Watershed Enhancement Strategies for Groundwater Sustainability

Photo: John Greening, 2010.

A San Joaquin Valley Greenprint Demonstration Project

Sequoia Riverlands Trust
Conserving California's Heartland

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AUTHORS

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Acknowledgment here does not imply agreement with any view expressed below, and any errors or omissions are the authors' own.

I. EXECUTIVE SUMMARY

The State of the Valley Report identifies water as "one of the central management challenges of the San Joaquin Valley," and emphasizes that "[b]oth surface water and water pumped from underground aquifers are critical to the region's farming, ranching, urban users, industry, and natural ecosystems."[1] Implementation of the Sustainable Groundwater Management Act (SGMA) is just beginning,[2] but the overall dialogue about water sustainability has focused more on technological solutions than on ways to improve the natural ability of watersheds to absorb, store and gradually release water in forms useful to people and the land. Sequoia Riverlands Trust's (SRT's) San Joaquin Valley Greenprint Demonstration Project explores the potential contribution of land-based strategies to watershed effectiveness, usable water supply and groundwater sustainability, focusing on three themes:

- Soil Enhancement and Water Resources;
- Floodwater Threats and Opportunities; and
- Mineral and Water Resources.

This report summarizes the results of mapping the scope and spatial distribution of potential land-based opportunities related to each theme. It then introduces an interactive web-based tool and Data Basin gallery that stakeholders can use to identify priority areas for watershed conservation and enhancement, and identifies key elements, partners and potential funding sources for a collaborative project in one such area. Finally, it offers a set of land-based strategies (i.e., best management practices) for GSA stakeholders, including recommendations for soil health enhancement, natural capture and storage of floodwater, and mine reclamation.

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[1] Thorne et al., 2014.
[2] Cal. Water Code § 10720 *et seq*.

II. INTRODUCTION AND BACKGROUND

A. Agriculture, Drought and Groundwater in Tulare County

The Central Valley has some of the most productive farmland and rangeland on the planet, producing over 250 crops and contributing tens of billions of dollars to California's economy.[3] Most of these crops are grown on irrigated land and, prior to the recent four-year drought, roughly 20% of U.S. groundwater extraction occurred in the Central Valley.[4] As the region's cities grow (nearly doubling in population from 1980 to 2009) and as statewide water demand rises, there is increasing competition for limited water supplies, and greater demand for groundwater.[5]

A USGS groundwater study conducted prior to the drought shows a continued decline in groundwater storage in the southern portion of the Central Valley, particularly in the San Joaquin Valley's Tulare Basin.[6] As illustrated in Figure 1, the region's aquifers lost almost 60 million acre-feet between 1960 and 2002.

[3] Faunt, 2009.
[4] Faunt, 2009.
[5] Faunt, 2009; USGS, 2009.
[6] USGS, 2009.

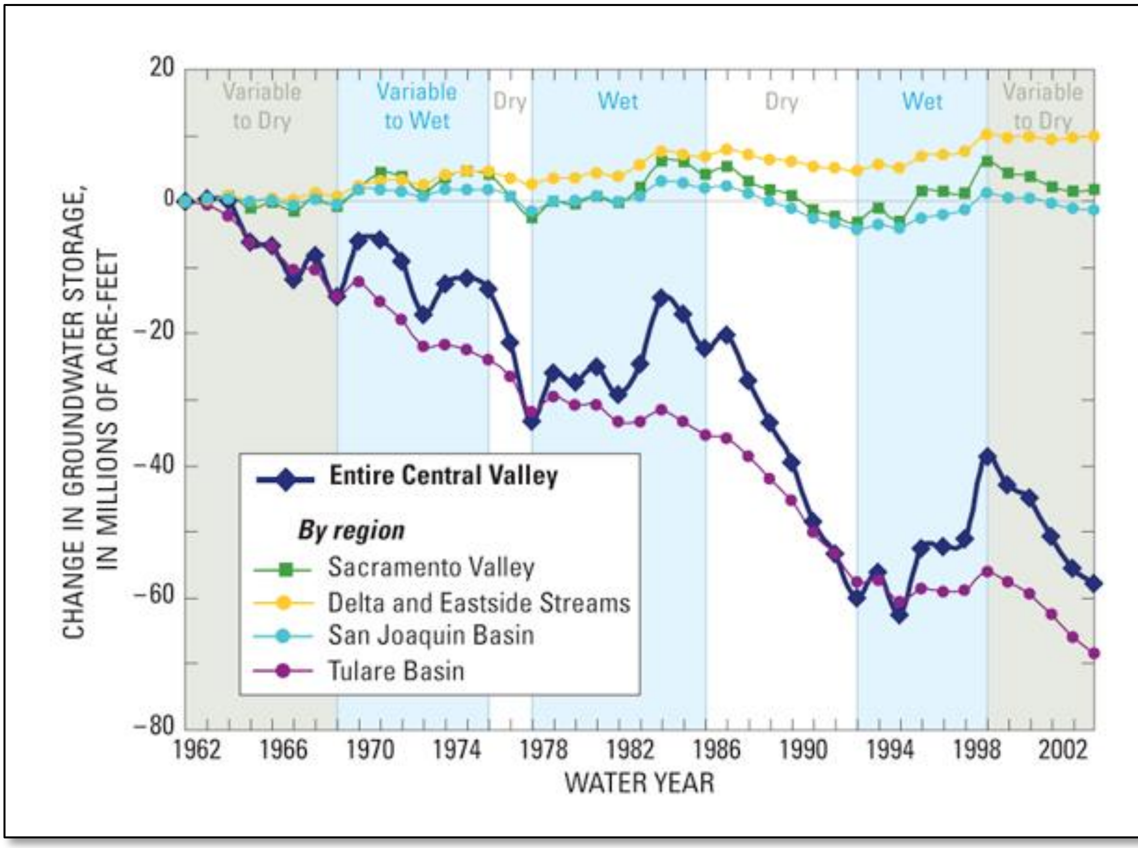

Figure 1: Change in groundwater storage across different regions of the Central Valley (USGS, 2009).[7]

Since that time, California has experienced a historic drought, including the driest four-year period on record. According to the California Department of Water Resources (DWR), the 2015 water year "produced by far the lowest snowpack in the Sierra Nevada since records have been kept, and by some estimates based on tree-ring analysis, was the lowest over the past five centuries."[8] This drought resulted in multiple, severe impacts to the environment. For example, the U.S. Forest Service announced in 2016 that aerial surveys had found over 102 million dead trees across 7.7 million acres of forest, with 62 million of those thought to have died that year.[9] This came alongside losses from the fallowing of agricultural land, economic impacts to industry, and a lack of reliable drinking water for many of the region's residents.

Less visibly, but just as importantly, the drought resulted in increased groundwater extraction as water users sought to balance out decreased surface flows. Groundwater levels in the San

[7] USGS, 2009.
[8] California DWR, 2016a.
[9] U.S. Forest Service, 2016.

Joaquin Valley dropped significantly between 2011 and 2016, with aquifers in some areas falling by 50 feet or more.[10] The loss of groundwater, in turn, caused portions of the aquifer system to compact and surface land to subside, resulting in permanent reduction of underground storage capacity. Overpumping greatly accelerated this process during the drought, while also damaging water delivery infrastructure such as the Delta-Mendota Canal.[11] As Figures 2 and 3 illustrate, subsidence due to groundwater depletion is evident in large portions of the Central Valley, with particularly severe impacts in the Southern San Joaquin Valley.

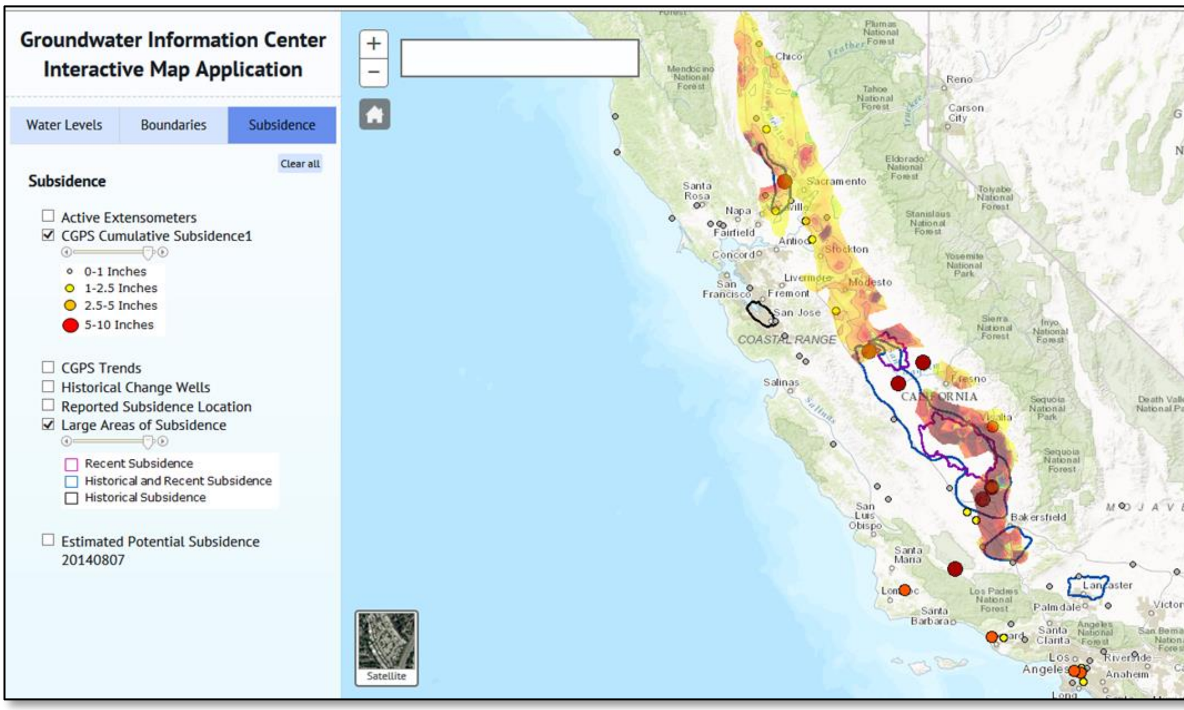

Figure 2: Groundwater depletion and subsidence in the Central Valley (California DWR, 2016b). Areas shaded in dark red saw groundwater levels decline 50 feet or more between 2011 and 2016, and colored outlines represent large areas of subsidence.

[10] California DWR, 2016b.
[11] California DWR, 2016b.

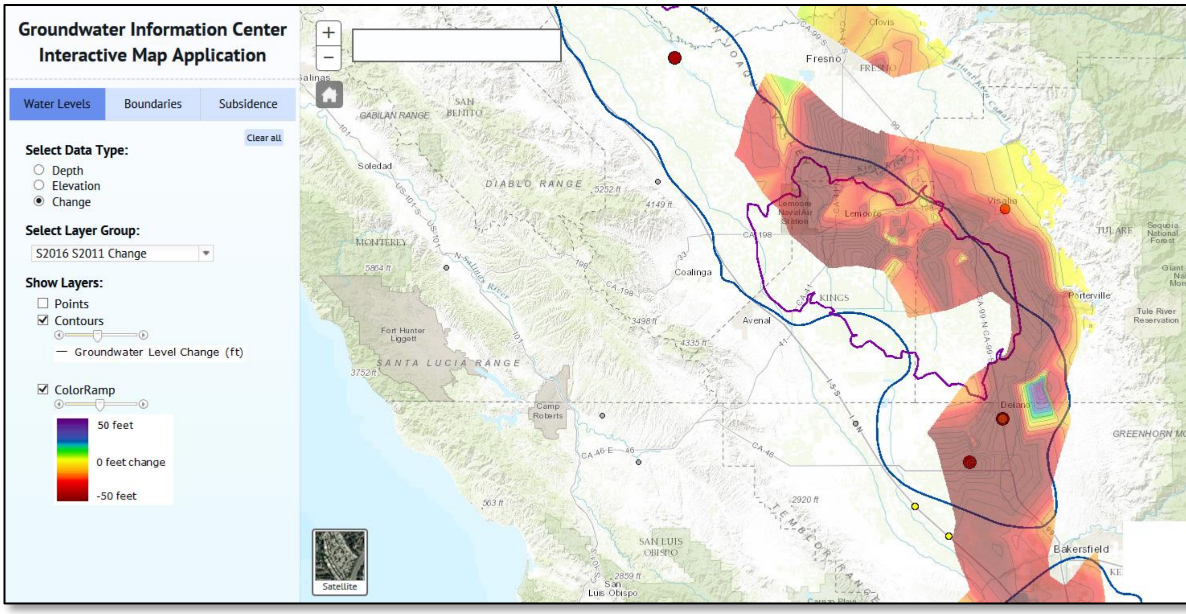

Figure 3: Zoomed-in map showing groundwater depletion and subsidence in the Southern San Joaquin Valley (California DWR, 2016b). Areas shaded in dark red saw groundwater levels decline 50 feet or more between 2011 and 2016, and colored outlines represent large areas of subsidence.

As Figure 3 suggests, Tulare County has been particularly hard hit. Its water demand has historically been met by surface water, groundwater and imported water.[12] But the drought reduced surface water flows and curtailed water deliveries, resulting in greatly accelerated groundwater pumping. A year into the drought, DWR estimated groundwater overdraft for the Tulare Lake Basin to be 820,000 acre-feet per year, more than any other basin in the state and a majority of California's total groundwater overdraft.[13] By December 2016, Tulare County had experienced 1,540 domestic well failures, with over 300 in the underserved community of East Porterville.[14]

The Kaweah Delta Water Conservation District (KDWCD), comprised of 340,000 acres in and around the Kaweah Delta, illustrates these patterns on a local level (see Figure 4). Within the District, 240,000 acres are devoted to irrigated crops, and approximately 50,000 are urbanized

[12] Tulare County, 2012. Surface water has been drawn from the Kings, Kaweah, Tule, Kern and White Rivers and Deer Creek, with San Joaquin River water imported via the Friant-Kern Canal. Additional supplies have come from the Central Valley Project and the State Water Project. Tulare County, 2012.
[13] Tulare County, 2012.
[14] Tulare County, 2016a (well failures as of December 19, 2016).

(mainly around the County's two largest cities, Visalia and Tulare).[15] In January 2016, a report on District water resources between 1981 and 2012 studied groundwater quantity, hydraulic movement, sources and volumes of natural recharge, and trends in water levels.[16] The report found that an average of 918,500 acre-feet of water per year was delivered to the District for irrigation, municipal, industrial and other uses.[17] Of this, 93% (852,100 acre-feet, coming from both surface water and groundwater) was used for irrigation.[18] Using the specific yield method, the study determined that a net water supply deficiency of about 2,403,000 acre-feet occurred during the 32-year study period. Of this, 68% (1,637,000 acre-feet) occurred between 2000 and 2012. Most of this loss was from the southwestern corner of the District (Unit VI).[19]

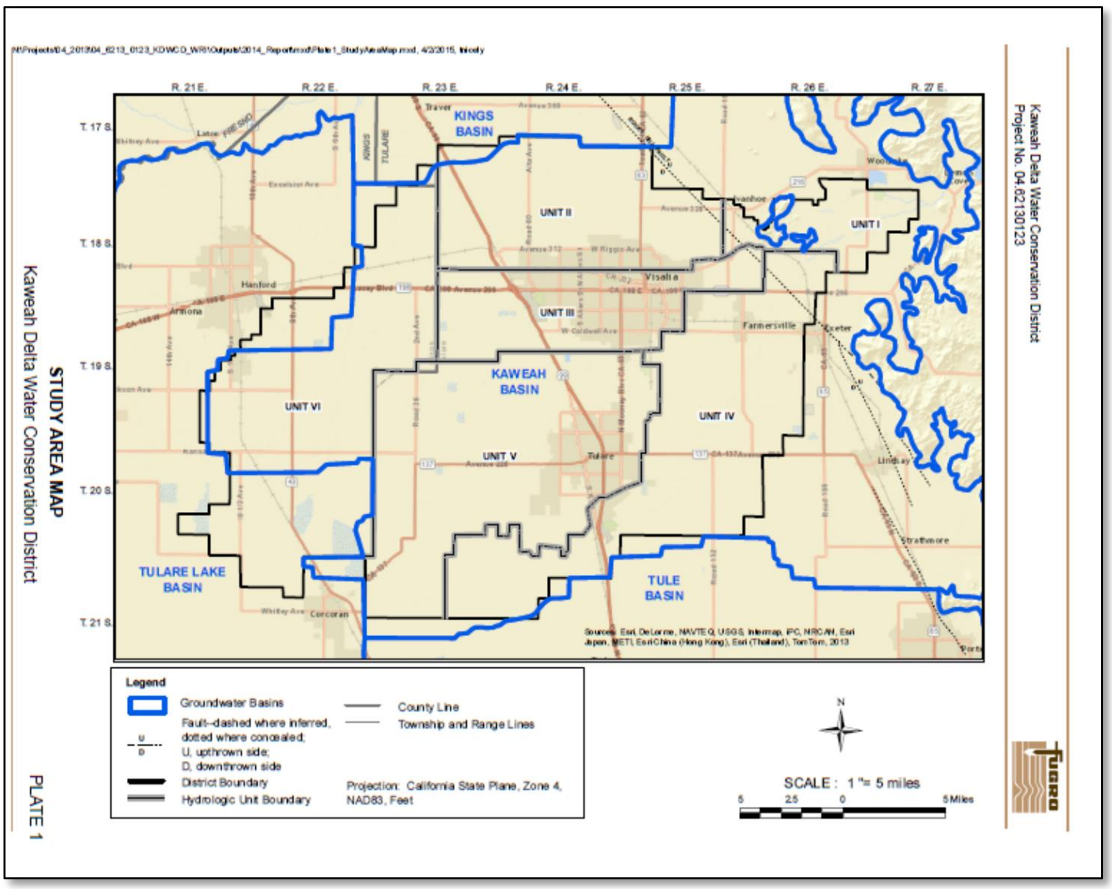

Figure 4: Map of KDWCD area (Fugro Consultants, 2016).

15 Fugro Consultants, 2016.
16 Fugro Consultants, 2016.
17 Fugro Consultants, 2016.
18 Fugro Consultants, 2016. Community and industrial water was obtained solely from groundwater during this period.
19 Fugro Consultants, 2016.

The combination of drought and record temperatures also led to tree mortality of "epidemic proportions" in Tulare County, resulting in habitat damage, increased wildfire risk and public safety issues from falling trees.[20]

In response to these impacts, the County declared states of emergency for both drought and tree mortality.[21] It used grant funds to deliver drinking water to low income families dependent on failed wells,[22] and began connecting homes in unincorporated areas to neighboring communities' water systems. The County also faced increasing demand for well permits, exacerbating the underlying problem. By the third quarter of 2015, the County had issued 1,958 such permits, as compared to 1,805 in the entire year of 2014, 513 in 2012 and 395 in 2011.[23] While recent rains have brought much-needed water to Tulare County's farms, cities and homes, groundwater depletion remains a pressing issue.

B. The Sustainable Groundwater Management Act

In September 2014, Governor Brown signed the Sustainable Groundwater Management Act (SGMA). This legislation requires local jurisdictions, water agencies and other stakeholders to establish Groundwater Sustainability Agencies (GSAs). GSAs in medium or high priority basins must develop Groundwater Sustainability Plans (GSPs).[24] For basins in critical overdraft, including much of Tulare County, GSAs must be formed by June 30, 2017, GSPs must be prepared by January 31, 2020, and the time horizon for achieving sustainability is 20 years.[25] As Figure 5 shows, GSAs in and around Tulare County are in varying stages of development.

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[20] Tulare County, 2016b.
[21] Tulare County, 2016a and 2016b.
[22] Tulare County, 2016a. As of December 2016, nearly 2,000 households qualified for this program. Tulare County, 2016a.
[23] Castellon, 2015.
[24] California DWR, 2017a.
[25] Cal. Water Code § 10720 *et seq*.; California DWR, 2016c. These designations are based on the California Statewide Groundwater Elevation Monitoring Program, which tracks seasonal and long-term groundwater elevation trends in basins that collectively account for 96% of groundwater pumping in the state. California DWR, 2014. As DWR notes, "[t]hese basins contribute close to 40 percent of the California's annual water supply in an average year and . . . [d]uring extensive dry or drought years, groundwater can provide close to 60 percent of the water supply." California DWR, 2014.

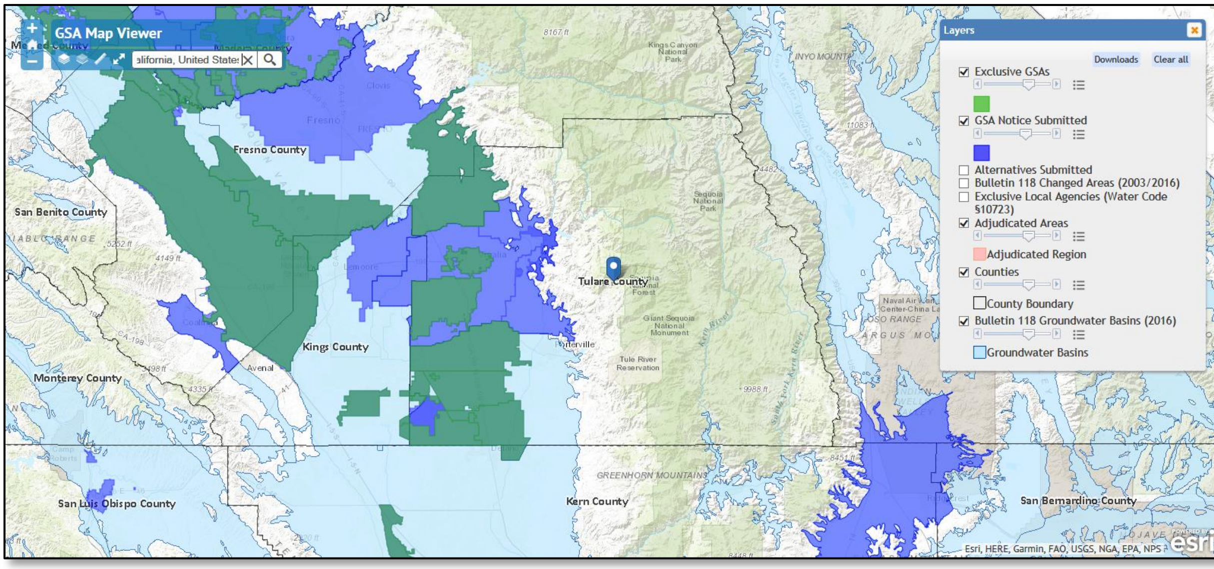

Figure 5: GSAs in the process of formation in Tulare County as of February 2017 (California DWR, 2017b).

In the Kaweah Subbasin, the Mid-Kaweah Groundwater Subbasin Joint Power Authority has been established as an Exclusive GSA (the Mid-Kaweah GSA).[26] This GSA includes the Cities of Visalia and Tulare and surrounding lands. Two other GSAs in the Kaweah Subbasin—the East Kaweah GSA and the Greater Kaweah GSA— are also in development.[27] In the Tule Subbasin, the Lower Tule River Irrigation District GSA (the Lower Tule GSA), the Tri-County Water Authority, the Pixley Irrigation District and the Delano-Earlimart Irrigation District have all received formal approval as GSAs.[28] Notice has also been submitted for an Alpaugh GSA.[29]

SRT's President and CEO, Sopac McCarthy Mulholland, is working with multiple GSAs in a technical or advisory capacity, currently including the Mid-Kaweah GSA, the Greater Kaweah GSA and the Lower Tule GSA.

C. Project Stakeholders

Beyond the GSAs discussed above, water management involves numerous stakeholders. Among those that SRT has engaged in the Kaweah and Tule River Watersheds are the following:

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[26] California DWR, 2017b.
[27] California DWR, 2017b.
[28] California DWR, 2017b.
[29] California DWR, 2017b.

- **KDWCD:** SRT has had extensive discussions with KDWCD to understand hydrology and groundwater recharge opportunities in the Kaweah Delta. KDWCD has provided data and technical assistance and, as discussed below, is now collaborating with SRT on designing and implementing a floodwater banking project at SRT's Kaweah Oaks Preserve (KOP).
- **Irrigation Districts:** Along with Sustainable Conservation, SRT has sought conceptual and technical feedback from the Tulare Irrigation District (TID).
- **Ditch Companies:** SRT has also consulted with the managers of the Peoples Ditch and Farmers Ditch Companies on floodwater layoff opportunities at KOP.
- **Local Jurisdictions:** Water management is affected by county and city governments, and relies in part on geospatial data held by local agencies. SRT has involved Tulare County, as well as the City Manager for the City of Visalia, in this project, and has incorporated County geospatial data in the mapping described below.
- **Conservation Agencies and Nonprofits:** SRT has coordinated with American Farmland Trust and Sustainable Conservation to ensure that all three Greenprint Demonstration Projects are aligned, while also sharing information with Sierra Nevada Conservancy, Tulare Basin Wildlife Partners (TBWP) and fellow members of the SRT-led Southern Sierra Partnership (SSP), including Audubon California, Sierra Business Council, Tejon Ranch Conservancy and The Nature Conservancy.
- **Consulting Firms:** In addition to GreenInfo, SRT staff have spoken with consultants working on the other two Greenprint Demonstration Projects (Earth Genome and Conservation Biology Institute, respectively). As described below, we have also worked with local consultants to lay the groundwork for the floodwater banking project at KOP.
- **Landowners:** Much of the land in our region is privately held, and SRT has reached out to multiple landowners in the course of this project. For confidentiality reasons, their identities and locations are not included in this report.

D. Past Planning in the Kaweah and Tule River Watersheds

The Kaweah and Tule River Watersheds and the Tulare Lake Basin have been the subject of intensive conservation and watershed management planning. These plans have given varying degrees of consideration to land-based approaches for addressing water balance and groundwater sustainability.

One such plan, the **SSP Framework**, is a nationally recognized, science-based strategy for climate adaptation in a seven million acre region that includes significant portions of the Kaweah and Tule River Watersheds. It examines the likely impacts of climate change on individual species, habitat connectivity and ecosystem services such as groundwater recharge.[30] Because rivers and streams play a central role in conveying melted snowpack to the Valley floor, while also providing habitat corridors that cross elevation gradients, the Framework recommends investing in at least two large-scale riparian restoration projects.[31] These projects would involve multiple stakeholders and contribute to "groundwater recharge, flood control, and enhancement of seasonal wetland habitat," while also supporting "riparian corridor connectivity, carbon sequestration, and scenic values."[32] As illustrated in Figure 6, the Framework includes regional conservation priorities, which emphasize riparian corridors and other areas that can support ecological and hydrological function—including natural groundwater recharge—in the face of climate change.

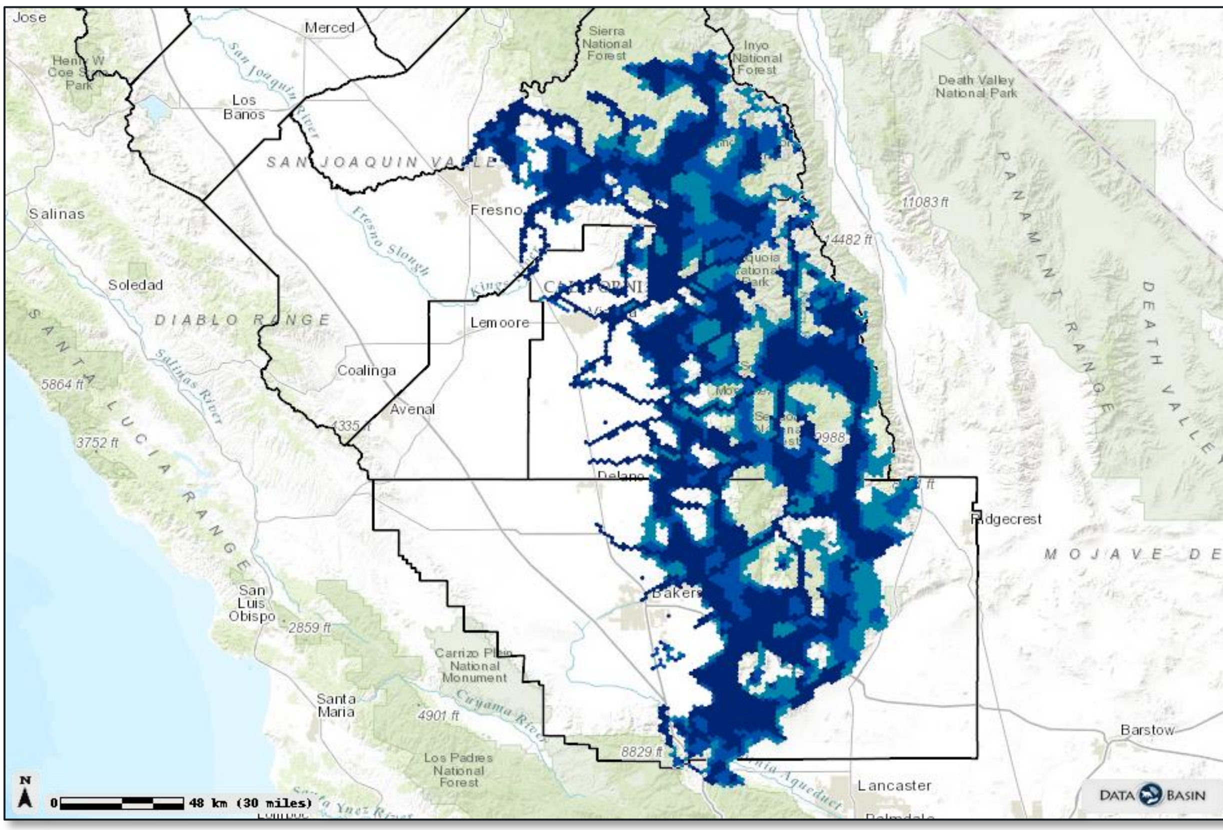

Figure 6: SSP Regional Conservation Design (SSP, 2010). From darkest to lightest, the three shades of blue represent Core Conservation Areas, Primary Buffers and Connectors, and Secondary Buffers and Connectors.

[30] SSP, 2010.
[31] SSP, 2010.
[32] SSP, 2010.

The **TBWP Regional Conservation Plan** focuses on protecting and restoring wetlands, riparian areas and upland habitat. It includes three area plans, as well as the Tulare Basin Riparian and Wildlife Corridor Conservation Plan, which identifies 16 key corridors connecting conservation areas and surrounding landscapes.[33] These include portions of the Kaweah and Tule River Watersheds, such as the "Oaks to Tules Corridor," which connects the Kaweah and Tule Rivers via Outside Creek (see Figure 7).[34] TBWP priority conservation areas are identified, with the goal of protecting habitat in light of climate change and shifting precipitation patterns.[35] The Regional Conservation Plan also includes the Water Supply Strategies Report, which quantifies water needs related to these goals and identifies potential supplies.[36] While its focus is primarily on the requirements for hydrologically viable wildlife habitat, it does identify wetland conservation as a floodwater storage strategy that can benefit urban, agricultural and environmental users.[37]

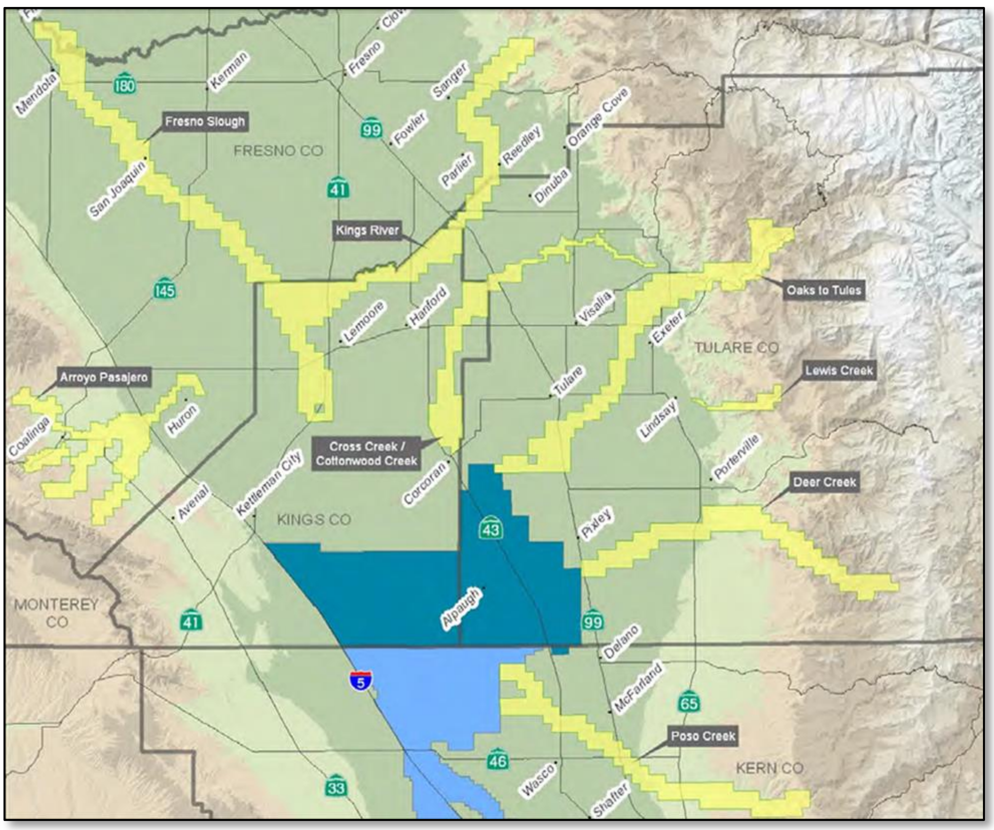

Figure 7: TBWP priority riparian corridors (highlighted in yellow) (Provost and Pritchard, 2010).

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[33] TBWP, 2010.
[34] Provost & Pritchard, 2010.
[35] Provost & Pritchard, 2010.
[36] Provost & Pritchard, 2010.
[37] Provost & Pritchard, 2010.

The Southern Sierra, Kaweah Delta and Tule Integrated Regional Water Management Plans (**SSIRWMP, KD IRWMP** and **Tule IRWMP,** respectively), are designed to provide frameworks for collaborative water management in the region encompassing the Kaweah and Tule River Watersheds.[38] Their IRWMP Reports identify a number of water management strategies, including approaches that emphasize natural resource stewardship and water banking. Among the SS IRWMP Report's recommendations are ecosystem restoration (both generally and as a component of "engineered projects, such as groundwater recharge basins"), conservation of aquifer recharge areas and collaborative watershed management.[39] The KD IRWMP Report considers opportunities for off-stream floodwater storage, though it concludes that one such opportunity may be lost to future urban development.[40] The Tule IRWMP Report suggests that approaches explored in the neighboring Kaweah Delta, including creation of multi-use areas to support "groundwater recharge, storm water control and habitat preservation/restoration," may be useful in the Tule as well.[41]

Sections III and IV build on these plans by exploring opportunities for land-based solutions to our region's water challenges.

III. MAPPING

A. Methodology

To identify opportunities for improved watershed function and natural groundwater recharge in the Kaweah and Tule River Watersheds, we focused our investigation on three themes. The first, **Soil Enhancement and Water Resources**, explores the potential to improve the "sponginess" of soils through compost application, grazing management and other practices that increase soil organic carbon. The second, **Floodwater Threats and Opportunities,** investigates ways to increase aquifer recharge through floodplain protection and restoration, as well as temporary storage of floodwaters on suitable farmland and conservation areas. The third theme, **Mineral and Water Resources**, focuses on strategies to enhance watershed effectiveness in Mineral Resource Zones and improve water-related outcomes of mine reclamation.

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[38] The SS IRWMP focuses on the headwaters and foothills region, while the KD and Tule IRWMPs focus on the Valley floor. Provost & Pritchard, 2014; KDWCD, 2014; Tule River Basin IRWMP Group, 2015.
[39] Provost & Pritchard, 2014.
[40] KDWCD, 2014.
[41] Tule River Basin IRWMP Group, 2015.

For each theme, we developed an initial hypothesis about the benefits of land-based strategies. We then gathered relevant layers from Data Basin and other sources, and went through an iterative process of mapping, review and consultation with experts. Based on the results, we prepared final theme maps and used them to locate the most promising areas for particular management strategies. As discussed below, these maps were then incorporated into the web-based reporting tool and used to zoom in on a case study area in the Mineral Resource Zone east of Visalia.

While the maps explore different themes, they have a common architecture. All three incorporate natural and human-made hydrological features, all incorporate land use data or designations, and all use the same model to identify the most promising locations for land-based groundwater recharge strategies. This model, the UC Davis Soil Agricultural Groundwater Banking Index (SAGBI), is one of several that have been developed to identify agricultural lands suitable for winter floodwater banking.[42] SAGBI evaluates data on soil type, crop type and topography in light of five critical factors:

- Deep percolation: Soils must readily transmit water beyond the root zone.
- Root zone residence time: Crops grown on the land must be able to tolerate saturated conditions during floodwater banking.[43]
- Topography: Level or near level topography is ideal.
- Chemical limitations: Soils with high salinity may result in groundwater contamination.
- Soil surface condition: Some soils are vulnerable to compaction and erosion if large volumes of water are applied. High sodium, resulting in soil crusting, is also an issue.[44]

Dr. Anthony O'Geen from UC Davis kindly provided SAGBI mapping data for Tulare County, and all three theme maps incorporate SAGBI "excellent" or "good" locations for floodwater banking.[45]

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[42] O'Geen et al., 2015.

[43] While results are still preliminary, agronomists have identified pears, wine grapes and trees with some *Prunus* rootstocks, including almond, peaches and plums, as the best crops for groundwater banking. O'Geen et al., 2015.

[44] O'Geen et al., 2015.

[45] Research on cropland floodwater banking is quite recent, and focuses primarily on irrigated croplands rather than the annual and perennial grasses typical on rangelands. Other models address additional factors that are important in identifying good locations for groundwater recharge, including depth to groundwater, soil type of different layers between the root zone

B. Theme Maps

1) Soil Enhancement and Water Resources

This theme encompasses the foothills and mountains of the Kaweah River and Tule River Watersheds as well as the Valley floor, and explores the potential to improve the ability of soils to act as a natural sponge through management practices that increase soil organic carbon (SOC).

a) Context

The relationship between soil organic matter (SOM) and the soil's capacity to soak up (infiltrate) and retain moisture is well established.[46] There is evidence that SOC, which averages about 50 – 56% of SOM,[47] has been significantly depleted over large areas of the landscape, due at least in part to past land management choices.[48]

This loss is lamentable, but also offers an opportunity, through SOC-enhancing management practices, to improve how well the land captures and stores precipitation that falls in our watersheds ("watershed effectiveness"). Benefits include:

- **Increased water supply and extended growing season** for plants and soil microbes living where the precipitation falls, enhancing food and fiber production, wildlife habitat, and soil formation.
- **Improved groundwater recharge and natural water storage**, since soils with greater amounts of organic matter do a better job of absorbing precipitation and gradually releasing it into waterways that flow into constructed reservoirs at a manageable rate, or into underground aquifers where it helps recharge groundwater and can be accessed via wells. This helps match the timing of water availability (rainy season) to the timing of greatest water need (the dry season).
- **Reduced surface runoff and erosion**, in turn reducing the amount of sediment and pollutants entering streams and reservoirs. This helps maintain both water quality and the storage capacity of constructed reservoirs.

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and groundwater, and hydrologic features. Faunt, 2009; USGS, 2015; USGS, 2016; FEMA, 2017. As a preliminary approach, we use only the SAGBI model.

[46] Huntington, 2007; Rawls et al., 2003.

[47] Pribyl, 2010.

[48] Chambers et al., 2016; Lal, 2016; Lal, 2010.

- **Less need for supplemental irrigation**. Many of the management practices that boost soil water-holding capacity also keep the soil surface covered with plants or plant litter that reduce the loss of soil moisture through evaporation. Farmers report that this enables them to reduce irrigation volumes and frequency.[49]

Research and case studies indicate that SOC-enhancing management practices also boost productivity and biological diversity on farmland and rangeland, and can transfer large amounts of atmospheric carbon (a greenhouse gas) into stable carbon compounds in the soil, such as humus. These diverse benefits address the interests of ag producers, water managers, conservationists and others who are often at odds over water issues.[50]

For example, the Marin Carbon Project explored the pros and cons of a single application of ½" of compost to experimental plots in grazed rangelands of the Coast Range and Sierra Nevada foothills. Investigators measured trends in soil carbon, as well as forage production and the soil's infiltration and water-holding capacity. One year later, they reported a 25% increase in overall soil water-holding capacity, and a 40% to 70% increase in forage production and these functional benefits persisted during the 6-year data collection period.[51] SOC increased an average of one metric ton per hectare per year during that time.[52]

Subsequent modeling efforts suggest that boosting SOM by 1% (e.g., from 1% to 2%) on California's rangelands would add 2.5 million acre-feet of water storage capacity.[53] Expressed in terms relevant to local land and water management, a 1% increase in SOM can enhance the land's ability to capture and naturally store water by 1" per acre per year, or one acre-foot of water for every 12 acres.[54] Studies like the Marin Carbon Project, and results reported by numerous ag producers around the country demonstrate that such increases in SOC and its water-related benefits are quite achievable, whether through compost applications or many other SOC-enhancing practices such as mulching, reduced tillage, cover crops, intensively managed grazing, high biomass crop rotations, and various combinations of these strategies (e.g., "pasture cropping").[55] These techniques have varying degrees of practicality and

[49] NRCS, 2017 (Profiles in Soil Health); see also Smith, 2016.
[50] Chambers et al., 2016; Swan et al., 2014; Ryals and Silver, 2013.
[51] Ryals et al., 2014; see also Ryals et al., 2016.
[52] Ryals et al., 2014; Creque, J. (personal communication, March 2017).
[53] Cf. Kansas State University, 2012 (noting studies indicating that "each one percent increase in SOM results in about 20,000 to 25,000 more gallons of available soil water per acre, or about one acre-inch").
[54] Huntington, 2007.
[55] Chambers et al., 2016; Lal, 2004.

effectiveness depending on factors like soil type, topography, road access, producer capacity, and economies of scale, but overall they show substantial promise to help address water supply and groundwater sustainability issues.

b) Opportunities in Our Region

The Soil Enhancement and Water Resources theme map (Figure 8) examines the potential water-related benefits of SOC/SOM-enhancing practices in the Kaweah and Tule River Watersheds. In the foothills, this would mainly involve compost application or intensively managed grazing. On the Valley floor, these and other practices like reduced tillage and cover crops would be applicable. The presumption is that these practices are likely to be most feasible in moderate terrain with reasonable road access and, for the compost strategy, proximity to a commercial composting facility. Thus, we incorporated the following data and parameters into our mapping:

- California Department of Conservation Farmland Mapping and Monitoring Program (FMMP*)* categories of farmland, grazing land and lands in natural vegetation.
- Slopes less than or equal to 30%. This includes virtually the entire Valley floor, so on the map, slopes are differentiated only for the foothill rangelands.
- Areas within 200 meters of a maintained road, paved or otherwise, that could accommodate compost hauling or spreading equipment, and would enable ready access for frequent interactions with livestock (e.g., to move animals frequently among small pasture subdivisions). The majority of lands meeting the slope criteria also had reasonable road access, so to prevent visual clutter we did not show road access as a separate map attribute. However, the computations displayed in Table 1 do reflect this parameter.
- Areas within 50 miles of a commercial composting facility with at least 10,000 tons of annual through-put. This was true for all lands meeting the other criteria, so this parameter was not differentiated on the map

We also assumed that SOM could be increased by at least 1% on all soils that met the other criteria. The foothill rangeland areas shaded in orange in Figure 8 satisfied all of these parameters, as did all of the ag lands on the Valley floor. Table 1 depicts acreage computations based on the map.

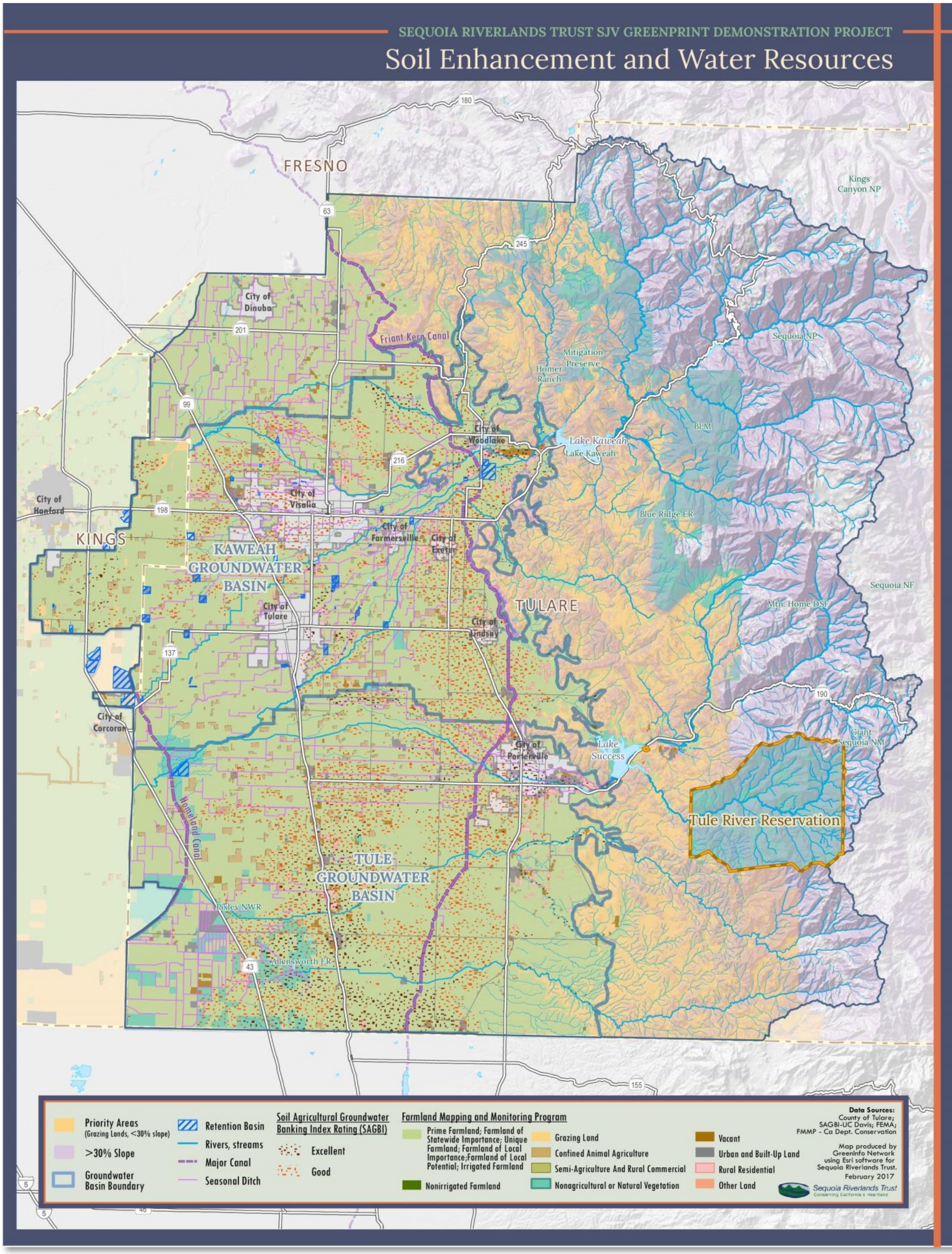

Figure 8: Soil enhancement and water resources map.

Category	Acreage	Percent	Acreage within 200 meters of maintained road	Percent within 200 meters of maintained road
Total land included in study	1,180,534	100%	-	-
FMMP Farmland, <30% slope	863,576	73%	416,989	35%
FMMP Grazing land, <30% slope	243,675	21%	106,861	9%
Natural Vegetation	73,283	6%	31,584	3%
Non-Agriculture (all other designations)	126,920	11%	93,414	8%

Table 1: Opportunities for soil organic carbon enhancement in the Kaweah and Tule River Watersheds.

There are 555,434 acres of farmland, grazing land and lands in natural vegetation that satisfy all of the mapping parameters. To be conservative, we assumed that SOM could be increased by at least 1% through deliberate carbon-focused management of about 20,000 acres of grazing land, 150,000 acres of farmland and 5,000 acres of natural lands. If this translated to an additional inch of water holding capacity per acre per year (i.e., 1/12 of an acre-foot of water for each acre of land), the total annual increase would be:

$$\frac{\text{175,000 acre-inches}}{12} = \text{approximately 14,580 acre-feet per year}$$

This equates to about 19% of the Kaweah Delta Water Conservation District's average annual water supply deficiency during the 32-year period from 1981 to 2012.[56] It seems well worth considering how to encourage adoption of soil carbon-focused management practices in our watersheds, especially given the other notable benefits of these practices.

[56] Fugro Consultants, 2016.

2) Floodwater Threats and Opportunities

a) Context

In addition to periodic droughts, which may become more severe as climate change intensifies,[57] the San Joaquin Valley experiences large flooding events. Floods may also become more frequent, as higher temperatures lead to earlier snowmelt and cause more precipitation to fall as rain.[58] In this environment, land-based strategies that capture water and allow it to percolate into aquifers may be able to provide both groundwater recharge and flood protection. For example, a recent study found that winter flooding of suitable farmland in Sierra Nevada watersheds in parts of Merced, Madera and Fresno Counties could reduce annual groundwater overdraft in that area by 12 – 20%.[59] Suitability was defined in terms of hydrologic soil conditions, crop types compatible with winter flooding, proximity to surface water courses and conveyance facilities, and availability of recharge water. Sustainable Conservation has since been working closely with the Madera and Tulare Irrigation Districts to develop a tool for optimizing groundwater recharge through deliberate on-farm flooding of suitable lands.[60] Beyond farmland, a study of Central Valley wetlands enrolled in the USDA Wetland Reserve Program found that these areas could hold up to 3.9 billion cubic meters of floodwater—nearly eight times the highest volume of floodwater in New Orleans during the Katrina disaster.[61]

b) Opportunities in Our Region

The Floodwater Threats and Opportunities theme map (Figure 9) is built around flood zones identified by the Federal Emergency Management Agency (FEMA) National Flood Insurance Program. These areas include both base flood zones (1% annual chance of flood) and moderate flood hazard zones (0.2%-1% annual chance of flood).[62] In our mapping we overlaid this with FMMP-identified farmland, grazing land and natural vegetation areas, as well as areas designated by SAGBI as “excellent” or “good” for groundwater recharge.

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[57] Cook et al., 2015.
[58] SSP, 2010.
[59] RMC Water and Environment, 2015.
[60] Mountjoy, D. (personal communications, June 2016 – March 2017).
[61] Duffy and Kahara, 2011; Smith and Rowland, 2006.
[62] FEMA, 2017.

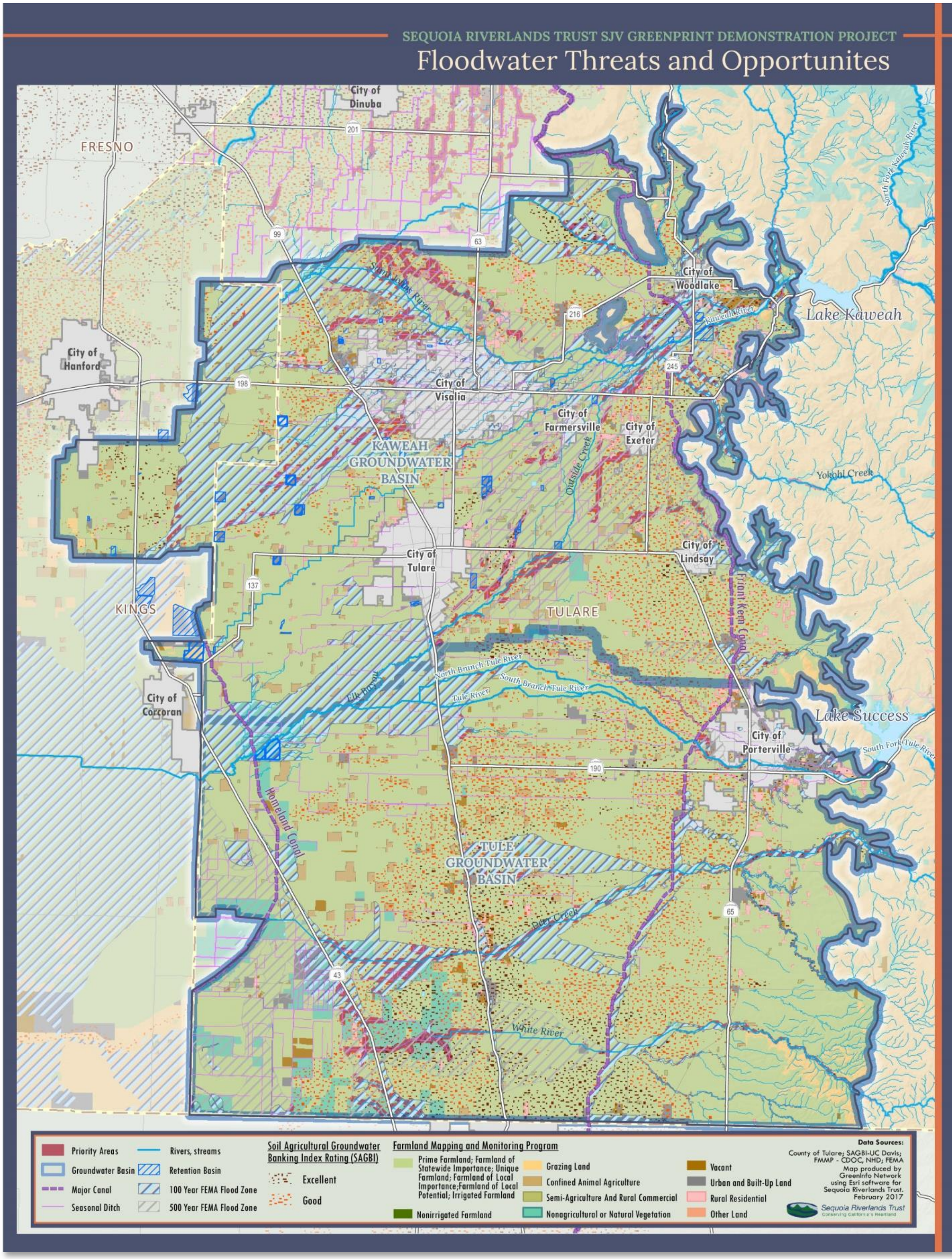

Figure 9: Floodwater threats and opportunities map.

Figure 9 depicts large flood zones along the Kaweah River and tributaries to the west of Terminus Dam. The flood zone includes much of northern Visalia, and pools in a large area to the west and south of Visalia. A flood zone also occurs along the Tule River and its tributaries to the south of Visalia, with Outside Creek/Elk Bayou connecting the Kaweah and Tule River Watersheds. A large flood zone in the vicinity of Elk Bayou contributes to a flood zone south of the City of Tulare. Additional flood zones along Deer Creek and White River add to flooding potential in the southern portion of the Tule Subbasin.

As Table 2 shows, a total of about 135,000 acres of farmland and rangeland in the Tule and Kaweah Subbasins are within the FEMA flood zones and are also rated as “excellent” or “good” for groundwater recharge.

Zone	Acres	Percentage
FEMA flood zone	366,578	100%
FMMP Farmland in flood zone	263,738	72%
FMMP Grazing land in flood zone	6,328	2%
SAGBI “Excellent” in flood zone	32,731	9%
SAGBI “Good” in flood zone	102,013	28%
Total SAGBI “Excellent or Good” rating in flood zone	134,744	37%

Table 2: Flood zone statistics (based on GIS data provided by GreenInfo).

It was beyond the scope of our project to determine how much of this acreage is in crops like almonds, alfalfa and vineyards that might be compatible with winter flooding, or to estimate the volume of floodwater that could be available for on-farm recharge. However, this mapping exercise at least provides an order-of-magnitude idea of the potential ag land available for on-farm floodwater infiltration and groundwater recharge.

Restoration of natural floodplain function also has the potential to make a substantial contribution to groundwater recharge, while conferring flood management and habitat benefits. In the course of agricultural and urban development, many streams have been channelized or otherwise modified to serve as part of the infrastructure for flood management and distribution of irrigation water. These streams are cut off from their historic floodplains, where high flows would have spread out, slowed down and had more opportunity to infiltrate to underlying aquifers. Water management agencies and municipalities are now constructing numerous dual-purpose floodwater layoff/groundwater recharge basins to replace some of this natural function. These basins are expensive and require ongoing management. There are still opportunities to protect remaining natural floodplain areas and to carefully restore some modified floodplains without threatening established agriculture or other resource values.

SRT's Dry Creek Quarry restoration provides an example. SRT received the 152-acre retired aggregate mine as a donation in 2004, and also took on the responsibility to meet state mine reclamation standards for the site. The original reclamation plan envisioned a lake constructed in the alluvial plain of Dry Creek, along with a water control structure to ensure delivery of a minimum supply of surface water to downstream water users. SRT chose instead to remove berms constructed to keep Dry Creek in a single channel during mining of alluvial sand and gravel. As illustrated in Figure 10, this partially restored Dry Creek's braided, multi-channel flow pattern that spread floodwaters over much of the original floodplain area. SRT has not attempted to measure how this has contributed to groundwater recharge, although monitoring wells set some distance from the main channels do show groundwater levels rising several feet when stream flows are high.[63]

Figure 10: View of post-restoration braided streamflow at Dry Creek Preserve (Photo: SRT, 2010).

[63] SRT, 2009.

Strategies for restoring natural floodplain function fall on a continuum from active diversion into constructed basins; to compensating farmers for "seepage easements" that allow periodic flooding of crop land adjacent to waterways (a mechanism already being tried in the Tulare Irrigation District, and used by the Bureau of Reclamation as part of implementing the San Joaquin River settlement agreement); to preservation of natural floodplain areas that are allowed to flood as a way of restoring wetland and riparian habitat. As discussed below in the context of the KOP project concept, several of these strategies can be combined to achieve multiple benefits of flood management, groundwater recharge, habitat restoration and enhancement of outdoor recreation. The high priority areas shown on the Floodwater Threats and Opportunities map (Figure 9) may be promising areas for such multi-benefit projects. Many overlap with high priority conservation areas already identified in the SSP Regional Conservation Design (see Figures 6 and 9),[64] the Southern Sierra Integrated Regional Watershed Management Plan, and conservation plans done by the Tulare Basin Wildlife Partners.

It is also worth exploring how to enhance the overall public benefit of any given flood management strategy, particularly for expensive strategies like constructed floodwater layoff and recharge basins. For example, KDWCD has designed its new basin southwest of KOP to augment riparian wildlife habitat. The City of Visalia is planning its East Side Regional Park for the multiple purposes of floodwater layoff, groundwater recharge and outdoor recreation. [65] Collectively KDWCD, Tulare Irrigation District and the City of Visalia have or are planning about 75 basins totaling roughly 7,000 acres, so even minimal enhancements such as re-vegetation with native plants can yield substantial cumulative benefits.[66]

3) Mineral and Water Resources

a) Context

Land currently used for mining operations, as well as state-designated Mineral Resource Zones (MRZs) that could host mines in the future, may have the potential to contribute to watershed function and groundwater recharge. In addition to CEQA review to identify and mitigate environmental impacts, an applicant for a surface mining permit must submit a plan for reclaiming the site once mining is completed. Reclamation plans are designed to return the land to a beneficial use, such as agriculture or wildlife habitat, and must address erosion

[64] SSP, 2010.
[65] City of Visalia, 2017.
[66] L. Dotson (personal communication, December 20, 2016); D. Damko (personal communication, December 30, 2016); J.P. Hendrix (personal communication, March 18, 2017).

control, slope stability, topsoil replacement, revegetation and related issues.[67] Depending on location, end use and site characteristics, mine reclamation plans could also include measures specifically aimed at restoring or enhancing groundwater recharge capacity.[68] Such measures might include restoring natural floodplain function (as discussed above for SRT's Dry Creek Quarry restoration), converting excavated areas to floodwater layoff/groundwater recharge basins, or implementing practices that improve soil infiltration and water-holding capacity, such as compost applications and revegetation with native perennials. These measures can also enhance other public benefits of reclaimed mines, such as flood management, wildlife habitat, scenic and recreational values.

b) Opportunities in Our Region

To identify opportunities for improving water-related outcomes of mining in the Kaweah and Tule River Watersheds we mapped areas where the following attributes overlap (see Figure 11):

- Designated Mineral Resource Zones and existing mine sites;
- FMMP categories of farmland, grazing land and natural vegetation;
- "Excellent" or "good" SAGBI ratings; and
- FEMA flood zones.

[67] California DOC, N.D. (Reclamation Plan Guidelines).
[68] MRZs are often located in alluvial plains and flood zones, and are incorporated into city and county general plans as areas to be kept relatively free of development to allow for future mining. See, e.g., Tulare County, 2012 (Tulare County General Plan incorporating MRZs).

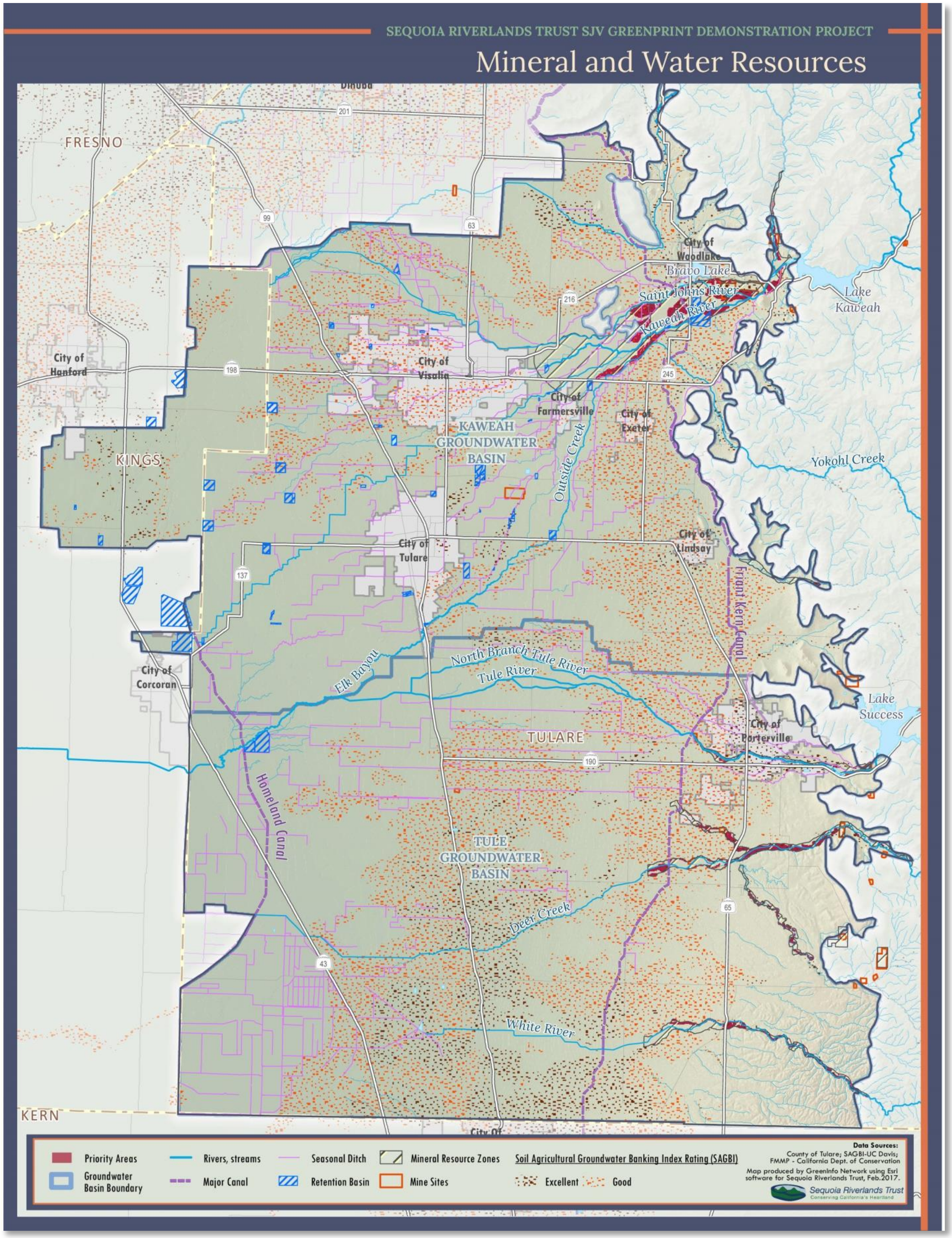

Figure 11: Mineral and water resources map.

Figure 12 and Table 3 zoom in on Tulare County's largest Mineral Resource Zone, the 16,210 acre MRZ between Lake Kaweah and the City of Visalia. A 0.25-mile buffer zone around the MRZ has been added to take in additional lands potentially available for floodwater layoff or enhancement of soil water-holding capacity, enlarging this study area to 23,168 acres. The Priority Areas show where the mapped attributes overlap.

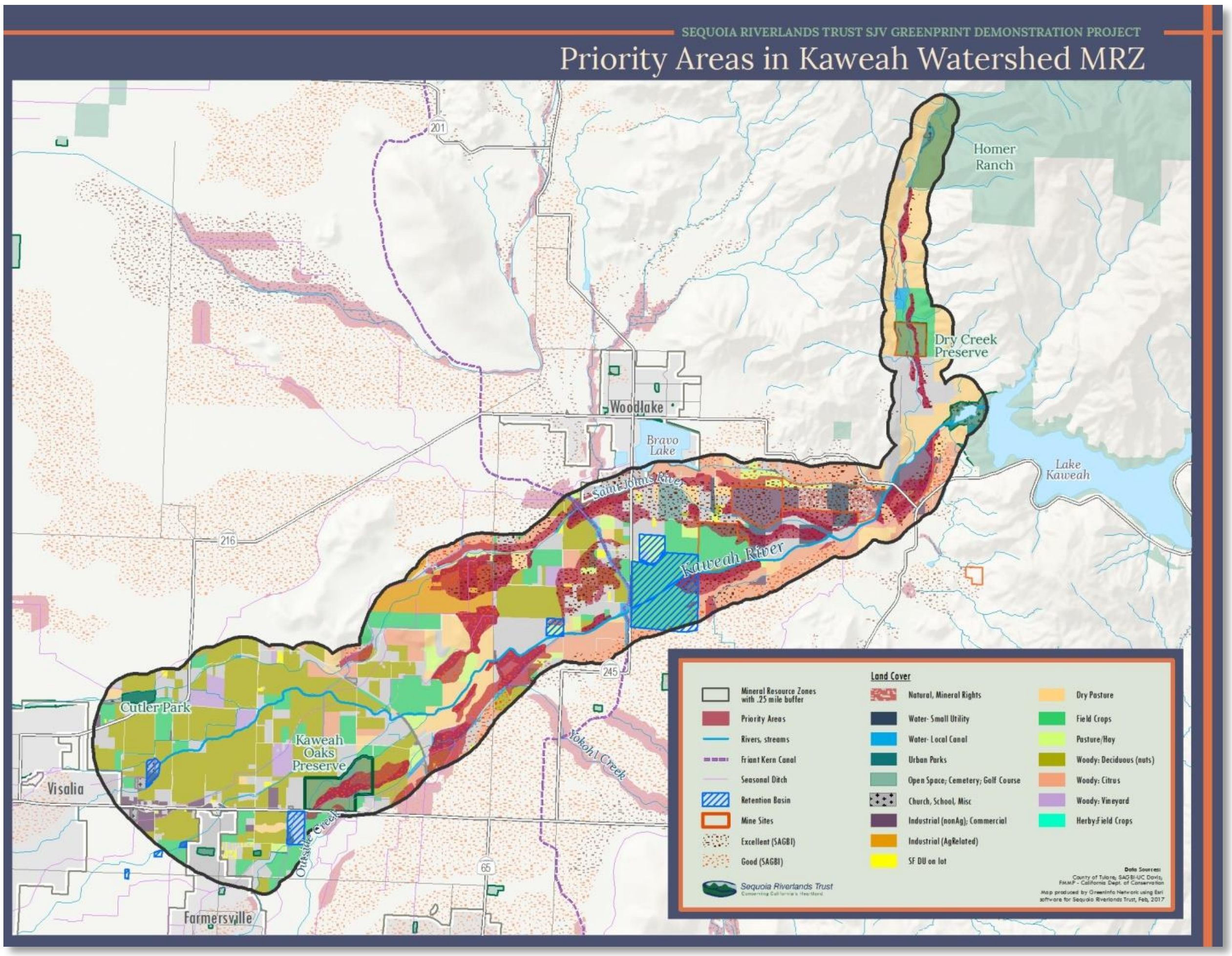

Figure 12: Priority areas in the Kaweah Watershed MRZ.

Category	Acres
Conceptual Area: Kaweah Subbasin = MRZ plus 0.25-mile buffer	23,168
Kaweah Subbasin MRZ no buffer	16,210
Agricultural (All crops)	9986
Field Crops	2685
Fruit Trees: Citrus	1,970
Fruit Trees: Fruit and Nut	2877
Vineyard	34
Pasture	2420
Natural Land/Conservation land	145
Total Agricultural and Natural Lands	**10,131**
Surface Mines	697
Priority Areas Within MRZ	**2,613**
Recharge Basins (KDWCD existing or under construction)	8 basins totaling 1,415 acres, holding capacity approx. 6,000 AF

Table 3: Land use and priority areas in the Kaweah Watershed MRZ.

The east end of this MRZ contains several existing mine sites in various stages of active mining, reclamation, or in the case of older mines, abandonment. The latter pre-dated California's Surface Mining and Reclamation Act requiring reclamation plans and bonding as part of the permitting process. These mines collectively affect about six miles of river corridor between Dry Creek Preserve and Bravo Lake, representing an interesting opportunity for coordinated restoration to enhance overall outcomes for water resources, flood management, riparian habitat, aesthetics and post-mining property values.

The MRZ also contains a number of existing and planned floodwater layoff/groundwater recharge basins, substantial farmland area in crops that may be suitable for on-farm flooding/recharge, and sizeable remnants of undeveloped land such as KOP. The area has been identified in several regional conservation plans as a high priority for conservation and restoration of riparian habitat (see, e.g., the SSP Regional Conservation Design in Figure 6).[69] In short, this MRZ is a promising area for collaborative, multi-benefit projects that support watershed effectiveness and groundwater sustainability.[70]

[69] SSP, 2010; TBWP, 2010.

[70] For example, projects could include parks that double as groundwater recharge basins, or incorporate a string of pleasant rest stops along a Visalia-to-Lake Kaweah bike trail.

C. Resources for Ongoing Use

1) Web-Based Tool

In addition to the static maps above, SRT and GreenInfo developed an interactive, web-based mapping tool, which allows for highly customized views of the data.[71] The tool provides an easy entry point, with the default views highlighting the priority areas for each theme. Users can then manipulate the Context Layers interface to select additional layers and begin identifying areas of opportunity. All layers shown in the static maps are also available here, with individual toggles and transparency sliders to give users control over how the data is presented. These features allow users to mix and match for their own priorities and compare them to SRT priorities. For example, Figure 13 shows the Floodwater Threats and Opportunities layer, combined with layers for SAGBI rating, land use, and rivers and streams, for the area near KOP.

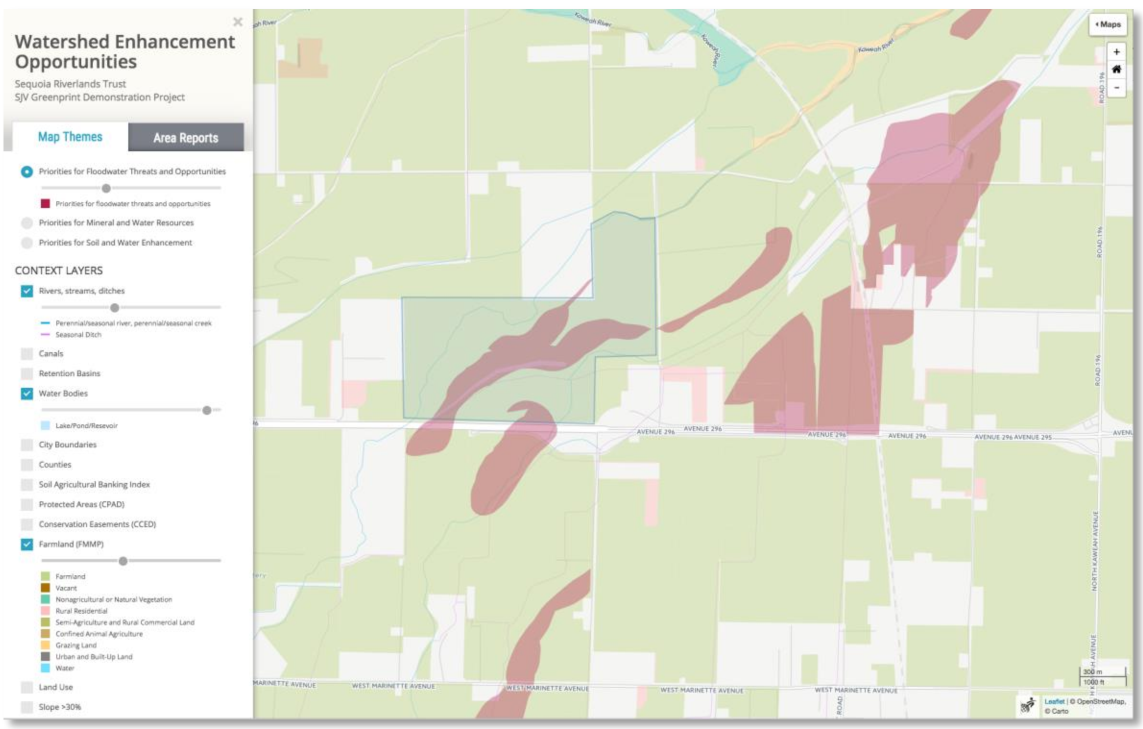

Figure 13: Screenshot of web-based tool map of floodwater threats and opportunities near Kaweah Oaks Preserve.

A simple basemap selector provides satellite imagery that gives further detail and information to help select sites for projects. Using these overlays, the web-based tool makes it easier to see the highest priority locations.

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[71] The tool is accessible at websites.greeninfo.org/srt/greenprint.

Finally, users can switch to the Area Reports tab to drop a pin, enter an address, or draw a custom area to get a report on that specific location. This will produce a downloadable report of all the metric data for the selected area (see Figure 14). Such reports can be used to compare alternatives, support funding requests or otherwise drive planning processes.

SEQUOIA RIVERLANDS TRUST SJV GREENPRINT DEMONSTRATION PROJECT

Watershed Enhancement Opportunities

Basic Info

Search area (acres)	325.68
County	Tulare
Cities	

Priority Areas (acres)

Mineral and Water Resources	0.00
Floodwater Threats and Opportunities	76.96
Soil Enhancement and Water Resources	0

Protected Lands (acres)

Protected areas (CPAD)	313.67
Protected areas (CCED)	0.00

Water Features

Canals (meters)	0.00
Rivers, streams, ditches (meters)	2,644.01
Water bodies (acres)	0.00
Retention basins (acres)	0.00

Slope (acres)

Slope greater than 30%	0.00
Slope less than 30%	0.00

FEMA flood zones (acres)

100 year flood zone	181.24
500 year flood zone	144.44

Soil Agricultural Banking Index [SAGBI] (acres)

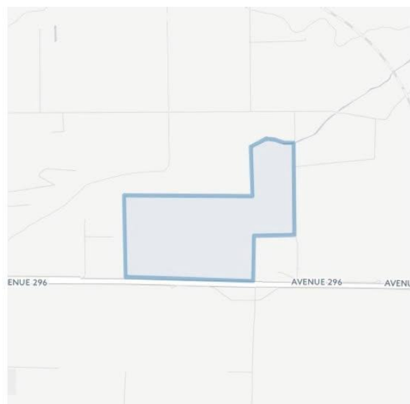
Excellent	0.00
Good	115.87

Mining (acres)

Mineral resource zones	272.00
Mines sites	0.00

Landcover

Grazing	309.97
Groundwater recharge	0.00
Agricultural uses	3.78
Natural	0.00
Semi-agricultural uses	0.91



Farmland Mapping and Monitoring Program [FMMP] (acres)

Farmland	314.60
Vacant	0.00
Grazing land	0.00
Semi-agricultural and rural commercial land	0.00
Nonagricultural or natural vegetation	0.00
Confined animal agriculture	0.00
Rural residential	0.02
Urban and built-up land	0.00
Water	0.00
Not surveyed	0.00

Sequoia Riverlands Trust
Conserving California's Heartland

Report created March 24, 2017

Figure 14: Pin-drop report from web-based tool.

2) Data Basin Gateway

All datasets used in the maps above and in the web-based reporting tool are documented and available for download on the San Joaquin Valley Greenprint Data Basin Gateway (https://sjvp.databasin.org/galleries/3be9db150c6945e189ce49f0adb720ed), which is the central repository for data from all three Greenprint Demonstration Projects. By using this shared platform, we seek to maximize data sharing and the future value of the data gathering and analysis we did for this project.

D. Next Steps

Based on the results above, there is substantial potential to improve watershed effectiveness and groundwater sustainability in the Kaweah and Tule River Watersheds through land conservation and management strategies. Kaweah River alluvial lands east of Visalia show promise for a major collaborative effort to achieve multiple resource benefits, with strategies including conservation easements, seepage easements, soil carbon-focused agricultural practices, floodwater layoff, floodplain and riparian habitat restoration, water-focused mine reclamation, and various combinations of these approaches. The next section illustrates how several of these strategies can be combined at SRT's Kaweah Oaks Preserve (KOP).

IV. WHAT SRT AND GSA STAKEHOLDERS CAN DO

A. Collaborative Project Concept at Kaweah Oaks Preserve

KOP is a 344-acre property owned and managed by SRT for its distinctive valley oak woodland and alkali meadow habitats, outdoor education and recreational values, and as a demonstration site for conservation-oriented livestock grazing. The site, dubbed "the swamp" by local residents, used to flood on a regular basis, but has been gradually drying out for the last 50 years due to the construction of a major upstream dam and related flood control and irrigation infrastructure. The recent historic drought sealed the fate of many of the Preserve's valley oaks, which began dying off at an alarming rate. SRT accelerated its efforts to find ways to re-wet the Preserve and help the Preserve's plant and animal communities be more drought-resilient.

Concurrently, SRT has been exploring land management practices such as intensively managed livestock grazing that enhance soil health and organic carbon levels, which in turn confer a wide range of ecological, economic and social benefits. In 2016, these parallel efforts came together in the form of the KOP "Carbon Farm Pilot." The pilot project consists of a carbon farm planning framework developed by participants in the Marin Carbon Project, several land "treatments" or management practices, and systematic monitoring of effects on several resource indicators, including soil infiltration and moisture-holding capacity.

The KOP Carbon Farm Pilot was initiated prior to SRT's Greenprint Demonstration Project, and we did not predict it would be the "collaborative project concept" described in our Greenprint proposal. However, as the lessons of the Greenprint project unfolded, the KOP Carbon Farm Pilot emerged as the obvious choice:

- KOP partially overlaps one of the high priority areas mapped within the Kaweah River Watershed MRZ, indicating it meets several suitability criteria for applying land conservation and management strategies aimed at improving watershed effectiveness and groundwater sustainability.
- SRT is already poised to experiment with, and monitor water-related results of, several SOC-enhancing management practices at the Preserve, including intensively managed grazing, compost applications, forest health treatments, floodwater layoff and riparian habitat restoration. The USDA Natural Resources Conservation Service has already established a compost trial plot at the Preserve as part of a larger investigation of compost application as a standard practice cost-shared with landowners under the Environmental Quality Incentives Program.
- Many partners are already engaged in the KOP Carbon Farm Pilot, representing water users, water managers, agricultural interests, conservationists, and private, state and federal funding entities interested in advancing soil health and regenerative agriculture. These can be diagrammed as follows:

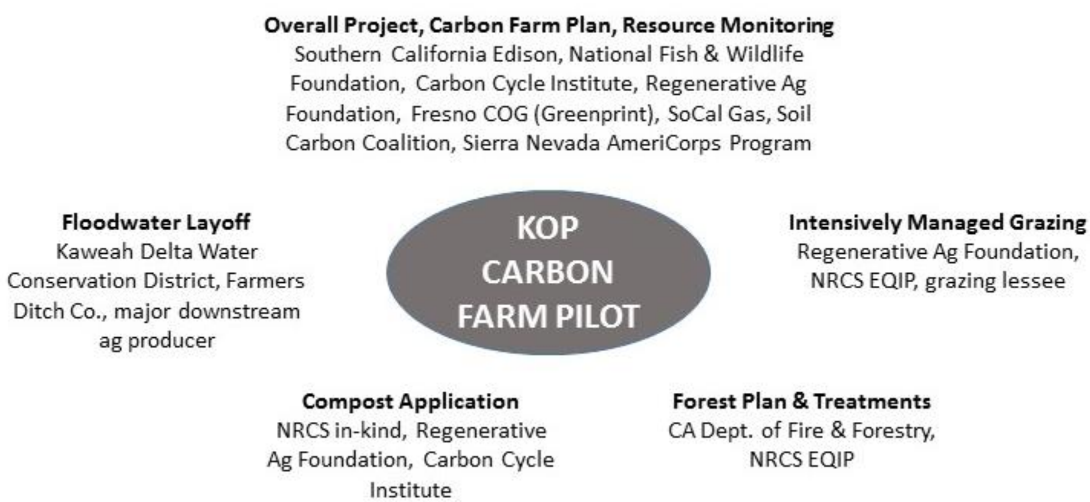


Figure 15: Elements and stakeholders for KOP Carbon Farm Pilot.

- The wet winter of 2016/17 has created strong demand for places to store excess water that threatens to flood farmland downstream from the Preserve. SRT recently added a former plum orchard to the Preserve that, with minimal earth moving, provides a suitable floodwater layoff area along Deep Creek. KDWCD, in partnership with SRT, Farmers Ditch Company and a major downstream ag producer, designed, constructed and are now pumping water into a shallow basin within this triangular parcel. If conditions are favorable, water will at least partially fill an old slough channel adjoining the basin to the east. In the future, we hope to also direct floodwaters into an old slough channel that runs diagonally through the Preserve's largest alkali meadow. SRT plans to establish native riparian vegetation in and around the basin, and along Deep Creek and the slough channels, choosing species adapted to intermittently wet and dry conditions. Ultimately, the project will function as a combination of constructed floodwater layoff/ groundwater recharge basin, restored natural floodplain, and riparian habitat area.

Figure 16, Figure 17 and Table 4, respectively, show the floodwater layoff conceptual design, a view of the recently-completed layoff basin discussed above, and a cost estimate provided by KDWCD.

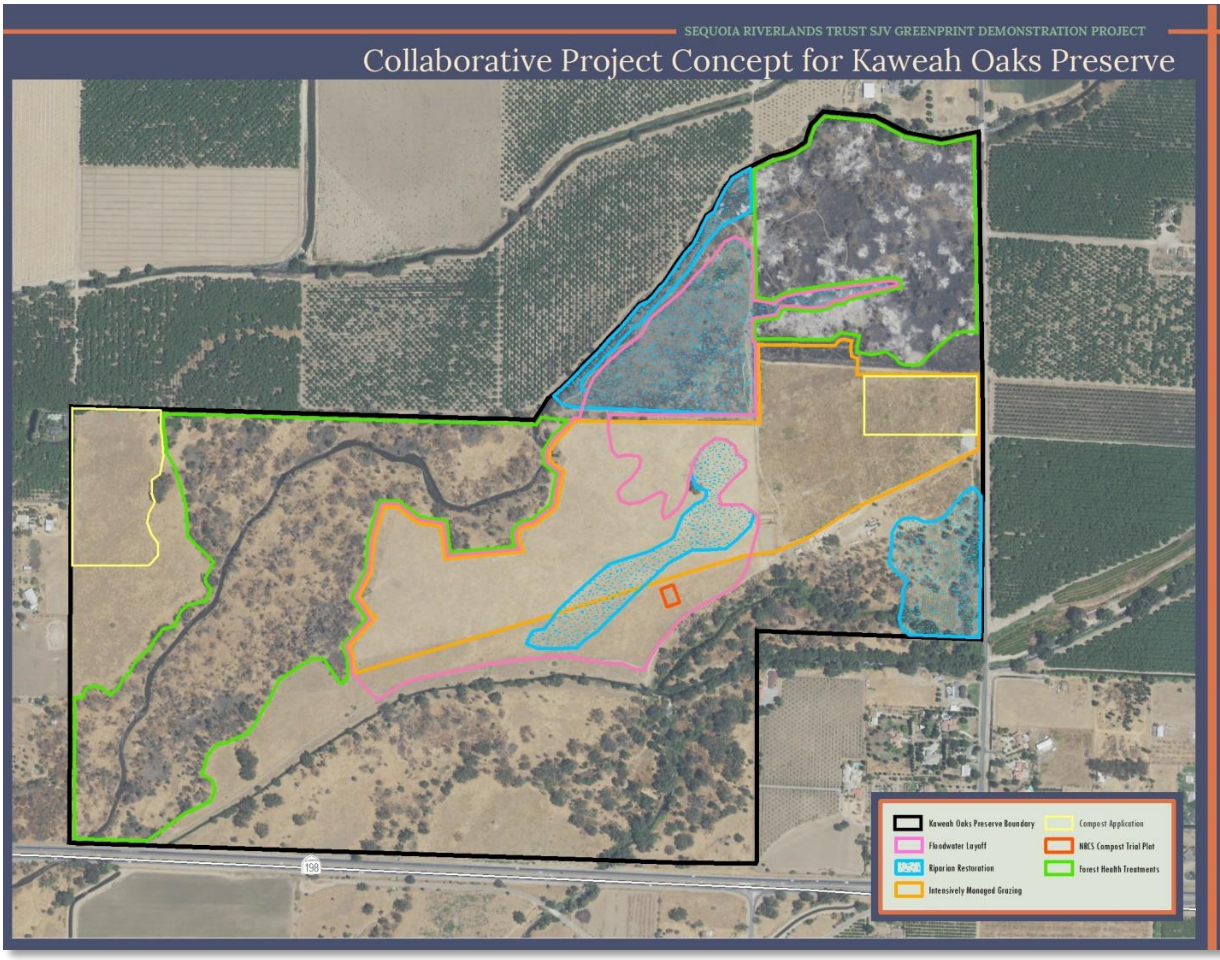


Figure 16: Collaborative project concept for Kaweah Oaks Preserve.

Figure 17: KOP floodwater layoff basin (Photo: Greening, 2017).

Kaweah Oaks Preserve

RECHARGE BASIN CONCEPT

Sequoia Riverlands Trust
Conserving California's Heartland

ESTIMATED PROJECT STATISTICS	
Basin Area	60 acres
Potential Wetted Area	40 acres
Basin Perimeter	8,000 feet
Average Water Depth	2 feet
Maximum Water Depth	6 feet
Basin Volume	80 acre-feet
Recharge Rate	0.5 feet per day
Inflow Rate	13 cubic feet per second
Embankment Slope	1:6 (Vertical : Horizontal)
Top Embankment Width	20 feet

ESTIMATED DEVELOPMENT COSTS				
Description	**Quantilty**	**Unit**	**Unit Cost**	**Cost**
Excavation/Embankment	100,000	CY	$ 1.75	$ 175,000
Lift Pump Wet Well	2	EA	$ 10,000.00	$ 20,000
3,000 gpm Lift Pump	2	EA	$ 25,000.00	$ 50,000
Pump Control Panel	1	EA	$ 10,000.00	$ 10,000
Inlet Discharge Ramp	30	LF	$ 200.00	$ 6,000
Concrete Pad (10'x10'x6")	2	CY	$ 500.00	$ 1,000
			Sub-Total Construction Cost	**$ 262,000**
			Contingency (15%)	$ 40,000
			Environmental Studies (CEQA)	$ 25,000
			Engineering Services	$ 25,000
			Permits	$ 8,000
			TOTAL PROJECT ESTIMATE	**$ 360,000**

Table 4: KOP Recharge Basin Concept statistics and costs provided by KDWCD.

The recharge rate is a rough estimate based on limited data about soils on the site. However, if the 40 acre "potential wetted area" in the current basin remains inundated for 60 days (which seems plausible this year) and the recharge rate averages 0.5 feet per day, the total recharge volume for the period could be:

40 acres x 0.5 feet/day x 60 days = 1,200 acre-feet

Even if one assumes that excess water is only available every 7 years on average, this amounts to an average recharge capacity of over 170 acre-feet per year. This amount could potentially be doubled or tripled if the larger floodwater layoff scheme for KOP is fully realized in the future. See the Floodwater Threats and Opportunities theme above for further discussion of the potential contribution of this land management strategy to groundwater sustainability.

The other "carbon farming" practices are also expected to boost the soil's infiltration and moisture-holding capacity, contributing to increased availability of water, both for the Preserve's plant communities and for groundwater recharge. A 1% in increase in SOM on 200 acres (less than 2/3 of the preserve) could increase soil water holding capacity by 200 acre-inches, or about 16.7 acre-feet.[72] As noted above, an average of 50 – 56% of SOM is thought to be SOC,[73] so this approach is likely to have significant carbon sequestration benefits as well.

The KOP Carbon Farm Pilot is in the early stages of implementation, so its ultimate water benefits may be greater or smaller than those cited here. However, given results achieved by other farmers, ranchers and researchers, we are intrigued by the potential cumulative benefits of broadly applying these soil carbon-focused management practices in our watersheds. We hope the KOP Carbon Farm Pilot will be a valuable point of reference for other land managers exploring these concepts.

B. Best Management Practices for GSPs

DWR's recently-published best management practices (BMPs) give GSAs a detailed framework for preparing GSPs, but offer less guidance on specific strategies to support improved watershed function and natural groundwater recharge.[74] The BMPs below, which focus on soil enhancement, flood management and mine reclamation opportunities, can help fill this gap. As part of our continuing engagement with GSAs such as the Mid-Kaweah and Lower Tule, SRT will advocate for the inclusion of these practices in the region's first GSPs. We will also recommend that GSAs support voluntary implementation through direct incentives, information sharing and linking landowners to federal, state and private funding sources.

[72] Creque, J. (personal communication, March 2017).
[73] Pribyl, 2010.
[74] See California DWR, 2016d (BMPs for designing monitoring protocols); California DWR, 2016e (BMPs for identifying data gaps and building monitoring networks); California DWR, 2016f (BMPs for developing a hydrogeological concept model); California DWR, 2016g (BMPs for creating water budgets); California DWR, 2016h (BMPs for modeling).

1) Soil Enhancement and Water Resources

BMP S-1 (recommended for farmers and ranchers): Where feasible, use agricultural practices that enhance the permeability of surface soil, create pathways for water to flow to deeper levels, and allow soils to retain water that would otherwise be lost to runoff or evaporation.[75]

- Maintain a cover of live plants or leaf litter (e.g., residue from previous growth) on the soil surface throughout the year.[76]
- Include deep-rooting plants like alfalfa in crop rotations, and promote the establishment and spread of native perennial grasses in pasture and rangeland settings.
- Where financially and logistically feasible, apply compost to farmland and rangeland to boost carbon cycling and increase SOC (see Figure 18).[77]
- In orchards and vineyards, combine reduced tillage, orchard floor vegetation and organic matter to improve soil structure.[78]
- Use regenerative grazing practices, such as "cell grazing" rest-rotation schemes, to enhance forage growth and carbon cycling while maintaining year-round vegetative cover.
- Integrate livestock grazing into crop rotations (i.e., "pasture cropping") to obtain benefits of animal impacts, such as fertilizer and trampling, and productively utilize crop residues.
- Use simple methods to monitor soil conditions on a regular basis, including organic matter, permeability and moisture-holding capacity; adjust management to promote soil health and productivity.[79]

[75] NRCS, 2017.
[76] Westbrook and Marshall, 2014.
[77] Funding for this and other soil enhancement practices may be available through NRCS cost-share programs, California's Healthy Soils Initiative, or other sources.
[78] O'Geen et al., 2006. For example, an untilled cover crop in the rows between trees can reduce erosion and protect soil from impacts (as RDM can on rangeland), while also providing SOM through decomposition. Cover crops can be annual or perennial, and some farmers have even found it effective to "allow both winter and summer weeds to grow and . . . manage them like a cover crop." O'Geen et al., 2006.
[79] See, e.g., Donovan, 2013 (describing Soil Carbon Challenge methods for monitoring soil organic matter). In addition, California ranchers such as Richard King regularly offer training on soil monitoring and other aspects of regenerative grazing.

Figure 18: Application of compost at NRCS trial plot on Kaweah Oaks Preserve (Photo: SRT, 2016).

BMP S-2 (recommended for land use planners, water managers and agricultural interests): Explore water-smart alternatives to irrigated agriculture, such as drought-tolerant pasture, on farmland that is expected to be fallowed due to salinity, water scarcity or other factors. Encourage management practices on these lands that promote improved soil health and water holding capacity.

BMP S-3 (recommended for developers and landscapers): Use practices described in California's Model Water Efficient Landscaping Ordinance (MWELO) and analogous local ordinances to ensure that landscaping soils are capable of absorbing and retaining water.

- Use friable, non-compacted soil for landscaping.[80]
- Enhance soil structure and water retention by infusing the top six inches of soil with compost.[81]
- Protect the structure and permeability of the soil surface by applying mulch to exposed areas, except where mulch would conflict with turf, groundcovers or seeding.[82]

BMP S-4 (recommended for GSAs or government, conservation or academic organizations): Monitor soil organic carbon and related soil and vegetation indicators (e.g., infiltration rates,

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[80] 23 Cal. Code Regs. § 492.6(a)(3)(A).
[81] 23 Cal. Code Regs. § 492.6(a)(3)(C).
[82] 23 Cal. Code Regs. § 492.6(a)(3)(D).

soil moisture holding capacity, forage production, vegetation composition) in representative locations over time and, where feasible, test responses to specific management practices. Share results with ranchers, farmers and others.

2) Floodwater Threats and Opportunities

BMP F-1 (recommended for landowners, resource agencies and GSAs): Conserve and restore ecosystems that link surface water to underground aquifers.

- Use conservation easements to protect groundwater recharge areas, including but not limited to wetland and riparian ecosystems.[83] To maximize the long-term effectiveness of conservation investments, easements should be held by LTA-accredited land trusts.

BMP F-2 (recommended for GSAs): Where feasible, incentivize landowners to use on-farm recharge to redirect surface water into underground aquifers.

- Use San Joaquin Valley Greenprint data, SAGBI and other tools, including the model developed by Sustainable Conservation, to identify suitable areas for on-farm groundwater recharge. Where feasible, collaborate with GSA participants and others to expand the use of the Sustainable Conservation tool to areas beyond those initially explored as part of Sustainable Conservation's Greenprint Demonstration Project.
- Where consistent with crop health, including root zone moisture and aeration requirements, incentivize landowners to enter into on-farm groundwater recharge agreements in these areas.[84]

BMP F-3 (recommended for developers and landscapers): Use practices described in California's Model Water Efficient Landscaping Ordinance (MWELO) and analogous local ordinances to ensure that constructed surfaces and landscaped areas capture runoff.

- Minimize the area of impervious surfaces and incorporate permeable surfaces, such as gravel or porous concrete, to reduce the flow of runoff to adjacent areas.[85] Where

[83] Cf. Sonoma County Agricultural Preservation and Open Space District et al., 2016 (announcing an $8 million NRCS grant secured by a coalition of resource agencies, including both land and water managers, "to purchase conservation easements from willing sellers on agricultural land along stream corridors, in areas that allow water to recharge groundwater basins and in areas that can hold flood water").
[84] See RMC Water and Environment, 2015 (study finding that flooding agricultural land during winter could reduce groundwater overdraft by 12% to 20% in eastern Merced, Madera and Fresno Counties).

permeable surfaces cannot be used, design impermeable surfaces with grading to direct runoff to landscaped areas, rain catchment systems or constructed wetlands.[86]

- Design landscaped areas to maximize retention of rainfall on the property.[87] Where possible, ensure that runoff from rain events of the magnitudes described in the MWELO (a "one inch, 24-hour rain event" or an "85th percentile, 24-hour rain event")[88] is entirely absorbed, rather than going to waste or contributing to flooding of adjacent areas.

3) Mineral and Water Resources

BMP M-1 (recommended for farmers, ranchers, resource agencies and local governments): Where feasible, manage MRZ-designated land that does not host active mines to improve watershed function and support natural groundwater recharge.

- On MRZ-designated farmland with high potential for floodwater banking, implement agricultural practices described in BMPs S-1 (enhancing soil quality) and F-2 (practicing on-farm recharge).
- On MRZ-designated land where the potential for future surface mining is negligible,[89] if any, implement the practices described in BMP F-1 to conserve and restore groundwater recharge areas. Where a higher potential for mineral extraction makes conservation easements inappropriate, short- to medium-term protection should be provided through land use designations, zoning or other policy measures, and restoration of groundwater recharge areas conducted as appropriate.

BMP M-2 (recommended for mining operations): Follow federal, state and local requirements, including but not limited to those set by the Surface Mining and Reclamation Act (SMARA) and associated regulations, to ensure that mining and reclamation do not impair watershed function or groundwater recharge. These requirements include, but are not limited to, the following:

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[85] 23 Cal. Code Regs. § 492.16(e).
[86] 23 Cal. Code Regs. § 492.16(e). Cf. Harrington and Cook, 2014 (describing rain catchment systems used in Australia, including designs that direct roof runoff into wells or sumps where it can percolate into underground aquifers).
[87] Tulare County Ordinance Code § 7-31-1040(b)(2)(F).
[88] 23 Cal. Code Regs. § 492.16(d).
[89] Cf. 26 U.S.C. § 170(h)(5)(B) (providing that an easement is not deemed to protect a property's conservation values in perpetuity unless "the probability of surface mining occurring on such property is so remote as to be negligible").

- Ensure that mining and reclamation activities do not compromise water quality, groundwater recharge potential or groundwater storage capacity.[90] Mining operations whose wastes come into contact with surface water, runoff or groundwater, or whose operations are otherwise subject to RWQCB regulation, should comply with RWQCB water monitoring requirements listed in Title 27, Sections 22500 and 20385-20430 of the California Code of Regulations.
- Control surface runoff and drainage to prevent erosion, gullying, sedimentation, contamination and other disruptions of natural drainage patterns.[91] For example, grading and revegetation measures should be designed to minimize erosion and convey uncontaminated surface runoff to natural drainage courses.[92]
- For mining operations that discharge to waters of the United States, comply with Clean Water Act permitting, monitoring and reporting requirements.[93]

BMP M-3 (recommended for mining operations): Upon completion of mining, use ecologically-based reclamation techniques to restore disturbed lands to a condition at least as conducive to natural groundwater recharge as that which existed before they were impacted by surface mining.

- Work with the California Office of Mining and Reclamation and Tulare County to review reclamation plan requirements related to restoration and enhancement of hydrological function, including groundwater recharge capacity, of lands affected by surface mining. Incorporate water-focused objectives and performance measures such as:
    - Remove berms, levees or other structures that prevent uncontaminated floodwater from spreading to areas of the floodplain capable of absorbing it.[94]
    - Revegetate the site with native species that contribute to watershed function and reduce the prevalence of invasive plants.[95]

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[90] 14 Cal. Code Regs §§ 3706(a)-(b); 27 Cal. Code Regs. §§ 22470 *et seq.*
[91] See 14 Cal. Code Regs. §§ 3706(c)-(g) (providing performance standards and specific practices for drainage, diversion structures and erosion control).
[92] 14 Cal. Code Regs. 3503(e).
[93] See 40 C.F.R. § 122.26 (covering National Pollutant Discharge Elimination System requirements).
[94] Cf. SRT, 2004 (committing to "[r]emove selected berms and levees that confine stream flow [at Dry Creek Quarry] to a single active channel, thereby encouraging formation of multiple braided stream channels, and allowing floodwaters to spread out over a larger area of the floodplain").
[95] See 14 Cal. Code Regs. § 3705 (setting performance standards for revegetation, including use of native species); see also SRT, 2004 (committing to "[e]stablish a program for collecting and propagating native seed and cuttings from the restoration site or Dry Creek vicinity,

- Re-contour disturbed areas to contribute to reestablishment of ecological and hydrological function.[96]

- Collaborate with willing mine operators, mine site owners, water agencies and conservation entities to review reclamation plans for existing mines and develop strategies for improving outcomes for water resources, flood management, habitat and other resource values. These strategies may include bringing additional funding sources to bear for enhanced restoration, or developing agreements for long-term stewardship of reclaimed lands.

4) BMPs Applicable to All Three Themes

BMP A-1 (recommended for GSAs): Actively support funding for implementation of management practices that improve watershed function and contribute to natural groundwater recharge.

- Provide review, comments and technical assistance on proposals for NRCS, Healthy Soils Initiative or other funding to implement BMPs.
- Prepare letters of support for proposals, or solicit them from other GSA stakeholders as appropriate.
- Provide a forum for GSA stakeholders to collaborate on proposals and projects, and to share information about the effectiveness of specific practices.

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emphasizing stock needed for re-establishment of the sycamore alluvial woodland and upland oak communities" and to manage populations of invasive species "to prevent future spread and reduce competition with native vegetation").

[96] Cf. SRT, 2004 (committing to "re-contour disturbed upland areas . . . to blend with surrounding natural landforms, minimize future erosion, convey surface runoff to natural drainage courses, provide a suitable growth environment for vegetation cover dominated by native species, and restore views to the restoration site . . .").

V. CONCLUSION

The land conservation, restoration and management strategies explored in this Greenprint Demonstration Project are not new. Many have been extensively researched, incorporated into funding programs and regulatory requirements, and applied to varying degrees. However, relatively little attention has been paid to the relationship of these land-based strategies to effective watershed function and groundwater sustainability. Sequoia Riverlands Trust applied existing Greenprint data and other information to map areas where these approaches might yield the greatest water-related benefits, and to roughly quantify their potential contribution to groundwater sustainability in the Kaweah and Tule River Watersheds.

Our results suggest that practical applications of these strategies could offset at least 25% of the annual groundwater deficit in the Kaweah and Tule River Watersheds by addressing both the supply and demand sides of the water balance equation. This assertion is based on estimates that:

- Soil organic matter-enhancing land management practices have the potential to increase the effective capture of precipitation by at least 14,500 AF, both reducing the need for supplemental irrigation and increasing the amount of water available for recharge;
- On-farm flooding and recharge could reduce annual groundwater overdrafts by up to 20% based on studies of similar groundwater basins in other parts of the Southern San Joaquin Valley; and
- Projects that restore at least some natural function to modified floodplains (e.g., at reclaimed alluvial mines, streamside areas of farms and ranches, or sites like KOP) could make a measurable contribution to groundwater recharge by slowing floodwaters down and providing larger areas for infiltration.

Furthermore, all of these land-based strategies provide additional ecological, economic and community benefits, such as increased agricultural production, flood management, habitat enhancement, drought resilience and aesthetic values, that make them politically palatable alternatives to new dams or regulations about water use. Water-focused land conservation, restoration and management strategies therefore deserve serious consideration as we work together to solve our region’s pressing groundwater sustainability concerns.

VI. TABLE OF AUTHORITIES AND REFERENCES

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