our case study of the Kings Basin region revealed opportunities for improved connectivity in groundwater management planning and implementation throughout California for the benefit of agriculture, the public, and the environment. It also offered some approaches to meeting the requirement of the SGMA of creating local groundwater sustainability agencies and developing sustainable groundwater management plans. Four primary areas of opportunity were identified during our inquiry process: (1) upper and lower watershed connectivity, (2) surface and groundwater storage connectivity, (3) alignment of governance structures and tools, and (4) improved public and stakeholder engagement. These recommendations should be treated as entry points into deeper explorations of policy and implementation strategies by other specific hydrologic regions. This is not a prescriptive roadmap; rather it represents our best understanding at this time.

OPPORTUNITIES FOR CALIFORNIA

Upper and lower watershed connectivity

RECOMMENDATION 1: Improve the scientific understanding of headwater processes and the influence of different vegetation treatments on the hydrologic cycle through research and monitoring to improve water supply and quality, and flood management.

RECOMMENDATION 2: Consider upper watershed conditions and processes in the water budgets developed for medium and high priority groundwater basins.

RECOMMENDATION 3: Align and augment institutional cooperation across the watershed scale, either through the development and implementation of shared priorities and projects across RWMGs, or the formation of unique multi-stakeholder coalitions.

Managing groundwater sustainably requires an understanding of, and collaboration across, the entire hydrologic cycle, from the upper headwaters to the lower valleys. Ideally, the water budgets to be calculated for groundwater management plans developed under the SGMA should consider the impact of upstream mountain landscapes on the water balance at a watershed scale. The better the upper watershed data, the more accurate the seasonal water supply forecasting, particularly in a warming and more variable climate. Climate change scenarios estimate significant losses in mountain snowpack by end of century, depending on global warming emission levels[8]. However, the KBWA conducted a thorough investigation of the Kings Basin IRWMP area and concluded that, from a surface supply standpoint, this region will be less impacted by climate change than other watersheds in the state due to its high elevation and long history of conjunctive management to control for extreme variability. DWR's climate change staff concurred with the KBWA's findings.

Although models of water balance in the Sierra Nevada are informed by field measurements in some areas, there exist significant data collection gaps. Basin-wide deployment of hydrologic instrument clusters, in combination with remotely sensed data, would allow for more robust spatial estimates of snowcover, soil moisture, and other water-balance components. A number of projects are being conducted or are planned in several places in the Sierra Nevada range by university scientists[9] and the U.S. Forest Service[10] to model headwater processes and assess how different vegetation treatments influence the hydrologic cycle (Fig. 6). Still, the influence of different vegetation management strategies on the water yield and timing of snowmelt and runoff requires further validation across time and the range and distribution of ecotypes.

RWMGs are a potential vehicle for integrated water management across a watershed, although individual groups are rarely structured according to watershed boundaries, and integrated planning criteria do not explicitly mandate whole-watershed approaches. Therefore, under current IRWM program guidelines, integrated water management over a watershed and across RWMG service areas can occur primarily through: (a) the development of whole-watershed IRWMP project priorities, (b) the backing of project funding requests put forward by a neighboring RWMG through letters of support, and (c) the development and implementation of multi-RWMG projects directly benefiting each service area.

FIGURE 6: DESIRED CONDITION OF A PINE FOREST IN THE KINGS BASIN UPPER WATERSHED AFTER TWO PRESCRIBED FIRE TREATMENTS. PHOTO BY THE U.S. FOREST SERVICE

Seventy percent of the southern Sierra Nevada region is in public lands managed by state and federal authorities (S. Campe, personal communication, February 28, 2015), and may therefore be ineligible for funding under the Water Bond. The agencies, however, often partner with others to manage and protect these watersheds. The Water Bond will provide new funding opportunities for water management related projects, and those projects that emphasize connected benefits or which involve multiple partners will likely receive greater consideration for funding. Other types of multi-stakeholder associations can inspire and initiate whole-watershed collaborations outside of the RWMG structure, such as the semi-formal Tulare Basin Watershed Connections Workgroup[11].

Surface and groundwater storage connectivity

RECOMMENDATION 1: New water storage efforts should include integration of all hydrological components affecting water availability, movement, and retention to improve supply reliability for evolving needs.

RECOMMENDATION 2: State government should reexamine current policies and regulations to encourage and expand groundwater recharge, especially for medium and high priority groundwater basins.

RECOMMENDATION 3: State government should regard the recovery of overdrafted groundwater basins as a public benefit and allocate public funds to incentivize net groundwater recharge.

Groundwater is an important source of water supply for much of California even during wet years, and it remains the state's primary buffer against droughts. In order for a more effective and flexible surface and groundwater storage system to be advanced by the Water Bond, we must undergo a shift in the way that we, as a society, understand, define, and use storage as an element of integrated water management. In a previous report on this subject, we advocated thinking about water storage in terms of water retention in the landscape (CRWFS 2012). This includes considering a diversity of storage scales, methods, and locations, as well as working in concert with natural watershed dynamics and ecosystem functioning for maximizing short- and long-term resiliency in the system. It also requires that we transition from a mostly centralized system to one that captures water in many places using every appropriate technology and method: cisterns, bladders, engineered underground storage, on-farm ponds, regional ponds, soils, seasonal wetlands and larger reservoirs. Such distributed systems add significant capacity when considered in aggregate, but also reduce costs, increase local control, and benefit local farms and food security. Also, the water cycle can be slowed down and enhanced through land and vegetation management strategies that slow runoff, increase infiltration and soil water retention, and enhance water yields from snowpacks.

Conjunctive management has been a goal of many water managers for decades, because "water supply and environmental performance of additional storage capacity is greatest when surface and groundwater storage are operated together" (12). However, several valuable aspects of water storage tend to be overlooked in terms of their ability to contribute to the availability and reliability of water supplies for uses that benefit society. In particular, there is a tendency to overlook the value or public benefit of the state's farmlands in helping to retain water for later use while achieving many benefits, such as recharge, food security, flood management and habitat restoration. In order for this strategy for improving water security not to be squandered, the following two recommendations are made: (a) state government should reexamine current policies and regulations to encourage and expand groundwater recharge, especially for medium and high priority groundwater basins; and (b) state government should regard the recovery of overdrafted groundwater basins as a public benefit and allocate public funds to incentivize net groundwater recharge. Only projects deemed having a public benefit are eligible for Water Bond funding, thus, the numerous promising on-farm floodwater retention and groundwater recharge projects are not currently eligible for Water Bond support.

Alignment of governance structures and tools

RECOMMENDATION 1: Perform a network analysis of the agencies and governance tools that influence groundwater management, identify inconsistencies and conflicts among them, and assess their alignment with the hydrologic cycle.

RECOMMENDATION 2: Increase coordination among state and federal agencies in support of integrated regional water management and groundwater sustainability.

RECOMMENDATION 3: Explore opportunities to integrate

water and land use planning and management by taking advantage of the requirement of the Sustainable Groundwater Management Act (SGMA) to share information between water supply or management agencies and land use approval agencies.

RECOMMENDATION 4: Explore opportunities for coordination and consultation between regional water management groups (RWMGs) and emergent groundwater sustainability agencies (GSAs).

The current state of groundwater governance in California is a matrix of local, state, and federal agencies so complex in composition that neither water managers nor the individual government bodies fully understand the entire picture. Even under the most well-intentioned scenarios, this complexity leads to fragmented and misaligned tools which government has at its disposal to influence the direction of groundwater management, including regulations, policies, and incentives. Misalignment occurs primarily inter-organizationally such that different agencies mandate or promote different water management approaches. For instance, resource-specific agencies (e.g. water, air, land, pesticides) might have conflicting requirements for water management activities, leading a water manager to be in compliance with one agency's regulations and out of compliance with another's. This is particularly worrisome because a connected approach to water management requires action across resource types, so the fact that agencies remain "siloed" by resource type can hinder holistic management approaches. In order to clarify misalignments in governance, a network analysis should be performed to identify which agencies and governance tools influence the groundwater management realities in the state, and where contradictions or inconsistencies exist. The Governor's Water Action Plan and the SGMA require state agencies to consider the impact of their policies and regulations on sustainable groundwater management objectives, but it remains to be seen how this will be accomplished.

Increased coordination between state agencies could support integrated regional water management and groundwater sustainability, and different models should be explored. For instance, the regional offices of state agencies (e.g., DWR, State Water Resources Control Board, and Department of Fish and Wildlife) could meet with their RWMGs to develop collaborative, regionally appropriate goals and policies. At minimum, agency staff could be assigned to participate in RWMG meetings to keep abreast of issues and needs, as well as provide any needed guidance or assistance. Also, existing multi-agency bodies, particularly the Strategic Growth Council and California Biodiversity Council, should support integrated water resources planning and management at watershed scales. Lastly, there may be merit in reviving and redefining advisory boards to the key state agencies, such as the Agricultural Water Management Council, a nonprofit, which worked in partnership with DWR and was dissolved in 2013.

There is a great disconnect between groundwater and land use planning and management, as these two domains have existed under different regulatory environments, managerial structures, and planning processes. The ways in which we use land and conduct our transportation directly and indirectly influences groundwater supply and quality, flood management, and other water issues. While city and county general plans must take into account certain water issues, such as water pollution concerns under the California Environmental Quality Act and the Porter-Cologne Act, the inclusion of water supply elements in general plans remains a voluntary option. In fact, there exists no state oversight agency for land use, and the comprehensive resource management strategy on land use planning contained in the California Water Plan is only advisory. Groundwater depletion continues and intensifies with population growth, urban

FIGURE 7: GROUNDWATER LAND USE SYMPOSIUM IN CLOVIS, CA ON OCTOBER 29, 2014. PHOTO BY THE KINGS RIVER CONSERVATION DISTRICT.

development and agricultural demands, so it is critical that land use planning and groundwater management become more unified (Fig. 7).

Improved public and stakeholder engagement

RECOMMENDATION 1: Continue financial and technical assistance programs to support the development and endurance of functioning multi-stakeholder collaborations around integrated regional water management.

RECOMMENDATION 2: Continue outreach to and engagement of segments of the public and the business community that have been inadequately engaged using a combination of traditional and new media outreach strategies.

Many Californians are disconnected from their watersheds and the sources of their water. Moreover, groundwater as a source of supply is even more abstract given its subterranean nature. In part, this may be because the state's water distribution system is vast, complex and heavily engineered, and the regulatory and management processes are opaque and technocratic. Improved public and stakeholder understanding and engagement are critical for the realization of sustainability in groundwater management. Getting diverse groups of stakeholders engaged in an enduring, effective partnership around integrated regional water management activities is not easy. Success in regional, multi-stakeholder collaboration tends to grow with increased commitments of time and resources, and requires the creation of respectful, transparent, and trusting relationships. Thus, it is recommended that such efforts continue to receive the financial and technical assistance necessary to develop into and endure as functioning collaborations. Additionally, there needs to be a long-term commitment to communicating with and educating the public and business community about resource stewardship issues. Californians must understand why water has value, how the systems of water governance and management are designed and implemented, and what models and assumptions underlie management approaches.

The public engagement process will need to be highly inclusive and educational, allowing for trust-based exchanges of information so that everyone feels that they are operating from the same information base. There needs to be a focus on reaching those segments of the public and business community that have been inadequately engaged, such as certain groups of disadvantaged communities, farmers, and urban populations. Also, outreach strategies need to be multi-modal, utilizing both traditional and new media approaches. Over the past decade, there have been major advancements in the social technologies required for effective public participation and community engagement[13], and outreach[14]. These new social technologies should be deployed across a broad range of community engagement programs focused on groundwater sustainability in the state. The public ultimately determines what the funding levels and governance approaches are for the various resource management strategies that will need to be undertaken to ensure groundwater sustainability.

CONCLUSION

Applying the connectivity approach to groundwater management in the Kings Basin allowed us to identify recommendations intended to enhance groundwater sustainability in California. The approach can be applied in similar fashion to many other natural resource challenges, and provides a framework for whole-systems thinking inclusive of social, economic, and environmental considerations at a range of scales.

As demonstrated here, efforts are already underway to develop connected benefit solutions in the areas of connected thinking, socioeconomics and institutional linkages, as well as stakeholder and public engagement. In the Kings Basin, significant strides have been made in understanding the region's hydrology, supporting projects that reduce groundwater overdraft, and encouraging efforts that benefit farmers and the environment simultaneously. The KRCD and KBWA foster collaboration throughout the region and among key parties, and have begun working with partners upstream of their management area to improve water supply reliability and quality. In addition to public, private and non-governmental organizations, the organizations have engaged the community whenever possible.

As the implementation of the 2014 Sustainable Groundwater Management Act (SGMA) progresses, water managers in California will need to develop groundwater management strategies that integrate with overall water management and land use planning strategies. The formation of groundwater sustainability agencies (GSAs) and development of local sustainable groundwater management plans should occur within the context of a watershed-scale, integrated resource management strategy. This example of the Kings Basin can benefit water managers in determining and clarifying their regional opportunities and challenges, particularly in the areas of upper and lower watershed connectivity, surface and groundwater storage connectivity, alignment of governance structures and tools, and improved public and stakeholder engagement. Specific regions are encouraged to apply the connectivity principles to their local situation through an inquiry process to have an honest and holistic exploration of water issues.

GLOSSARY OF TERMS

California Department of Water Resources (DWR)
A state agency founded in 1956 which has a mandate to conserve, manage, develop, and sustain California's watersheds, water resources, and management systems. DWR also works to prevent and respond to floods, droughts, and catastrophic events.

Conjunctive management (use)
The coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives.

Connected benefit projects
Projects which develop synergistic solutions across the whole range of needs — agricultural, urban, and environmental — within any given system or region. Also referred to as multiple benefit projects.

Connectivity
The understanding that ecosystems and human systems form one interrelated system, with connected features, operational dynamics, and processes that act upon each other.

Disconnect
A missing, broken, or dysfunctional connection between human and natural systems which requires certain interventions or solutions in order for sustainable resource management to occur.

General plan
California state law requires each city and county to adopt a general plan that expresses the community's development goals, and embodies public policy relative to the distribution of future land uses, both public and private.

Groundwater
Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

Groundwater basin and subbasin
An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom. There are 515 alluvial groundwater basins and subbasins in California as defined in DWR's Bulletin 118.

Headwaters
Defined by the Mountain Counties Water Resources Association as the watershed areas from the peaks of the Sierra Nevada Mountains, down through the mid-level conifer forests, and include portions of the blue oak forests within the lower foothill zone.

Integrated Regional Water Management (IRWM)
A collaborative effort to identify and implement water management solutions on a regional scale that increase regional self-reliance, reduce conflict, and manage water to concurrently achieve social, environmental, and economic objectives. The fundamental principle of IRWM is that regional water managers, who are organized into Regional Water Management Groups (RWMGs), are best suited to manage water resources to meet regional needs according to an adopted IRWM Plan (IRWMP).

Kings Basin
The DWR Bulletin 118 defined Kings Groundwater Subbasin.

Kings River Conservation District (KRCD)
The leading resource management agency for the Kings River region serving agriculture, business and residential communities within 1.2 million acres spanning portions of Fresno, Kings and Tulare counties. The KRCD has taken a leading role in facilitating the efforts of the Kings Basin Water Authority (KBWA), and has dedicated staff support to the KBWA for KBWA business.

Kings Basin Water Authority (KBWA)
The Upper Kings Basin Integrated Regional Water Management Authority, which is a collaborative effort between 55 public, private and non-governmental agencies, 16 Joint Powers Agreement (JPA) Board Members and 39 Interested Parties, to manage water resources in the Kings Basin.

Network analysis
The mapping and measuring of relationships and flows between people, groups, and organizations.

Overdraft
The condition of a groundwater basin where the amount of water extracted exceeds the amount of groundwater recharging the basin over a period of time.

Recharge
Water added to an aquifer or the process of adding water to an aquifer. Ground water recharge occurs either naturally as the net gain from precipitation, or artificially as the result of human influence.

Surface water
Water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Sustainable Groundwater Management Act (SGMA)
Enacted in 2014, the Act requires basins designated as medium or high-priority basins to form a groundwater sustainability agency, adopt a groundwater sustainability plan, and meet the sustainability goal within 20 years of the adoption of the plan.

Water Bond
California Proposition 1, the Water Bond (Assembly Bill 1471), was passed in 2014 to enact the Water Quality, Supply, and Infrastructure Improvement Act.

Watershed
An area of land from which runoff (from rain, snow, and springs) drains to a stream, river, lake, or other body of water. A watershed can be stratified according to elevation from its high points (upper watershed) to its low points (lower watershed). The upper watershed is commonly defined as the area lying above the reservoir line.

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