Sacramento Valley Groundwater Assessment

Active Management – Call to Action

Prepared for

Northern California Water Association

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June 2014

Call to Action

The Northern California Water Association (NCWA) developed this assessment of current groundwater conditions in the Sacramento Valley as part of its continuing effort to address issues regarding sustainability of the Valley's water supplies. This year we face unprecedented drought conditions, following a decade of relatively dry years and increased demands on our groundwater resources. These increased demands have two principal causes. The reduced availability of surface water during dry years brings a predictable shift towards greater use of groundwater. The second is expanding and intensifying agricultural land use within the Sacramento Valley, together with increasing urban water demands, leading to increased reliance on groundwater even in "normal" years.

As addressed in NCWA's July 2011 report, *Efficient Water Management for Regional Sustainability in the Sacramento Valley*, the essential indicators of sustainability are a vibrant and growing economy, reliable high-quality surface water and groundwater supplies, stable groundwater levels to protect water supplies and stream ecological values, preservation and enhancement of fish and wildlife habitat, and the preservation of agricultural productivity. The 2011 Sustainability Report concluded that all our water use efficiency initiatives need to contribute to maintaining or improving these indicators of sustainability, and started an important dialogue within the Sacramento Valley on what measures should be considered to assure the long-term sustainability of our economy and environment.

The water supply and environmental stresses of the current drought are focusing more attention on groundwater, our essential drought reserve when surface supplies are limited. We summarize on the following pages what appear to be important long-term trends going on within the Sacramento Valley that affect our groundwater resources. It is not yet possible to separate out such trends from the impacts of the current drought. Real-time monitoring alone does not tell the full story since groundwater responses to changes in use are slow to appear. No matter what the combined impacts of these trends and the increased use of groundwater during drought times, the current stresses on our groundwater reserves need to be addressed.

We have actively invested in and managed our surface water resources for many years, and the collective efforts of our water managers are models for effective stewardship. The Sacramento Valley is a highly managed system, with flows in the Sacramento River and its tributaries regulated by upstream reservoirs – a mix of local agency facilities and those developed by the federal and state governments. As to groundwater, many efforts throughout the Valley in recent years have focused more attention on groundwater management at the county and irrigation district level. We have many ongoing successes at the local level, made possible through the development of additional water supplies, more efficient water use, and development of new water delivery and management infrastructure. However, a more comprehensive approach to managing groundwater in conjunction with our surface supplies will need to consider the Valley as a whole. More aggressive, proactive conjunctive water management supported by local and regional leaders should be pursued. The interdependence of groundwater and surface water is an essential factor related to sustainability. Comprehensive water management cannot be fully realized until water users in the areas within water districts and the non-district areas work together toward common objectives.

This new report relies on extensive technical information collected by local agencies, the California Department of Water Resources (DWR), and other sources. Our report comes at a time when there is far more attention to groundwater management, particularly as it relates to potential new legislation. In January 2014 the State released its *California Water Action Plan*, highlighting the importance of groundwater management at the local level. In March the Legislative Analyst's Office released its report, *Improving Management of the State's Groundwater Resources*, setting forth its suggestions for State legislation. In April the Association of California Water Agencies released *ACWA Recommendations for Achieving Groundwater Sustainability*, a suite of recommendations for improving management of groundwater basins throughout California. Also in April DWR released their *Report to the Governor's Drought Task Force–Groundwater Basins with Potential Shortages and Gaps in Groundwater Monitoring.* In early May, the independent California Water Foundation released its report, *Recommendations for Sustainable Groundwater Management*, developed through a stakeholder process at the request of the Brown Administration and containing specific recommendations essentially aimed at new State legislation. The Nature Conservancy is putting substantial technical resources into a general evaluation of the potential impacts of declining groundwater levels on local stream flow, which could have significant impacts on stream resources.

In addition, CH2MHill (for NCWA) has developed a Groundwater Quality Assessment Report (GAR) in anticipation of pending requirements of the Central Valley Regional Water Quality Control Board's Irrigated Lands Program (ILP). This report is a regional-level analysis designed to aid in the initial prioritization of water quality monitoring and implementation activities, and provides the foundation and framework for the long-term program of monitoring and implementation that is required under the ILP. The GAR is posted to the NCWA web site at norcalwater.org/groundwater-quality-report.

The following pages summarize detailed technical information and analyses set forth in a separate NCWA Technical Supplement, available through our web site (norcalwater.org/groundwater-technicalsupplement). Our new report raises important questions and issues:

- Can we arrive at a shared understanding of sustainability for the Sacramento Valley?
- Are we close to or at a tipping point on the sustainability of our groundwater resources in many areas of the Sacramento Valley?
- Do we have adequate technical, institutional and legal tools to measure the components of sustainability and support local groundwater management?

The **Northern California Water Association (NCWA)** is committed to advance the economic, social, and environmental sustainability of the Sacramento Valley by enhancing and preserving its surface and groundwater rights, supplies, and water quality for the rich mosaic of farmlands, cities and rural communities, refuges and managed wetlands, and meandering rivers that support fisheries and wildlife. NCWA was formed in 1992 to present a unified voice to ensure that this region has reliable and affordable water supplies – both now and into the future. For more information, please visit the NCWA website at www.norcalwater.org.

We encourage active engagement in these issues from surface and groundwater users as well as local government. This is a region-wide challenge. Public outreach will be important to tell the story and get fuller engagement. Our strong local leadership and our extensive water management experience will be essential for the future of the Sacramento Valley. As we engage in these issues, it will be important to consider (1) increasing data collection, monitoring and modeling, (2) augmenting water supplies, (3) improving water management activities, and (4) addressing land use. Overall management of our water resources require that we look at all factors affecting the water balance – both supply and demand.

David J. Guy, President
Northern California Water Association

Introduction

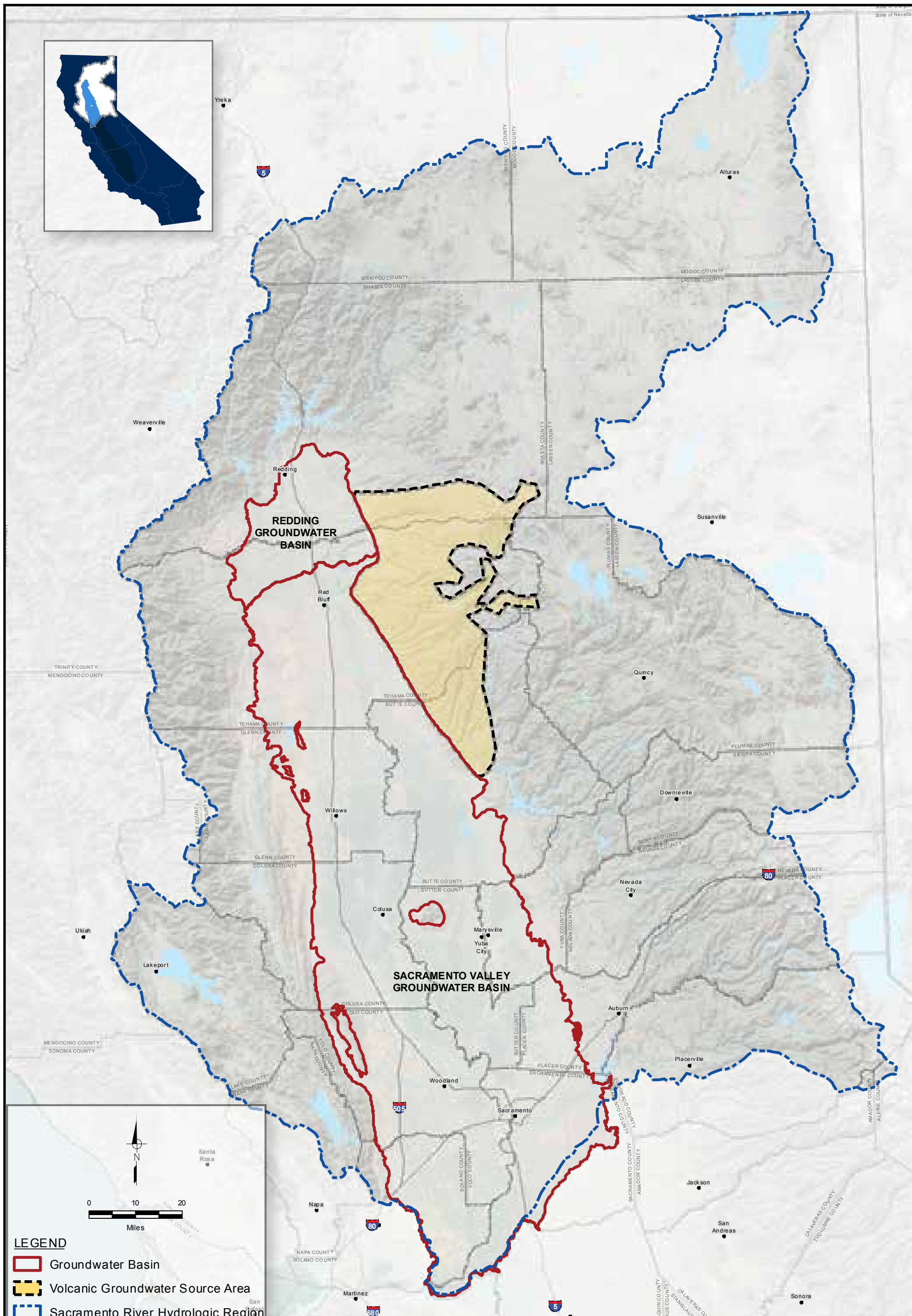
The study area of this report is the Sacramento Valley. The principal focus of this report is on the area overlying groundwater aquifers. The study area is shown in Figure 1.

This report is organized into four sections:

1. Historic Development of Land and Water Resources
2. Sustainable Groundwater Management
3. Effects of Increasing Use of Groundwater
4. Conclusions

The technical, institutional and policy information in this short report summarizes more detailed information contained in a Technical Supplement, available through NCWA's web site (norcalwater.org).

Figure 1. Study Area



Historic Development of Sacramento Valley Land and Water Resources

California's central valley ranges from 40 to 60 miles wide and 450 miles north to south. The Sacramento Valley occupies the northern portion of the Central Valley, stretching about 150 miles from the City of Sacramento northward to the City of Redding. The Sacramento Valley lies within the Sacramento River Hydrologic Region, a 17.4 million acre area drained by the Sacramento River and its tributaries. The Sacramento River enters the Valley at its northern end while major tributaries – the Feather, Bear, Yuba and American Rivers – flow from the Sierra Nevada on the Valley's east side. Tributaries from the Coast Range enter the Valley on the west side. With the notable exceptions of Cottonwood, Stony, Cache and Putah Creeks, the west side tributaries are mostly small and ephemeral. The Sacramento River system has an average unimpaired flow of about 22 million acre-feet (MAF) (DWR, 2007), representing roughly one-third of California's total annual runoff and the dominant source of inflow to the San Francisco Bay-Delta. The Valley's productive soils combined with reliable water supplies and Mediterranean climate make the Sacramento Valley among the most productive agricultural regions in the world. Continued changes in crop mix and irrigated acreage are expected to continue to respond to market forces, including commodity prices and other factors.

Sacramento Valley agriculture began in earnest in the mid 1800s, shortly after and as a result of the California Gold Rush. Initial efforts addressed identifying crops and cultural practices suitable for the region, as well as land clearing and preparation. The most notable efforts were to drain and protect the land from flooding, and to deliver reliable water supplies for irrigation (Olmsted and Rhode, 1997) during the long, dry summer growing season. Huge, mostly private investments were made in water control infrastructure to achieve these functions. The initial irrigation water source was almost exclusively surface water, resulting in most of the irrigated land being located adjacent to and under gravity flow from rivers and creeks. Later, beginning in the early 1900s, the advent of efficient groundwater pumps and the expansion of rural electrical energy supplies enabled irrigation of lands more distant from and at higher elevations than surface water supply sources. Today, roughly 40 percent of the Valley's irrigated areas lie outside of organized surface water supplier service areas and primarily use groundwater (USBR 2003, 2009; DE 2014). The remaining 60 percent use mostly surface water with groundwater serving as a supplemental supply.

The progression of Sacramento Valley irrigated area over the past several decades is illustrated in Figure 2, including trends derived from three sources. Because these sources rely on somewhat different methods and relate to somewhat different periods and areas, the lines on Figure 2 do not agree exactly. Nevertheless Figure 2 gives a good indication of recent historical trends. The lower trace in Figure 2 represents data extracted from DWR's current historical California Central Valley Simulation (C2VSim) model[1]. It shows the Sacramento Valley irrigated area increasing from about 1.23 million

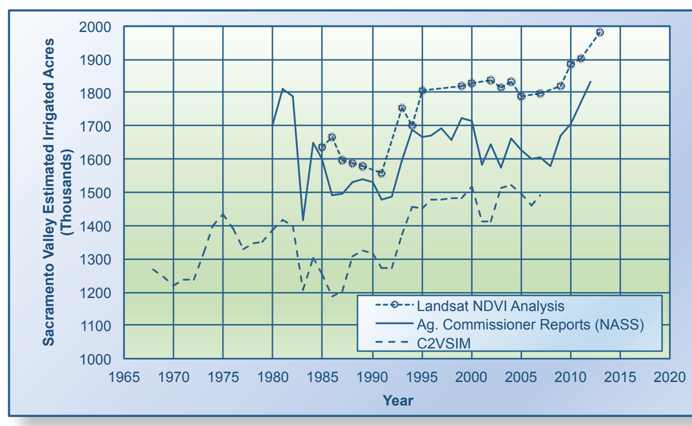


Figure 2. Estimated Irrigated Area in the Sacramento Valley

[1] C2VSim is an integrated surface and groundwater hydrology model maintained by the California Department of Water Resources. For purposes here, irrigated acreage, surface water diversion and groundwater pumping data were extracted from the current calibrated version of the model representing historical conditions, for the portions of the model representing the Sacramento Valley. As with all models of complex natural systems, C2VSim data is subject to a certain degree of uncertainty. Nevertheless, the data provide a consistent and useful means of understanding development trends in the Sacramento Valley (and other regions of the Central Valley).

acres in 1970 to about 1.48 million acres in 2008. The upper trace is derived from a recent remote sensing analysis of Landsat satellite data, showing a 400,000-acre increase in the irrigated area in 1985 of 1.6 million acres to 2 million acres in 2013. The middle trace displays a mostly flat trend at ≈ 1.6 million acres from the early 1980s through the late 2000s, and then a sudden increase in 2012 (when available data ends). This data is from a compilation of primarily ground-based data reported by county agricultural commissioners; among the three sources this information is regarded as the most reliable. However, such information is at the county level and may include some acreage above the floor of the Sacramento Valley. Despite the differences in the records and the fact that none of these data sets is a perfect estimate of irrigated area in the Sacramento Valley, it is reasonable to conclude that the current irrigated area in the Sacramento Valley is somewhere between 1.8 and 2.0 million acres.

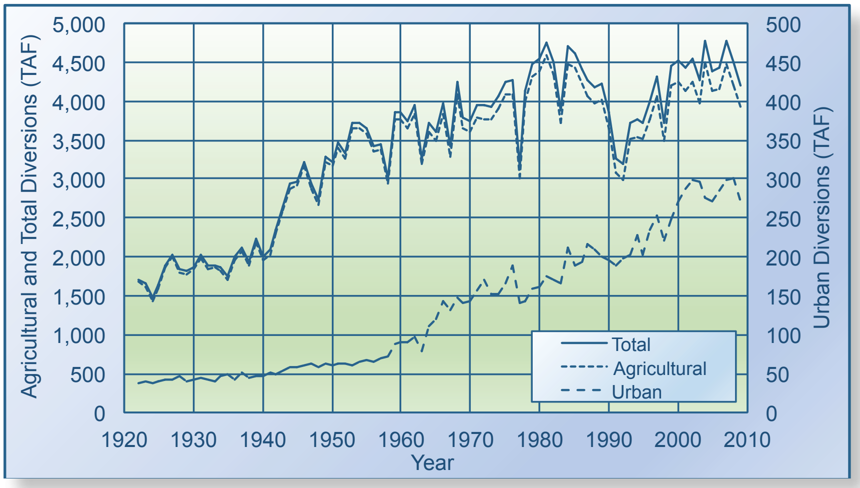


Figure 3. Estimated Annual Surface Water Diversions for Irrigation and Urban Use in the Sacramento Valley

In addition to the expansion of Sacramento Valley irrigated area, recent remote sensing analyses indicate that the density of crop vegetation on the land is also increasing. Over the past three decades, vegetation density has increased by about 20 percent, reflecting a trend toward plantings of higher water use crops, particularly permanent tree crops (discussed below) and also improved farming and irrigation practices. The increase in vegetation density is supported by appreciable increases in crop yields over the same three-decade period, as reported by county agricultural commissioners.

The consumptive use of water on the irrigated area is currently estimated at 3 acre-feet per acre annually (West Yost Associates, 2014) or on the order of 6 MAF valley-wide, with the bulk of that derived from applied irrigation water (rainfall and accumulated soil moisture also contribute to meeting this consumptive use).

Based on DWR's C2VSim historical model data, agricultural and urban diversions of surface water have both increased over time in the Sacramento Valley (Brush et al., 2013, DWR 2014). Urban and agricultural diversions have increased substantially over the past 90 years with urban diversions increasing from approximately 41 thousand acre feet (TAF) per year in the 1920s to 286 TAF per year in the 2000s (a seven-fold increase, mostly in the Sacramento metropolitan area) and agricultural diversions increasing from approximately 1,700 TAF to 4,200 TAF (more than a two-fold increase) over the same period. Thus, total diversions increased from approximately 1,750 TAF in the 1920s to 4,500 TAF in the 2000s. Annual estimates of irrigation and urban diversions are provided in Figure 3. In the last 40 years, following the development of the federal Central Valley Project (CVP) and the California State Water Project (SWP), decreases in diversions are particularly apparent in the dry years of 1977, 1991, and 1992. Estimated average annual diversions by decade are shown in Figure 4, reflecting long-term trends in diversions resulting from increased agricultural development and urban growth, made possible through increased surface water storage.

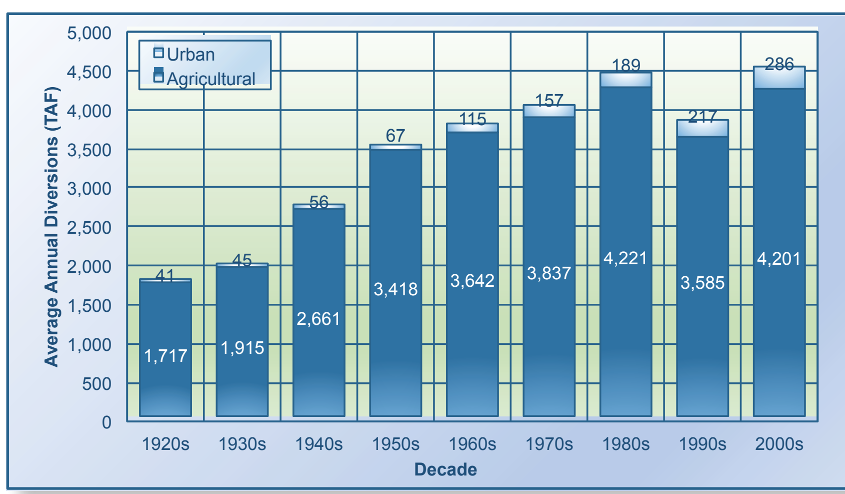


Figure 4. Estimated Surface Water Diversions for Irrigation and Urban Use by Decade in the Sacramento Valley

Agricultural and urban groundwater pumping has increased over time (Brush et al., 2013, DWR 2014). Urban pumping increased from approximately 18 TAF in the 1920s to 314 TAF in the 2000s (a 17-fold increase) and agricultural pumping increased from approximately 433 TAF to 1,939 TAF (more than a four-fold increase) over the same period. Thus, total pumping increased from approximately 450 TAF in the 1920s to 2,250 TAF in the 2000s. Annual estimates of agricultural, urban, and total pumping are provided in Figure 5. Increases in agricultural pumping are particularly apparent in the dry years of 1976, 1977, 1981, 1991, 1994, 2004, 2007, 2008, and 2009, when groundwater was relied on to meet water demands under conditions of limited surface supplies. Noteworthy is the fact that groundwater pumping since around 2005 appears to be consistently greater than the one year "spike" in pumping during 1977. Estimated average annual pumping by decade is shown in Figure 6, reflecting long-term trends in pumping resulting from increased agricultural development and urban growth and most recently in part due to dry or drought conditions.

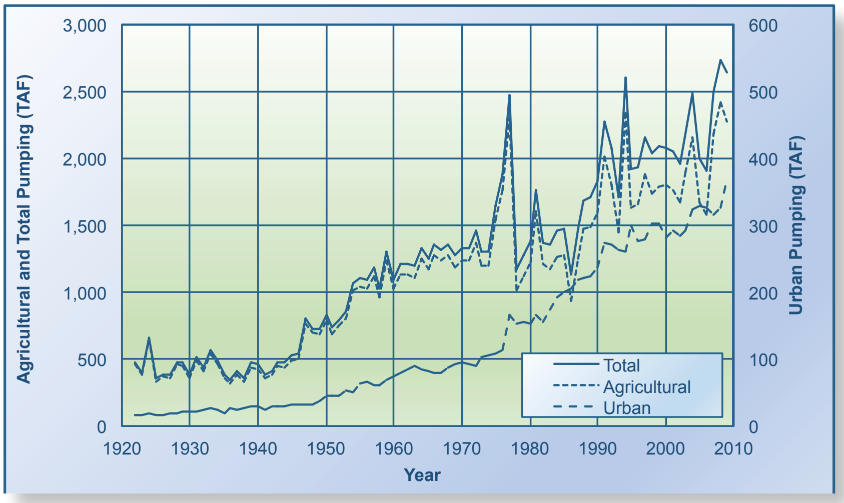


Figure 5. *Estimated Annual Groundwater Pumping for Irrigation and Urban Use*

For agricultural and urban purposes under land and water use conditions that existed during the 2000s, it is estimated that about 2.25 MAF of groundwater were pumped annually in the Sacramento Valley, representing about one third of the combined total agricultural and urban water supply. Not reflected in these values is the additional groundwater pumping (and surface water diversions) associated with the ongoing expansion of irrigated area that began in the past decade. As shown earlier in Figure 2, both the middle and upper traces indicate that irrigated area has increased by about 200,000 acres from 2008 to date. Spatial analysis indicates more than half of this expansion has occurred outside of surface water supplier service areas (USBR 2003, 2009; DE 2014). Thus, based on an estimated demand of 3 acre-feet per acre, an additional 300,000 acre-feet will be pumped to meet agricultural demands (once crops on the newly developed lands mature within a few years of planting), bringing average annual pumping to an estimated 2.55 MAF.

Finally, two additional trends related to Sacramento Valley agriculture merit attention. First is the ongoing rapid expansion of permanent tree crops such as almonds, olives and walnuts, in response to currently favorable market conditions. In most cases, such crops are being planted on land that has historically grown annual crops, and in some cases on previously undeveloped rangeland. This in part results in an increase and hardening of water demands, the latter because tree and vine crops cannot be idled. The increases in water demand are a function in part of the previous water uses on such lands, which have not been analyzed in this report.

Second, and driven in part by the expansion of tree and vine crops is the increasing use of pressurized irrigation systems. Farmers are increasingly using subsurface drip systems for row crops such as processing tomatoes, as well as surface or subsurface drip systems

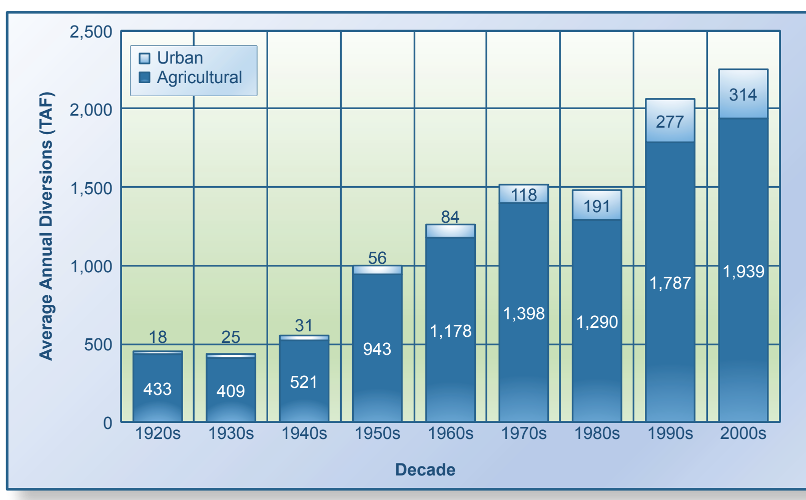


Figure 6. *Estimated Annual Groundwater Pumping for Irrigation and Urban Use by Decade in the Sacramento Valley*

and micro-sprinkler systems for tree crops. Although these pressurized systems are typically more efficient than traditional surface irrigation systems that would otherwise be used, their increased use is not strongly associated with water conservation. Rather, farmers are adopting pressurized systems due to the many crop production advantages those systems provide (including water and fertilizer distribution tailored to crop needs and production). Farmers irrigate to optimize their crop production systems, using the quantity of water that maximizes their yield, crop quality and farm revenues.

From the standpoint of groundwater management, adoption of high-efficiency pressurized systems has a desirable effect in areas irrigated with groundwater because less groundwater pumping is needed to meet water demands. However, in surface water areas, the more uniform and efficient application of water achieved with pressurized systems results in reduced deep percolation (recharge) to the groundwater system. Furthermore, some growers elect to use groundwater to supply pressurized systems even when surface water is available. This is addressed further in the Technical Supplement. Conversion to groundwater supplies even when surface water is available will have some impact on the groundwater balance due to the increase in groundwater pumping and the reduction of deep percolation of applied surface water. The increasing use of pressurized irrigation systems using groundwater is likely to be an increasingly important factor in the overall management of groundwater and surface water in the Sacramento Valley as a whole, particularly as such systems displace the use of available surface water.

Sustainable Groundwater Management

The Sacramento Valley has a number of DWR-approved groundwater management plans (GWMP). These plans have been developed and are administered by local entities, including individual counties and water districts. The boundaries of these plans are shown in Figure 7.

In addition, a number of counties in the Sacramento Valley have adopted ordinances that are intended to exert some level of control over discrete groundwater activities. Much of this was in response to concerns raised in the State Drought Water Banks in 1991, 1992 and 1994. More details on the GWMPs and county ordinances are in the Technical Supplement. The degree of active engagement in managing groundwater varies throughout the region, and is associated with a variety of factors including sub-regional groundwater challenges, the nature of county ordinances, and other factors. In general, county ordinances have been put in place to react to new events (for example, short-term water transfers) and may not necessarily call for active year-to-year management activities in the absence of new events.

The Technical Supplement also contains information on the various integrated regional water management plans (IRWMPs) that have been adopted or are being developed within the Sacramento Valley. Such plans are collaborative efforts of local decision-making organizations, and give an indication of the future potential for addressing region-wide water resource management issues.

NCWA's 2006 Sacramento Valley IRWMP included the following description of the Sacramento Valley in terms of long-term water uses:

The Sacramento Valley is a rich mosaic of farmlands, cities and rural communities, refuges and managed wetlands for waterfowl and shorebird habitat, and meandering rivers and streams that support numerous fisheries and wildlife. The natural and working landscape between the foothills of the Sierra Nevada and the Coast Range is dependent on the fertile lands of the Sacramento Valley floor, water supplies from rivers, streams, and the underlying groundwater basins to support and sustain a healthy and vibrant local economy and environment.

This set forth an initial marker for sustainable water uses in the Sacramento Valley that explicitly addresses both economic and environmental values. Following up on the theme of sustainability, NCWA's 2011 report, "Efficient Water Management for Regional Sustainability in the Sacramento Valley" addressed the topic of sustainability in more depth. This paralleled the emerging focus over the past decade throughout California on both water supply reliability and the broader theme of "sustainability". In its December 2013 comments to the SWRCB concerning the SWRCB's "Groundwater Workplan Concept Paper", NCWA referred to the classic "three pillars of sustainability": the economy, environmental stewardship, and social and community well-being. Each of these relies heavily on reliable, long-term water supplies for the Sacramento Valley.

This short report (supported by the Technical Supplement) begins with a discussion of sustainability from NCWA's perspective. There is broad recognition of the contributing factors to water sustainability. Those include, but are not limited to:

- Surface water hydrology (variability)
- Interaction between surface water and ground water (as described above)
- Long-term balance of groundwater resources, including changes in storage and quality
- Water demands, both consumptive and non-consumptive (variability)
- Water infrastructure, for both storage and regulation of water supplies, and those facilities needed for treatment and distribution
- Regulatory restrictions
- Economic, social and environmental goals

Some of these can be measured, others can be controlled, and some are difficult to assess. We do know that most of these factors continue to change, posing significant challenges to characterizing the overall water balance of the Sacramento Valley. It is not only

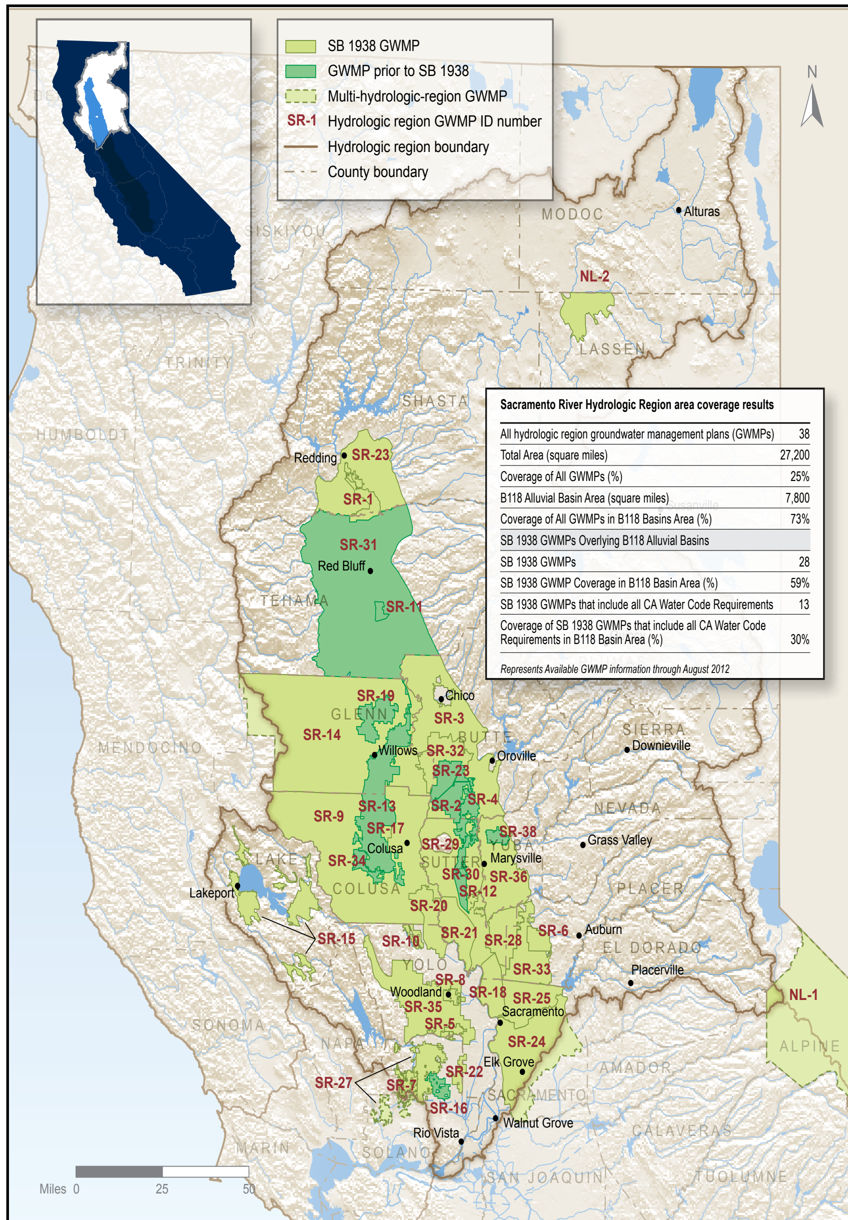


Figure 7. Groundwater Management Plans in the Sacramento River Hydrologic Region (primarily the Sacramento Valley)

the weather, which gives us wet, dry and drought years. Urban and agricultural land uses continue to change, and this is affecting groundwater use and likely the effects on streamflow. As noted earlier, groundwater changes can take many years to become apparent, and we have not yet been able to measure with certainty the long-term impacts of the current level of groundwater use as it affects our measures of sustainability. And of course regulatory pressures continue, with some degree of uncertainty regarding the need for the Sacramento Valley – and other areas where most of California's water supplies originate – to contribute to downstream water demands. It is an extremely complex mix of legal, technical and policy issues, and NCWA remains diligent in protecting the Valley's water resources.

Despite this complexity, there are basic physical indicators that signal when groundwater use is or may not be sustainable, and there are water balance principles that define the realm of solutions. Persistently declining groundwater levels in many areas of the Sacramento Valley over the past decade reveal that groundwater discharge exceeds recharge. Simply put: if the objective is to stem or reverse the trend, the groundwater balance must be adjusted either by putting more water into the ground or taking less out.

Recent droughts indicate that the Sacramento Valley's water supplies are vulnerable. Even so, the Sacramento Valley has a number of dramatic groundwater management successes, several summarized below. More details on these successful programs are provided in the Technical Supplement. While representing a relatively small percentage of the land area of the Sacramento Valley overlying groundwater aquifers, they provide important examples of how long-term problems with declining groundwater levels were successfully addressed. These successes are a credit to local water resource managers, and share the common feature that recovery and maintenance of groundwater systems has been accomplished through conjunctive management with surface water supplies. It is essential to note that every subregion within the Sacramento Valley is different from a number of standpoints – hydrogeology, access to surface water, water infrastructure, soils suitable for irrigation, urban development and water management institutions – such that successful solutions at the subregional level need to account for local conditions.

South Sutter Water District

The South Sutter Water District (SSWD) is located in southern Sutter and western Placer counties. The District was formed in 1954 to develop, store and distribute surface water supplies. Today SSWD encompasses a gross area of nearly 64,000 acres, including 57,000 acres authorized to receive surface water. In recent years, due to urban encroachment and other factors, fewer than 36,000 acres in SSWD are irrigated using a combination of surface and groundwater supplies. The dominant crop is rice, accounting for more than 80 percent of the irrigated area.

The primary driving factor for forming the district was to develop and distribute supplemental surface water supplies to replenish over-drafted groundwater aquifers. This was accomplished by constructing the enlarged New Camp Far West Dam and Reservoir on the Bear River. These facilities were completed in 1964 creating 104,400 AF of additional storage capacity.

Water is released from New Camp Far West Reservoir into the Bear River and is diverted for irrigation 1.25 miles downstream, about 15 miles above the confluence with the Feather River. The diversion dam and distribution facilities originally had a capacity of 380 cfs, but this was increased to 480 cfs in the 2000s. The enlarged capacity enables more flexible release and diversion operations, so that SSWD can continue to meet a sufficient part of its irrigation demands with surface water while also meeting certain obligations to make reservoir releases for Delta water quality maintenance.

With the delivery of surface water beginning in 1964, groundwater pumping decreased and groundwater levels immediately began recovering. On average, enough surface water has been delivered such that groundwater levels have recovered and appear to have stabilized more or less at pre-development levels. This pattern of steady decline before 1964 and recovery afterward is illustrated by the groundwater well hydrograph shown in Figure 8.

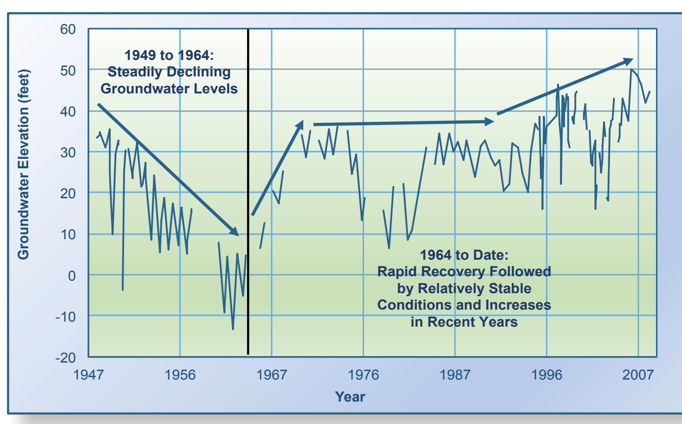


Figure 8. Water Levels in a South Sutter Water District Groundwater Well Showing Recovery of Groundwater Levels with Increased Surface Water Deliveries Beginning in 1964

Yuba County Water Agency

The Agency's early achievement was construction of New Bullards Bar Dam and Reservoir, completed in 1970, to reduce Yuba River peak flood flows and store water for beneficial use. Funding limitations delayed the construction of distribution facilities to deliver surface water to areas that had groundwater levels that had declined dramatically since the early 1940s. In 1983 water deliveries to a portion of the Agency's service area began and the immediate recovery of the groundwater basin commenced.

Figure 9 shows the dramatic recovery of groundwater levels due to surface water deliveries from this project. Because of the replenishment of the basin, which today is near pre-pumping levels not seen over the last 100 years, this important subregion of the Sacramento Valley has restored its groundwater conditions to sustainable levels. Separate Agency programs have also promoted environmental stewardship. Finally, farmers in the Agency's service area have implemented a conjunctive use program that provides groundwater substitution transfers to water short areas of California, including transfers to south-of-Delta water users.

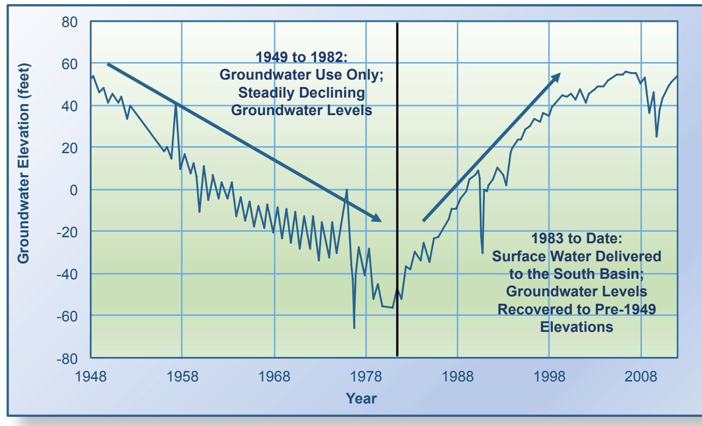


Figure 9. Water Levels in Typical South Yuba Subbasin Groundwater Well

Yolo County Flood Control and Water Conservation District

The District serves surface water supplies to irrigated lands in western Yolo County. These supplies supplement groundwater use throughout the region. Prior to 1977, groundwater levels had been steadily declining throughout most of the District's service area. In 1977 the District completed construction of Indian Valley Reservoir in the Cache Creek watershed. This surface storage has added an annual average of 80,000 acre-feet to the District's historic surface water supplies from Clear Lake. Since Indian Valley Reservoir began operations, groundwater levels have steadily recovered, due to the increased in-lieu recharge made possible by the increased surface water supply. The recovery of groundwater levels was made possible by a combination of delivery of additional surface water to farmers who would otherwise pump groundwater, together with the direct recharge of surface water in the District's unlined canals. In an average year, more than 25 percent of the surface water diverted from Cache Creek for irrigation goes directly to groundwater recharge. Figure 10 shows the recovery of groundwater levels since Indian Valley Reservoir began operation.

The District recognizes that adequate management warrants the development of reliable monitoring data. The District measures almost four hundred wells per year: once in the spring before the irrigation season, and then again in the fall after the irrigation season is finished. This monitoring program has been in place for over fifty years and serves as a valuable continuous record of groundwater level through multiple cycles of drought and high water years. This data has all been put into an electronic database that is accessible to the public. The District participates in a multi-agency Yolo County-wide subsidence monitoring program that serves as an early warning of potential problems with the groundwater aquifer's ability to store water.

Facilities alone are not enough. The District has initiated a number of policies, programs and tools to enhance its ability to conjunctively manage groundwater and surface water supplies for the benefit of its customers. In 2007 the District initiated a pump-incentive program, which links the District's water delivery system with the region's privately managed well network in such a way as to maximize the effectiveness of both systems. More recently, the District adopted a water rate structure that encourages surface water use in wet years and groundwater use in dry years, while helping to stabilize the District's surface water sales revenues through wet and dry cycles. Finally, the District commissioned and maintains an integrated hydrologic computer model of its surface and groundwater systems that enables evaluation of possible future changes in water supplies, cropping patterns, irrigation practices and other factors.

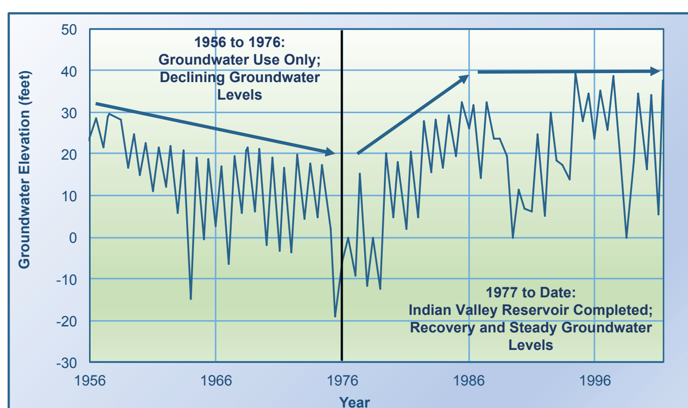


Figure 10. Water Levels in Yolo County Well Showing Recovery of Groundwater Levels

Northern Sacramento County

In April 2000, some 40 stakeholder interests (urban water purveyors, environmental groups and business interests) entered into the Water Forum Agreement (WFA). The WFA is a nationally recognized collaborative process that resulted in a plan to provide a safe and reliable water supply for planned growth in the region to 2030 and preserving the environment of the lower American River. Urban water purveyors were concerned about how they could meet their long-term water needs. Environmental conditions (in particular, flow and temperature) were problematic for a number of fish species including the endangered fall-run Chinook salmon and steelhead. While the WFA required nearly seven years of careful negotiation to complete, it resolved several decades of conflict concerning water supply and the environment.

The WFA has seven required implementation elements. One of those is effective groundwater management. In particular, a sustainable groundwater basin was needed for dry years, so that urban water suppliers could reduce their surface water diversions to provide additional water for the environmental resources on the lower American River.

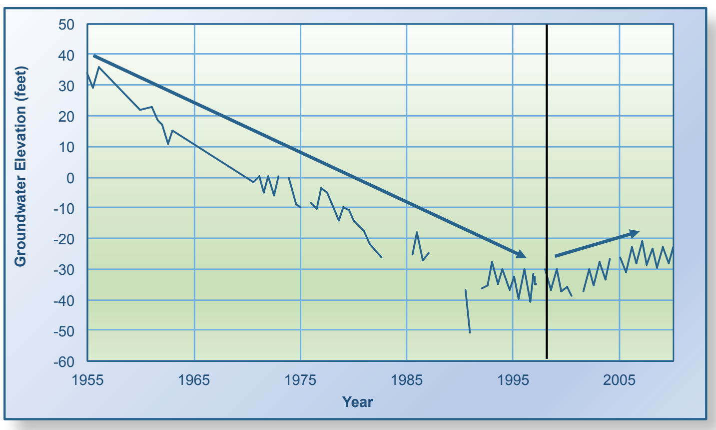


Figure 11. Sacramento Area Water Level Responses to Water Management Actions (well located near main cone of depression, north of former McClellan Air Force Base. Data from DWR's Water Data Library at water.ca.gov/waterdatalibrary)

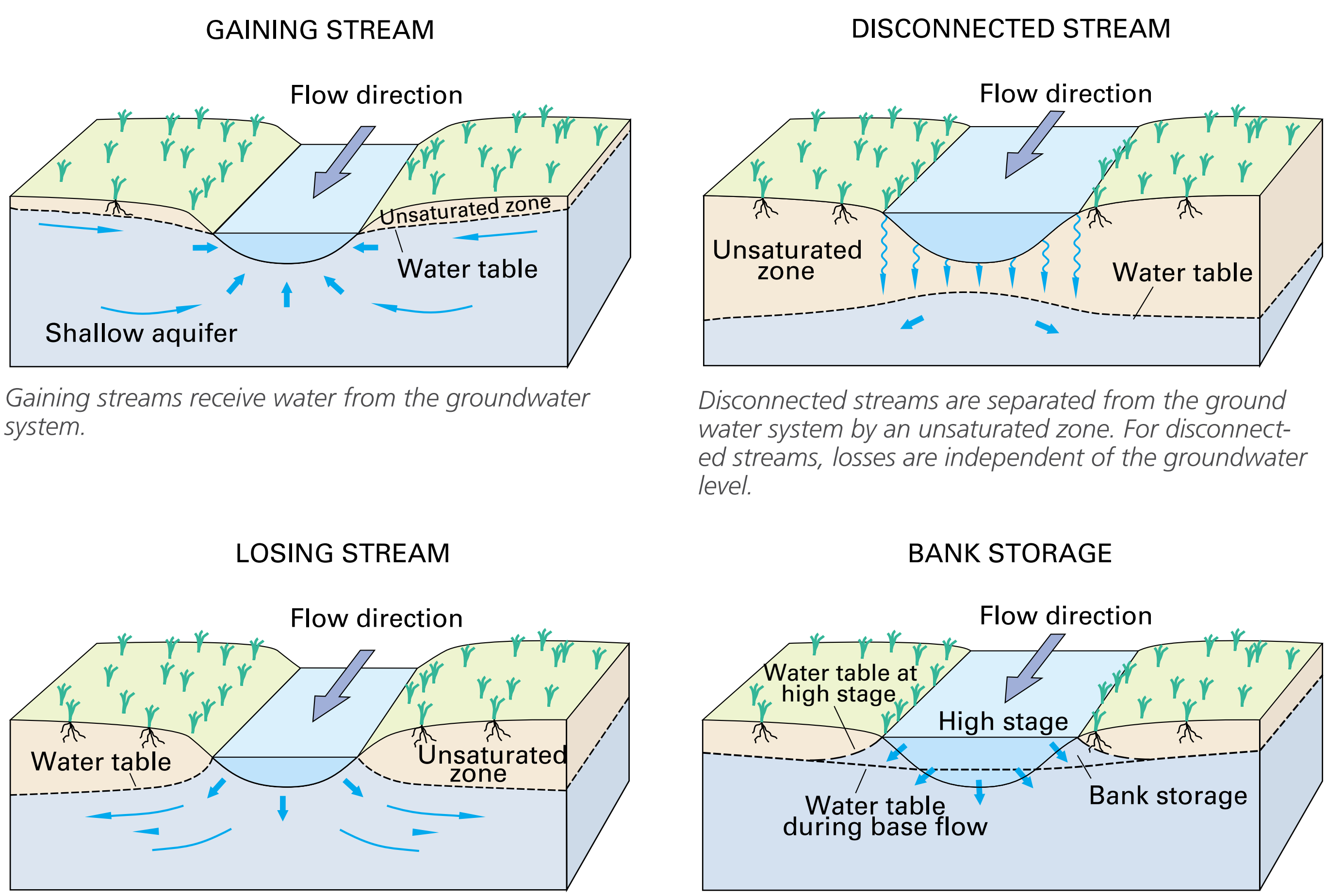
The water purveyors that eventually signed the WFA agreed in 1998 to form the Sacramento Groundwater Authority (SGA), created "…for the purposes of protecting, preserving, and enhancing, for current and future beneficial uses, the groundwater resources in the North Area Groundwater Basin, in Sacramento County, north of the American River…" (SGA Groundwater Management Plan available at sgah2o.org). The SGA was formed under a joint powers agreement (JPA), with a governing board of directors with representatives of the JPA members and other water users within their jurisdiction. The SGA developed an initial groundwater management plan (GMP) in 2003, setting forth management objectives for managing the groundwater basin. The SGA agreed that it would conduct a comprehensive review and update of its GMP every five years, with a revised GMP adopted in December 2008. A third GMP revision is currently in progress.

The SGA has made remarkable accomplishments in the 15 years since it was formed. Conjunctive use of surface and ground water has been promoted, as has the banking of water to meet future needs. An early SGA activity was to facilitate an exchange of previously-banked water to the State's Environmental Water Account to aid in environmental protection downstream in the Delta, which proved the viability of such exchanges from the region. In 2010, SGA adopted a Water Accounting Framework, which established policies and procedures to promote greater conjunctive use in the region. Overall, groundwater levels in the basin have reversed a significant downward historical trend (as noted in the long-term hydrograph shown in Figure 11) through the actions of SGA members to construct facilities to shift to more surface water supply in wetter years to achieve in-lieu groundwater recharge. Through its many management actions, SGA has put in place the institutional and technical means to accomplish long-term sustainable management of its groundwater basin.

Effects of Increasing Use of Groundwater

A widely held perception based on historical observations is that Sacramento Valley groundwater is drawn down seasonally due to irrigation pumping, but generally recovers each year. On an annual basis, groundwater pumping and other groundwater discharges are matched by groundwater recharge from deep percolation of applied water and precipitation, leakage from canals and streams, and other recharge sources. However, in recent years, groundwater level monitoring performed by DWR reveals that groundwater levels in some areas of the Sacramento Valley do not fully recover, although it is not yet known how much of this is due to the ongoing drought and the resulting decrease in surface water supplies. These are typically areas near the edges of Valley that have been developed for irrigation and are completely or predominantly dependent on groundwater as a supply source (see Figures 14 and 15 presented later in this section). These downward trends are exacerbated by the current drought.

Groundwater is not a distinct water supply source; rather, it originates as surface water. In the same way that natural lakes store surface water, groundwater is simply the accumulation over time of surface water



Gaining streams receive water from the groundwater system.

Disconnected streams are separated from the ground water system by an unsaturated zone. For disconnected streams, losses are independent of the groundwater level.

Losing streams lose water to the groundwater system.

If stream levels ride higher than adjacent groundwater levels, stream water moves into the streambanks as bank storage.

Figure 12. Conceptual Diagram, Groundwater/Surface Water Interactions

that has seeped into the ground by the force of gravity. The typical types of interactions between surface and groundwater systems are illustrated in Figure 12. Streams interact with groundwater in two basic ways: streams gain water from inflow of groundwater through the streambed (gaining stream) or they lose water to groundwater by leakage through the streambed (losing stream). If a stream is connected to the groundwater system (it is in physical contact with the groundwater system), the rates of flow gains and losses depend on the stage of the stream, the groundwater level, and the streambed permeability. If the stream is disconnected from the groundwater system (the stream is separated from the groundwater system by an unsaturated zone), the stream loss is dependent on streambed permeability only and not on the groundwater level. As stream levels rise above groundwater levels, such as during rainfall events, water is put into bank storage, which might flow back into the stream when stream levels recede. Typically, the pattern of stream gains and losses changes with time depending on hydrologic conditions and location, with most streams gaining in some reaches and losing in others at any given time.

When surface water and groundwater systems are connected, any change in one inevitably affects the other. In particular, fundamental physics tell us that the lowering of groundwater levels attendant to groundwater pumping leads to depletion of streamflow and groundwater storage (as well as potential induced groundwater recharge). Depending on when streamflow depletion occurs, it can potentially reduce supplies for human and environmental surface water uses. The interactions between groundwater and streams in the Sacramento Valley are highly complex, but these fundamental relationships are undeniable. In the Sacramento Valley (and all hydrologically similar systems), all groundwater pumping ultimately comes from streams, preceded by reduction of water stored in the aquifer system. These relationships are accounted for in DWR's C2VSim model, which indicates that Sacramento Valley stream accretions (taking the Sacramento Valley as a whole, but not accounting for regional differences) from groundwater gradually declined from an average of about 1 MAF per year in the 1920s to -0.4 MAF per year in the 2000s (Figure 13). The stream system went from net gaining to net losing between the 1980s and 1990s.

An adequate understanding of the complex and dynamic interactions between groundwater and surface water is essential for effective water resource management, both to achieve sustainable development of water resources, and to avoid unintended environmental harm. It is essential to recognize the interaction between the two systems and how management actions applied to one system will affect the other. However, this complexity also represents opportunity because a connected system has the greater range of management options. In contrast, disconnected systems are simple because there are no groundwater management options that affect stream flow so long as groundwater levels stay below the threshold that reconnects the system.

Management of connected surface and groundwater systems is challenging for several reasons. First, the duration of streamflow depletions caused by pumping depends on the spatial scale: in general (depending on soil conditions and strata) the greater the distance or depth between groundwater pumping and an affected stream, the lower the magnitude but the longer the timescale of depletions. As a consequence, the ultimate effects of pumping can occur significantly after pumping starts, or even after pumping has ceased. The timescales involved in aquifer responses to pumping and other stresses can be on the order of decades, making it difficult to associate cause with effect. As such, monitoring must account for this lag in impacts. In general, the longer the timeframe for effects to be observed at a given monitoring point once they become evident, the longer those effects will persist, even if the

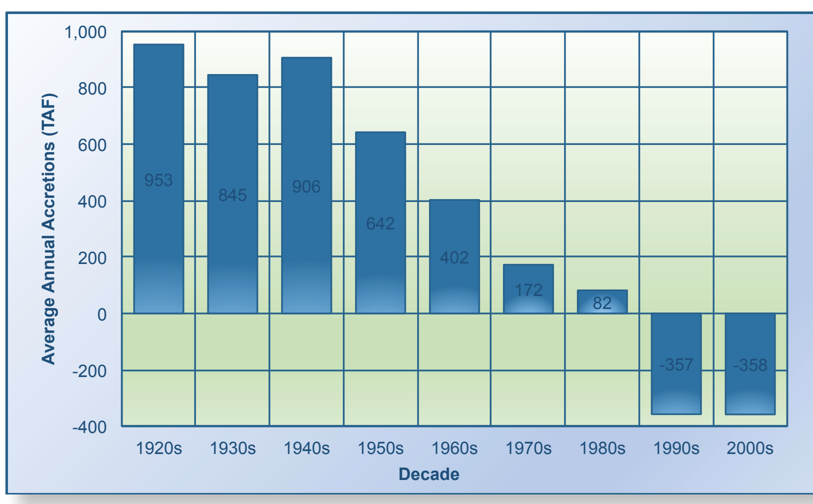


Figure 13. Average Annual Accretions to Sacramento Valley Streams and Rivers as Simulated by C2VSim

pumping causing the effects is halted immediately.

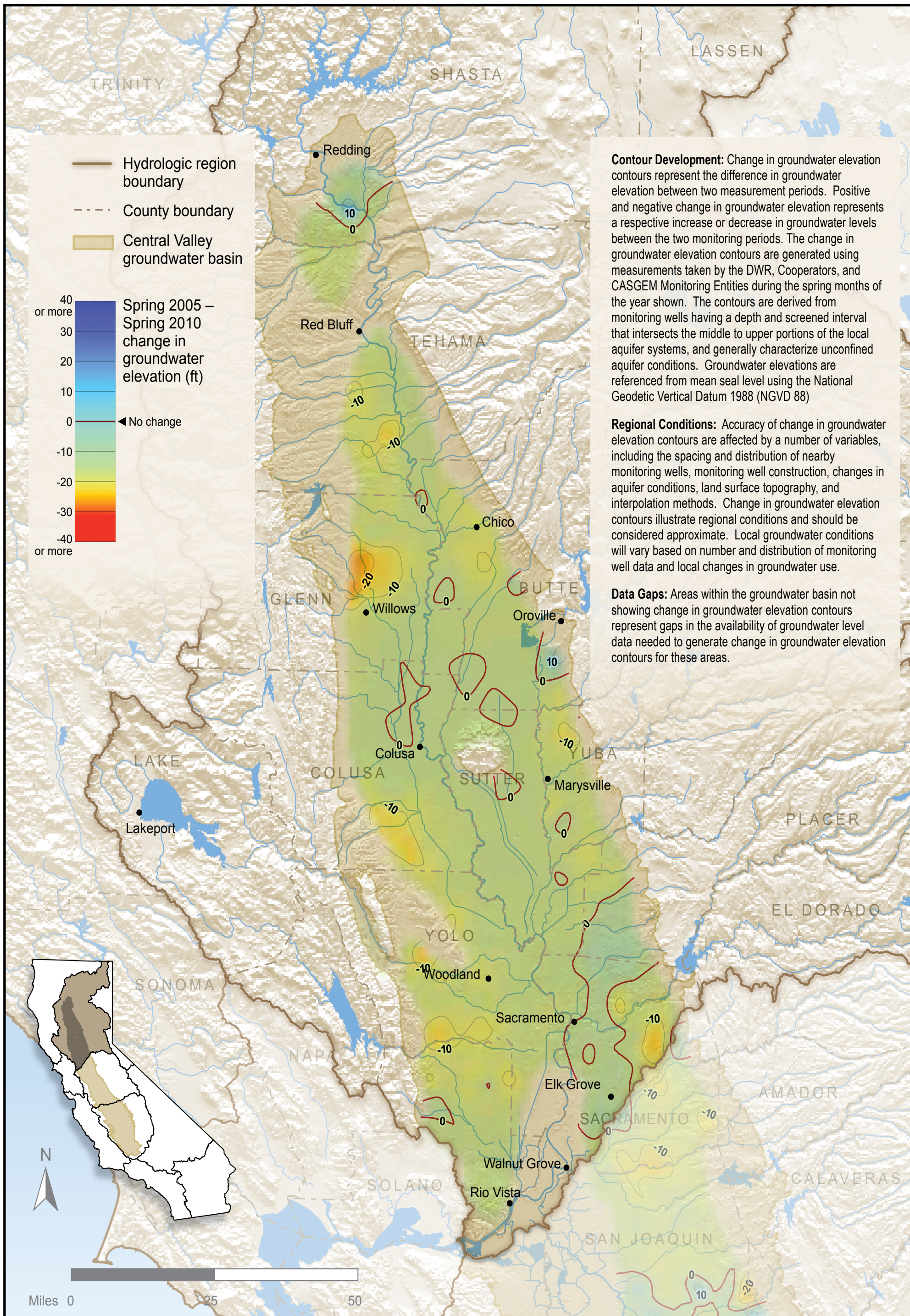
This means that typical adaptive management approaches (modification of management decisions based on observed current effects in the aquifer system) will not necessarily ensure that adverse outcomes will be avoided. Instead, it may be necessary to anticipate or forecast management outcomes, using appropriate tools, which may include documented case studies with similar characteristics, mathematical models of the hydrologic system, and economic forecasting models utilizing "what-if" scenarios that account for lagging impacts to conduct cost-benefit analysis of water management scenarios.

Included here are two graphics from DWR that show recent trends in groundwater levels. The first figure, Figure 14, is taken from the draft 2013 Update to the California Water Plan (at the time our report was prepared, the final 2013 Update along with final figures had not been released). This figure shows the changes in groundwater levels within the Sacramento Valley from Spring 2005 to Spring 2010. A number of areas within the Sacramento Valley show groundwater levels declining during this period, although data is unclear how much of this was related to dry conditions and how much associated with long-term increases in groundwater use.

Figure 15 is from the DWR April 2014 report, *Report to the Governor's Drought Task Force—Groundwater Basins with Potential Shortages and Gaps in Groundwater Monitoring.* This figure shows statewide changes in groundwater levels from Spring 2010 through Spring 2014. While a figure showing only the Sacramento Valley is not available, it is clear from this figure that groundwater levels in many areas of the Sacramento Valley have continued to decline during the ongoing drought.

Finally, there are a number of important unknowns as to future changes in land and water use. These include future changes related to market factors, the hardening of demand for tree and vine crops that may affect overall water supply reliability during droughts,

Figure 14. Spring 2005 – Spring 2010 Changes in Groundwater Levels, Sacramento Valley



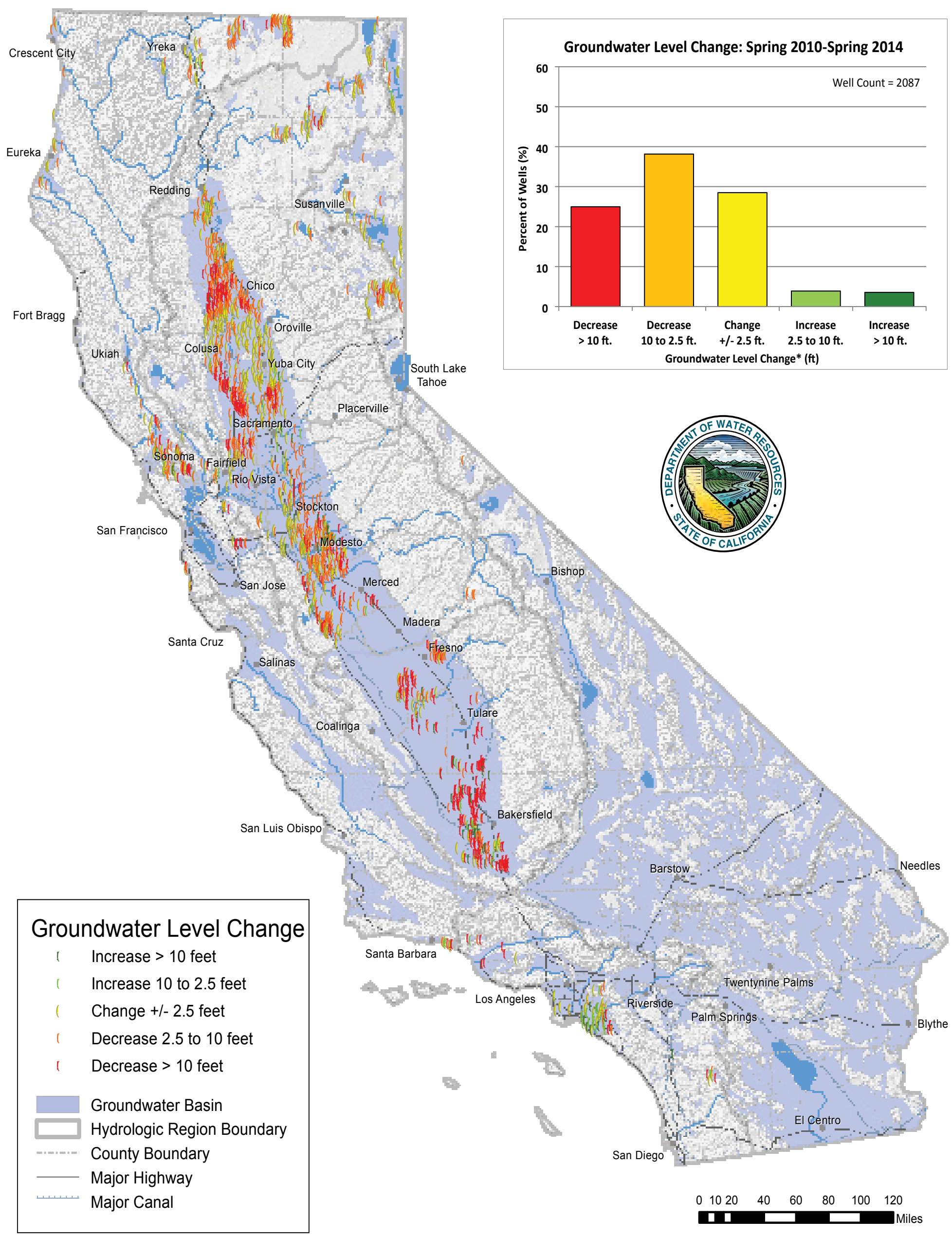
and changes in irrigation efficiency to increase crop production.

There are a number of important challenges to managing all aspects of the water balance. One is that a substantial amount of groundwater withdrawals are outside water district, irrigation district or municipal boundaries. Such areas, with access only to groundwater, do not have the institutional capability at present to work together towards common management goals, such as are made possible through groundwater management plans. Further, the lack of access of these areas to surface water, combined with the physical circumstances of how groundwater is replenished, means that the reliability of their groundwater supplies is greatly aided by the distribution of surface water supplies by adjacent irrigation and water districts. Comprehensive water management cannot be fully realized until water users in the areas within water districts and the non-district areas work together.

A further challenge to more comprehensive groundwater management is the lag time in groundwater responses. As noted earlier, management actions cannot rely solely on real-time monitoring. The impacts of increased groundwater pumping during the current severe drought might not be fully seen for many years, particularly as they may impact flows in the Valley's rivers and streams. It is easiest to take action in response to what can be measured today, but other credible, technical tools will be needed to convince water managers regarding what actions to be taken now to address impacts likely to be seen in future years. Such tools could include better predictive modeling, coupled with an appropriate level of monitoring support.

The management challenges are great in order to assure the Sacramento Valley will continue to meet its sustainability goals. Each of the variables – water diversions, groundwater recharge and land use – has its controversies, and there are not yet obvious solutions.

Figure 15. Spring 2010 – Spring 2014 Statewide Changes in Groundwater Levels (Ongoing drought conditions)



*Groundwater level change determined from water level measurements in wells. Map and chart based on available data from the DWR Water Data Library as of 04/15/2014. Document Name: DOTMAP_S2010_S2014 Updated: 04/21/2014 Data subject to change without notice.

Conclusions

Substantial technical information – groundwater level monitoring, land use changes, long-term water use trends – are indicators that the Sacramento Valley is approaching an important point in water development and use. We are enjoying high levels of agricultural production based on an expansion of irrigated lands, a shift to higher value and higher water use crops and generally increased crop yields. All of these factors result in increased water use. As addressed in the Technical Supplement, much of the increased water use in recent years has come from groundwater. In addition, as addressed in more detail in the Technical Supplement, the increased frequency of drought and associated decrease in reliable surface water supplies in the past several decades as compared to the prior 60+ years during which most of our water systems were developed, has put greater pressures on our groundwater supplies.

Our success stories have been made possible by local leadership, the development and careful management of surface water supplies, and critical water delivery infrastructure. Every success story recognized that augmentation of water supplies was necessary, and that active conjunctive management of surface and ground water supplies was essential. Groundwater management plans have made an important "down payment" on the stewardship of our groundwater resources. However, we remain vulnerable as Sacramento Valley water use continues to increase and as pressures continue on our water resources to meet water demands within and outside the Sacramento Valley.

In addition, there are many differences between the historically driest year of record in 1977 and current conditions:

- California's population has nearly doubled;
- The Endangered Species Act and other laws have been implemented in the Bay-Delta for various fish, placing restraints on water operations and reducing flexibility in meeting various beneficial purposes;
- California agriculture has evolved, with changes in cropping patterns and significant new plantings (particularly in trees), many of which require water in all years;
- The SWRCB has updated its Bay-Delta Water Quality Control Plan, which has generally led to less water available in storage in dry years;
- Significant water conservation and efficiency in urban and agricultural water use throughout the state has tightened the water system. This is generally positive, but it also means that there is much less flexibility in managing local water supplies in dry years.

We have seen many new water demands since 1977, making California – and the Sacramento Valley – more vulnerable to drought than in the past. Regulatory changes have also greatly increased the vulnerability to drought in meeting all water needs. At the same time we may be facing drought conditions (coupled with increased water uses) that are potentially more severe than we have seen in past droughts. This reinforces the need for a long-term view. Time and time again the Sacramento Valley has learned the lesson that the range and frequency of historic conditions (wet and dry) are not necessarily a predictor of future hydrology. Vulnerability of water uses will continue to be influenced by changes in land use, many driven by economic and commodity market conditions.

We reach the following conclusions, supported by additional information in the Technical Supplement:

1. Our water supplies are under far more stress than ever before. Groundwater levels have declined in some areas because increases in groundwater use, coupled with recent dry conditions, have resulted in greater groundwater withdrawals than groundwater recharge.

2. The full impact – particularly on stream flow – of past and current groundwater pumping from the Sacramento Valley's aquifers may not be apparent for many years, because of the large volume of water in storage and the slow rate of groundwater movement.

3. In areas that rely wholly or predominantly on groundwater, only a portion of the water pumped percolates back to the groundwater system, resulting in net extraction of groundwater where groundwater pumping (in part due to recent dry conditions) has exceeded recharge.

4. The Sacramento Valley's surface water and groundwater systems are coupled in many locations, meaning that streams are in physical contact with the groundwater system. Stream gains and losses at any particular location and time depend on the stage of the stream, the groundwater level, and the streambed permeability. Even small changes in groundwater levels can affect stream flow by reducing discharge to streams or by inducing leakage from streams.

5. Groundwater management plans cover much of the Sacramento Valley and there are a number of successful subregional comprehensive water management programs that have been implemented. This has been possible through leadership instituted within existing institutions, with the exception of the Sacramento area where there is broad support for a new overall water management structure for more than a decade to accomplish broad goals within that subregion. But there is no integration of the more than 35 individual groundwater management plans for the Valley as a whole, although these plans cover ¾ of the lands above our groundwater aquifers. This points to a potential benefit of coordinating such plans Valley-wide.

Where does all this lead? The introduction to this short report asks for engagement in three questions: (1) Can we arrive at a shared understanding of sustainability for the Sacramento Valley? (2) Are we close to or at a tipping point on sustainability of our groundwater resources in many areas of the Sacramento Valley? and (3) Do we have adequate technical, institutional and legal tools to measure the components of sustainability and support local groundwater management? Assuming water leaders in the Valley come to agreement on a common sustainability vision, the second and third questions lead to issues that can be objectively addressed. It is clear and been suggested for years that more comprehensive monitoring and groundwater modeling is warranted. These tools would be helpful/valuable to inform decision makers as to potential future water management actions needed to have a positive impact on the overall water balance. But technical tools alone would not be enough.

This short report does not suggest specific actions; rather it concludes that engagement in the issues raised by the report is essential to long-term water resources management within the Valley. We believe that such engagement should consider the following topics:

- Increase data collection, monitoring and modeling. Increase the frequency of ground-based land use surveys and investigate options for remote sensing. Develop groundwater models to better assess future groundwater levels and quality.

- Improve water management activities. Develop a shared understanding of sustainability for the Sacramento Valley. This will require active engagement by surface and groundwater users as well as local government on common objectives, and is a region-wide challenge.

- Augment water supplies. Additional storage, such as the proposed Sites Reservoir, could add valuable water supplies and water management operational flexibility. These needs are particularly important to meet critical water needs during drought conditions.

- Address land use. Long-term sustainability of the Sacramento Valley's water supplies will need to account for continuing changes in land use, where decisions are currently distributed among cities, counties, local water district and landowners. While there are no clear solutions, a frank and open dialogue regarding future land use is essential. "Business as usual" threatens our future.

More information on each of these topics is included in the Technical Supplement (norcalwater.org/groundwater-technicalsupplement). NCWA intends to continue its engagement in our water resources future. Updated information across all water resources topics can be found on the NCWA web site: norcalwater.org.

References

Brush, C. F. et al. 2013. Development and Calibration of the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) Version 3.02-CG. California Department of Water Resources. Sacramento, CA.

California Department of Water Resources (DWR) 2007. California Central Valley Unimpaired Flow Data, Fourth Edition, Draft.

DWR 2014. C2VSim: California Central Valley Groundwater-Surface Water Simulation Model. Accessed at: baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSIM.cfm.

Davids Engineering, Inc. (DE) 2014. Changing Sacramento Valley Land and Water Use. Presentation to the Northern California Water Association (NCWA) Annual Meeting, March 14, 2014, Chico, California.

Olmstead, A. L. and Rhode, P. W. 1997. The Evolution of California Agriculture, Overview of the History of California.

U.S. Bureau of Reclamation (USBR) 2003. Private Water Districts of California, 1:24,000 Scale. ESRI shapefile. USBR Mid-Pacific Region MPGIS Service Center, Sacramento, California. Accessed at www.atlas.ca.gov/download.html#/casil/boundaries.

USBR 2009. Federal Water Contractors - Mid-Pacific. ESRI personal geodatabase. USBR Mid-Pacific Region MPGIS Service Center, Sacramento, California. Accessed at www.atlas.ca.gov/download.html#/casil/boundaries.

West Yost Associates 2014. Northern Sacramento Valley Integrated Water Management Plan, Chapter 1 – Governance and Region Description. 2014. Accessed at: www.nsvwaterplan.org.

Special thanks to the California Department of Water Resources for Figures 7, 14 and 15. These figures came from the Draft 2013 Update to the California Water Plan, as well as the April 2014 special report to the Governor's Drought Task Force.

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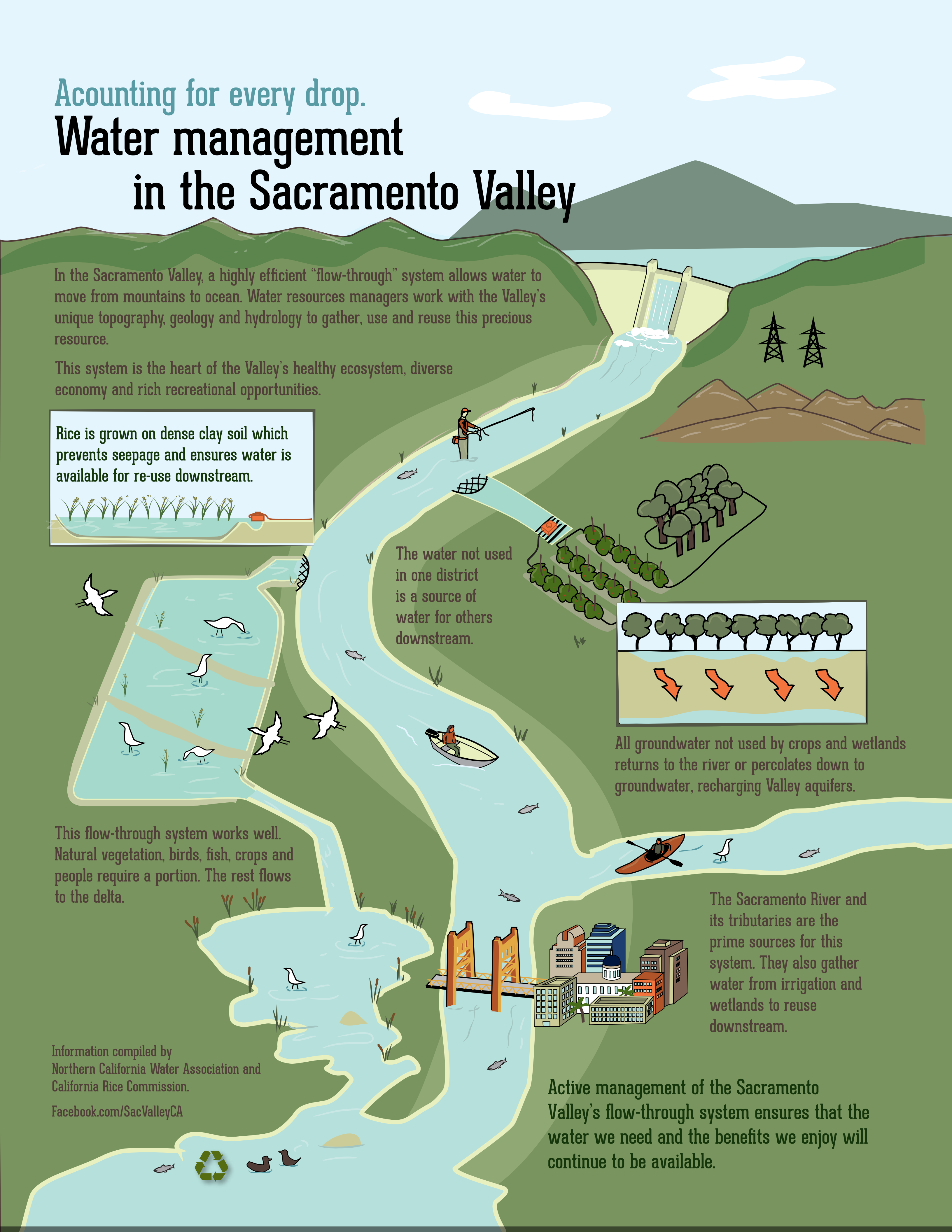
Acounting for every drop.
Water management in the Sacramento Valley
In the Sacramento Valley, a highly efficient "flow-through" system allows water to move from mountains to ocean. Water resources managers work with the Valley's unique topography, geology and hydrology to gather, use and reuse this precious resource.
This system is the heart of the Valley's healthy ecosystem, diverse economy and rich recreational opportunities.
Rice is grown on dense clay soil which prevents seepage and ensures water is available for re-use downstream.
The water not used in one district is a source of water for others downstream.
All groundwater not used by crops and wetlands returns to the river or percolates down to groundwater, recharging Valley aquifers.
This flow-through system works well. Natural vegetation, birds, fish, crops and people require a portion. The rest flows to the delta.
The Sacramento River and its tributaries are the prime sources for this system. They also gather water from irrigation and wetlands to reuse downstream.
Information compiled by Northern California Water Association and California Rice Commission.
Facebook.com/SacValleyCA
Active management of the Sacramento Valley's flow-through system ensures that the water we need and the benefits we enjoy will continue to be available.