Salt and Salinity Management

Photo caption. Salt in irrigation evaporation ponds near Kettleman City.

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Chapter 18. Salt and Salinity Management

Salts may be defined as materials that "originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals" (Ayers and Westcot 1994). "Salinity" describes a condition where dissolved minerals, of either natural or anthropogenic origin and carrying an electrical charge (ions), are present. In water, salinity is usually measured as electrical conductivity (EC) or total dissolved solids (TDS), and the major ionic substances found in water are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and nitrate. Both salinity measurement methods give an indication of how concentrated salts are in water or soils, but since mineral ions do not all carry the same electrical charge, and organic dissolved solids can skew TDS readings, these measurement methods must either be placed into context (was the sample collected in a tidal estuary, at a municipal outfall or from a domestic supply well?, for example) or used in tandem with additional analyses.

With the exception of freshly fallen snow, salt is present to some degree in virtually all natural water supplies, because soluble salts in rocks and soil begin to dissolve as soon as water reaches them. Water reuse increases salinity since each use subjects the water to evaporation. If reused water passes through soil, additional dissolved salts will be picked up. Most salts provide some benefit to living organisms when present in low concentrations; however, salinity very quickly becomes a problem when consumptive use and evaporation concentrates salts to levels that adversely impact beneficial uses. Salts are essential to plant, human and animal nutrition; salts are present in our food, in our soils and in the cleaning and personal care products we use every day; and all Californians make choices that contribute to or compensate for salinity problems, whether they are aware of it or not.

In California, as in other parts of the world, salinity problems tend to have both natural and human causes. Many of California's most productive soils originated from materials that were once under the ocean. These soils are naturally high in salts. Oftentimes salts are added to soil or water intentionally as fertilizers or soil amendments, or to assist in some industrial, domestic, or other process. Examples of the latter include food processing and water softening. Salts may also enter a watershed through inadvertent means. These might be thought of as "unintentional salts," where human action aimed at some other purpose has resulted in salts being added to the watershed. One example of this is seawater intrusion in coastal aquifers triggered by the removal of more fresh water than is being recharged. Climate change and the predicted sea level rise associated with it will worsen this problem.

In California's interior valleys, our extensively modified natural water systems and constructed conveyance channels supply large cities, small communities, farms and wetlands with water, but each water delivery carries a salt load. When water is consumed through use, the majority of its salt load remains behind. In fact, San Joaquin

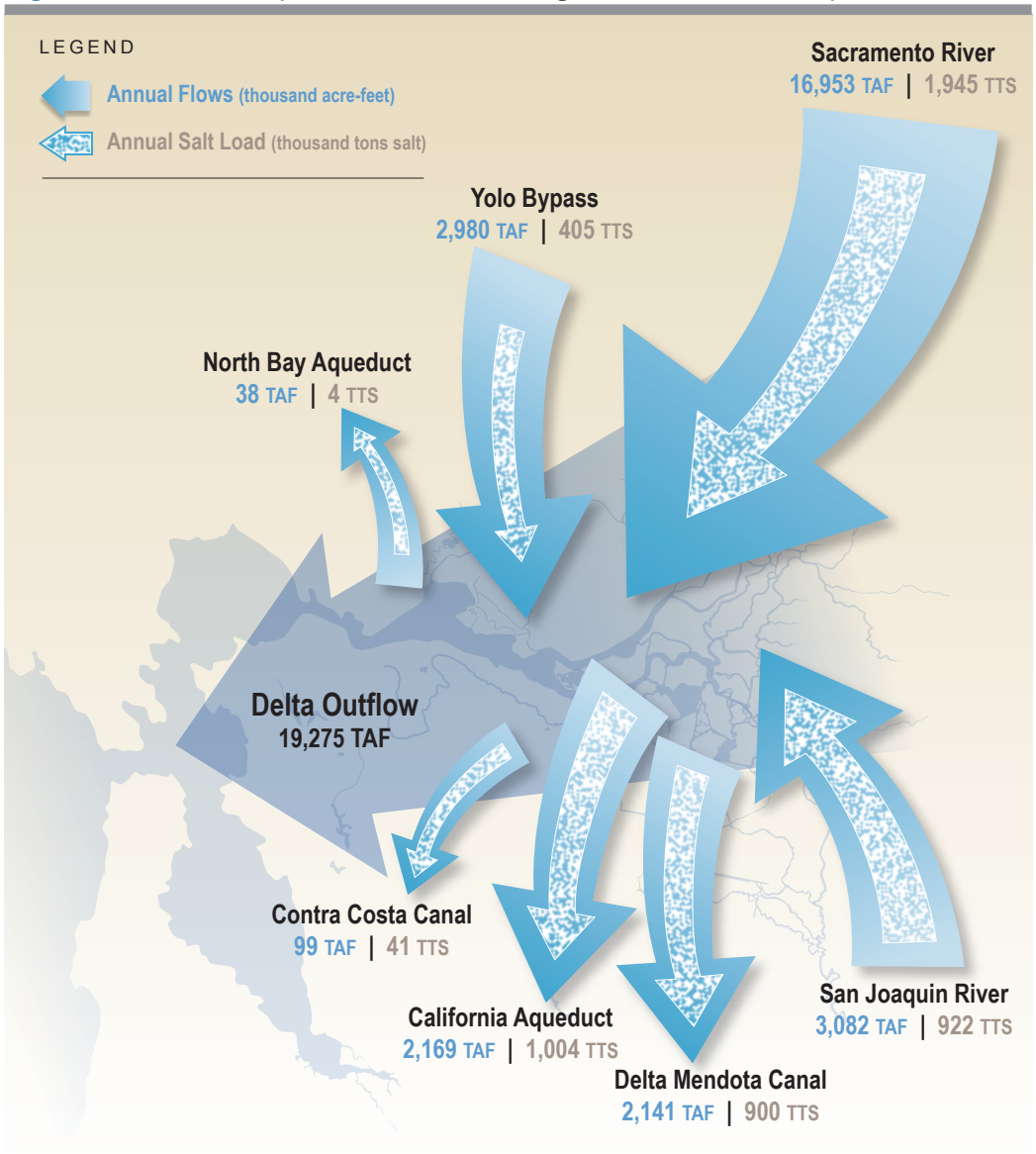
Box 18-1 Acronyms and Abbreviations

AB	California State Assembly bill
AGR	agricultural production
Basin Plans	Water Quality Control Plans
CV-SALTS	Central Valley Salinity Alternatives for Long Term Sustainability
DWR	California Department of Water Resources
EC	electrical conductivity
FAO	Food and Agriculture Organization of the United Nations
GAMA	Groundwater Ambient Monitoring and Assessment
IFDM	Integrated On-Farm Drainage Management
IWRIS	Integrated Water Resources Information System
mg/L	milligrams per liter
MUN	drinking water
PRO	industrial processing
Prop.	ballot proposition
Regional Water Board	Regional Water Quality Control Board
SARI	Santa Ana Regional Interceptor
SAWPA	Santa Ana Watershed Project Authority
SRWS	self-regenerating water softeners
State Water Board	State Water Resources Control Board
SWAMP	Surface Water Ambient Monitoring Program
TDS	total dissolved solids
TMDL	total maximum daily load
µS/cm	microSiemens per centimeter
USBR	US Bureau of Reclamation
USCR	Upper Santa Clara River

Valley's Tulare Lake Basin is a closed basin, i.e., no stream normally exits the basin. In the San Joaquin Valley, an area highly dependent on irrigation, not enough salt exits the basin through the area's rivers and streams to offset the imported and recirculated salts. Figure 18-1, taken from the Central Valley Regional Water Quality Control Board's 2006 salinity overview report depicts the mean annual salt loads conveyed to and from the Delta through the major river systems of the Central Valley (CVRWQCB, 2006).

Coastal and estuarine environments require some measure of salinity to remain healthy. But even these systems can be adversely impacted when salt becomes too concentrated, nutrient salts become excessive and create hypoxic zones, or, in the case of estuarine systems, when the mix of saline and fresh flows gets out of balance. The salt evaporation ponds in the southern portion of San Francisco Bay provide a noteworthy example of this. The salt produced in these ponds came at a high environmental cost, impacting thousands of acres of marine habitat and reducing bird and fish populations in San Francisco Bay. Today they are slowly being restored to their natural condition, serving as a reminder that restoration is always more difficult than prevention.

Figure 18-1 Salt load (mean of annual averages from 1959 to 2004)



Beneficial Uses

In California, waters of the state are designated as having one or more beneficial uses. State Water Resources Control Board (State Water Board) Resolution No. 88-63 (SWRCB, 1988) directs each Regional Water Quality Control Board (Regional Water Board) to designate surface water and groundwater in the region as being potentially suitable for drinking water unless certain existing conditions apply, and individual boards may use other region-wide use designations in their Water Quality Control Plans (Basin Plans). (A water body is exempted from the designation if, for example, salinity is 5000 µS/cm or more and where "it is not reasonably expected by Regional Boards to supply a public water system.) For example, in addition to the aforementioned drinking water designation, surface water and groundwater in the Central Valley Region

is designated as also having agricultural and industrial use unless specified conditions similar to those constraining municipal use exist or the water body has been evaluated and found to have specific beneficial uses. This is important because the three uses that are generally impacted by salinity first are agricultural production (AGR), drinking water (MUN), and industrial processing (PRO) as shown in Table 18-1. Regulatory thresholds are determined by taking into consideration established thresholds, background conditions, and existing and potential beneficial uses.

Several environmental uses can also be impacted by excessive salinity. Habitat can be impaired, breeding areas can become less functional, and in extreme cases, organisms can succumb to salt toxicosis. It is beyond the scope of this general salinity discussion to address the impacts of specific ions in great depth, but certain individual ions can limit attainment of beneficial use even when the general salinity level may not otherwise pose a problem (See Box 18-1 Case Study 1: Santa Clara River Salinity Success Story). Groundwater recharge can be impacted when the receiving aquifer cannot accept the saline water without violating California's anti-degradation policy (SWRCB, 1968). Groundwater overdraft also poses a salinity problem in areas like Madera County, where excessive drawdown of fresh water leaves the aquifer vulnerable to intrusion from high salinity shallow groundwater in neighboring areas, threatening the basin's supply of usable water for drinking and irrigation. Recreational use can be lost, as happens in Southern California periodically when the Salton Sea becomes too saline to support fish and sport-fishing. The Salton Sea Authority reports that salinity is a growing problem in this water body—if trends continue, beneficial uses including fish reproduction, commercial fishing, and recreation will be increasingly negatively impacted (Salton Sea Authority, 2009).

Beneficial use discussions sometimes leave the impression that water supports one set of uses and then becomes waste. In California, as in most arid states, this is rarely the case. Most California communities routinely reuse, reclaim and recycle water multiple times. There is often a high demand for recycled water for landscape use but salt concentrations must be managed to protect the beneficial use (in this case, irrigation and possibly groundwater recharge) or this potential water supply is lost.

Salt and Salinity Management in California

Salts have been managed and mismanaged (or not managed) over the centuries in all parts of the globe where irrigation has been used. Mismanagement has often been attributable to a poor understanding of the dynamics of salt movement—how displaced salt can accumulate over time to salinize soils and aquifers, in much the same way as sweeping a room displaces dust. Unless sufficient dust is picked up and taken out of the room at some point, it will continue to accumulate and redisperse, ultimately making the room unfit for use. Traditional irrigation practices tend to have this effect on agricultural land unless steps are taken to close the loop on salt displacement (Case Study 2 is an example of farm-level salt management).

Table 18-1 Example of impacts of salinity on three beneficial uses

Beneficial use	Salinity threshold (µS/cm)[a]	What does the target protect?
AGR	Variable	The Food and Agriculture Organization of the United Nations (FAO) notes that an EC of 700 µS/cm protects the most salt-sensitive crops under normal irrigation operations. Ayers and Westcot describe how the target can be shifted somewhat by adjusting irrigation practices.
MUN	900 (long term) 2200 (short term)	This range of numbers, used by the Department of Public Health, is based on taste thresholds. Health-based standards exist for concentrations of specific ions such as nitrate and chloride
PRO	Variable	The Basin Plans do not cite a threshold value to protect industrial process use, but it is known that some industrial processes require low salinity water.

[a] Electrical Conductivity is reported in Siemens (or in this case, microSiemens) per centimeter, expressed in Table 1 as µS/cm. Some readers may be more familiar with an older unit of measure: mhos. 1 microSiemen = 1 micromho.

Lack of knowledge is not the only cause of salt mismanagement. In his book *Collapse*, Jared Diamond describes how Australia's current salinity problems can be traced back to decisions to mine the continent of its resources rather than harvest resources sustainably and preserve the land for future generations (Diamond, 2005). Today's Australians are living with that legacy and attempting to reverse the damage caused by over a century of salt mismanagement, on top of facing unprecedented drought conditions. It's an uphill battle that Californians will only avoid by making sustainable salt management a priority today.

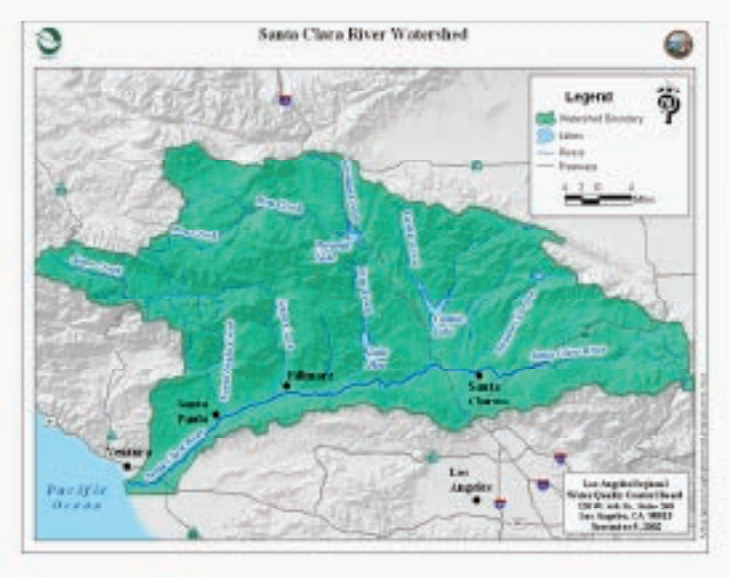
How Salt Dilution and Displacement Works

High salinity in surface water, soil, or groundwater impacts the organisms that rely on these media. Historically, dilution and displacement have been used to deal with excess salinity. Agricultural operations typically displace soil salts by applying more irrigation water than the crop is able to take up to flush salts out of the root zone and relocate them in a lower part of the soil profile or in groundwater (the leaching fraction). The salt may then wick upwards again if evaporation exceeds recharge. Salt concentrations in surface water can be decreased by dilution with lower salinity water. Conversely, the load of salt transported in water can increase with dilution since dilution water generally carries some load of salt as well. A high volume of low salinity water can move significant amounts of salt to other areas, making it worthwhile to also investigate whether management of salinity is appropriate in areas where salt problems do not yet exist. All of these factors and more must be taken into account and dilution and displacement strategies must be coupled with long-range water, ecosystem, and land resource management planning so that opportunities to move closer to a sustainable salt balance in California's hydrologic basins are not missed. Opportunities could include taking full

Box 18-2 Case Study 1: Santa Clara River Salinity Success Story

The Los Angeles Regional Water Quality Control Board adopted a chloride Total Maximum Daily Load (TMDL) for the Upper Santa Clara River (USCR) that became effective in 2005. Implementation of the TMDL included special studies to look at crop effects, endangered species protection, and groundwater impacts. Earlier TMDL studies had identified chloride sources in the region. Significant amounts of chloride are imported in State Water Project deliveries, but about one-third of the chloride entering the watershed could be attributed to self-regenerating water softeners. Although technically not nonpoint sources, water softener discharges end up aggregated in municipal wastewater collection systems, so it makes sense to include these in the TMDL approach.

The State Water Project picks up water in the Sacramento-San Joaquin Delta and delivers it to Southern California. In drier years, greater proportions of saltier seawater and San Joaquin River water are exported by the State Water Project and chloride concentrations therefore increase. The Los Angeles Regional Board first adopted a Total Maximum Daily Load (TMDL) for chloride in the USCR in 2000. The TMDL showed that chloride is loaded primarily into the Santa Clara River from water reclamation plants serving residential, commercial and industrial users in the Santa Clarita Valley. The sources of the chloride which are loaded into the Santa Clara River are primarily chloride contained in the imported source water and chloride added by domestic uses, including self regenerating water softeners (SRWS). In 2003, a ban on SRWS installations was enacted. A buy-back program was initiated for existing SRWS, and by 2005 approximately 1,200 of these softeners had been inactivated or removed. Chloride loads in the Santa Clara River improved measurably. In 2009 the California Legislature enacted Assembly Bill (AB) 1366, Residential Self-Regenerating Water Softeners, that included a voluntary buy-back or exchange program for residential self-regenerating water softeners, consistent with existing law.

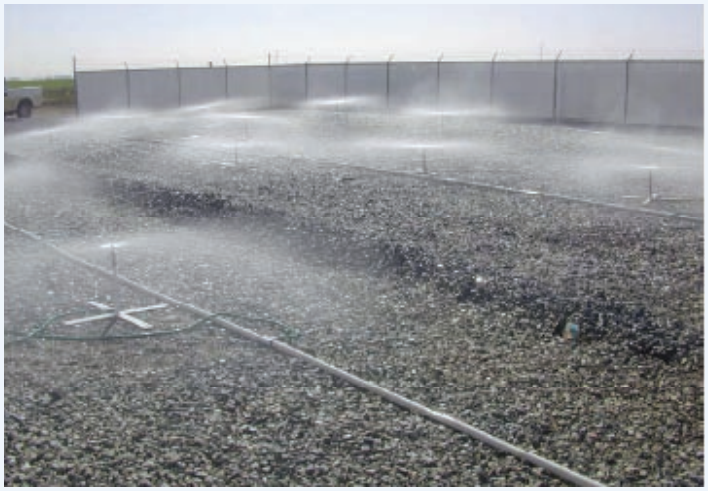


Box 18-3 Case Study 2: Integrated On-farm Drainage Management—A Farm-level Solution to Problem Salinity

Salinity problems tend to impact individual operations long before the effects are noticed in neighboring areas with more favorable hydrology and soil conditions. This was the case for Red Rock Ranch, where Integrated On-Farm Drainage Management (IFDM) was first pioneered. IFDM is a salinity management tool that is gaining in popularity as a means of maintaining the ability to farm salinity-impaired agricultural land.

IFDM is an integrated agricultural water management system that applies subsurface drainage water to a sequence of increasingly salt-tolerant crops. The number of steps comprising the reuse sequence is variable, as are the crops to which the drainage water is applied at each stage of the sequence. The residual drainage effluent from the final stage in the sequence of reuse is disposed in a solar evaporator, an enhanced evaporation system that uses timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the surface of the solar evaporator. When conditions are not favorable for evaporation, drainage water is stored, temporarily, in underground and/or covered reservoirs. The operation and management of solar evaporators are regulated by Title 27 of the California Code of Regulations.

Existing IFDM systems have three or four stages designed to come to equilibrium at differing salinities for each of the crops being grown so that the equilibrium salinity is appropriate to the salt tolerance of the particular crop. The concentrated brine collected from the final stage is unsuitable for further treatment by agricultural processes and must be disposed in a solar evaporator. IFDM can be implemented at different scales. Different stages of the treatment process can be contained within a single farm, as is the case at Red Rock Ranch and Rainbow Ranch. Alternatively, different stages of treatment could be sited at different locations so that the overall IFDM system would assume a district or regional scale. At a regional scale, the Grasslands Area farmers are planning to implement a version of an IFDM system in their Westside Regional Drainage Plan on their 97,000 acres, using 6,000 acres for drainage reuse and a zero liquid discharge system to treat the effluent from the reuse area.



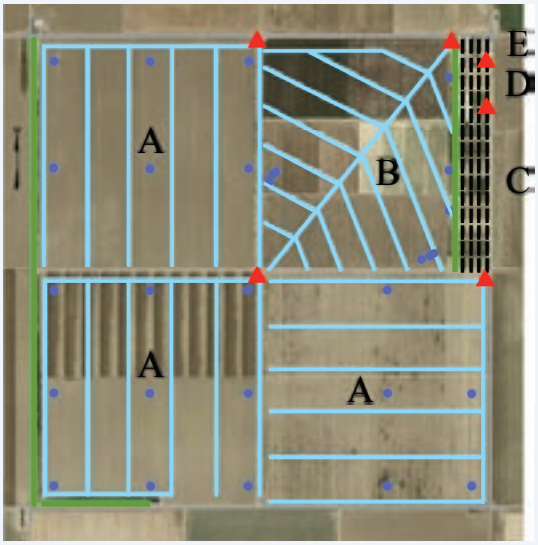
Drain water being applied to a gravel bed collector in a solar evaporator (vertically oriented nozzles at riser height = 1.00 ft)

Box 18-3 Case Study 2: Integrated On-farm Drainage Management—A Farm-level Solution to Problem Salinity (continued)

The IFDM system at Red Rock Ranch starts with low salinity water to irrigate salt sensitive crops. Subsurface drainage water from this low salinity zone is blended with tailwater (irrigation water, in the case of Rainbow Ranch) and used to irrigate salt-tolerant commercial crops such as cotton, sugar beets and grasses on a "low-saline" zone occupying about 20 percent of the area. The drainage water from this zone is used on very salt-tolerant grasses or halophytes in the "moderate-saline" zone. This drain water is used on halophytes in the "high-saline" zone (the Rainbow Ranch system only has the first three stages). The concentrated brine collected from the "high-saline" zone is disposed in a solar evaporator.

An advantage of IFDM is that it uses drainage water to produce marketable crops. For example, the cotton grown in the "low-saline" zone at Rainbow Ranch produces high yields. Research has determined the suitability of various salt-tolerant forages such as Bermuda and Jose Tall Wheat grasses that could be grown in the "moderate-saline" zone. These forages could be used to make up the existing shortfall of forages on the west side of the San Joaquin Valley. Continuing research is examining the potential of halophytes, such as Atriplex, *Prosopis alba* (a tree), Creeping Wildrye, and Salt Grass to concentrate brine in the "high-saline" zone and to produce marketable products such as biofuels and construction materials. Brine discharged as tile drainage from the "high-saline" zone is disposed safely in a solar evaporator, resulting in crystallized salt.

Another option would be to collect the brine for further treatment and disposal by non-agricultural processes at regional centers. These centers could attract mining companies to separate and recycle marketable salts from the brine such as calcium sulfate (gypsum), sodium chloride, and sodium sulfate. Currently, high costs of transportation favors establishment of regional industries close to their markets.



Legend

- A Non-Salinity Zone - Vegetables
- B Low-Salinity Zone - Alfalfa or Cotton
- C Moderate-Salinity Zone - Trees or Grass
- D High-Salinity Zone - Halophytes
- E Solar Evaporator
- Eucalyptus Trees
- Drainage Tiles in A and B
- Drainage Tiles in C, D and E
- Sump
- Monitoring Well

Design of the Integrated on-Farm Drainage Management (IFDM) System at Red Rock Ranch

Box 18-3 Case Study 2: Integrated On-farm Drainage Management—A Farm-level Solution to Problem Salinity (continued)

Red Rock Ranch IFDM Project

Total acres	640		
Water Sources	California Aqueduct, Subsurface Saline Drainage Water, Recirculated Surface Runoff Water (Tailwater), and a water well on site.		
Crop Mixes	**Before IFDM**	**After IFDM**	
	Wheat Alfalfa Seed Safflower Cotton	Salt-sensitive crops Broccoli Lettuce Tomatoes Other vegetables	Salt-tolerant crops Canola Cotton Jose wheat grass Rye grass
Average yields	**Before IFDM**	**After IFDM**	
Cotton	2 to 2.5 bales/ac	3.5 to 4 bales/ac	
Land Value	**Before IFDM**	**After IFDM**	
	$1,500/ac (salinized soils)	$5,000/ac (2008 value)	
Recycled Irrigation Salinity Range (TDS)	**First reuse**	**Second reuse**	**Third Reuse**
	3,000 mg/l	10,000 mg/l	20,000 mg/l
Drainage Systems	**Estimated Infrastructure Costs**		
Six fields with drainage collector placed 6 feet deep with 18 monitoring wells.	Drainage System $320,000	Pilot Solar Evaporator $50,000	

advantage of wet water years to flush salts back to the ocean and to store water for future use as dilution flow or to prevent saline water intrusion; leveraging funding availability, where a community can use both public and private monies to upgrade infrastructure to improve salt management; and developing a new business such as energy production (using saline water for cooling, sending high salt, high nitrate dairy waste to digesters for methane production, collecting salt to capture energy in solar ponds, etc.).

Salt Treatment, Salt Storage

Other salt management strategies have included treatment using membrane or distillation technologies. Treatment, however, generates a highly saline solid or liquid waste product that must be managed appropriately and also has a significant energy demand. Treatment technologies are used sparingly in much of the state because energy and waste disposal costs can often exceed the economic value of the fresh water being produced. There have been some pilot studies of combined energy generation/salt separation methodologies. Given the heightened focus in California on energy and greenhouse gas these methodologies may gain more attention as a possible salt management strategy. Because mineral salts are not all the same, salt treatment

Salt-crusted soil near Fresno.

technologies vary in effectiveness and cost for any given situation. Desalination of high sulfate groundwater, for example, requires a different approach than desalination of high sodium seawater. Seawater desalination is a relatively mature technology, but additional research and development is needed to make brackish water desalination cost effective in a broader range of settings. For a broader discussion of desalination the reader is directed to the desalinization resource management strategy, Chapter 9.

Salt collection and storage is another strategy that is often used in inland areas, however, this may not be a sustainable solution if the collection area could release the salt to groundwater or if a severe storm event could potentially re-disburse the salt outside of the collection area. Evaporation basins such as the one shown in the photo raise other issues as well. A collection and storage strategy is expensive, requiring a large amount of land and appropriate mitigation for the impacts to wildlife. It can also be complicated by other water quality issues. An evaluation of the impacts of evaporation basins should be weighed against possible alternatives such as construction of a brine line. Ideally, collected salt could be marketed as an industrial product. Some preliminary studies have been undertaken but it is not generally considered feasible to market salt harvested as a byproduct of drainage management, for example, since industrial salt users require a purer and less seasonally variable product than can be produced from most saline drainage collection facilities. There has also been some discussion of harvesting and marketing other materials (selenium, boron) from certain salty waste streams to make the waste less of an environmental problem, but this strategy would have the same issues of cost effectiveness, purity and seasonal variability. However, markets change and it may be worthwhile to pursue these options in the future. Salt treatment, including brackish water and seawater desalinization will continue to be an expensive but increasingly attractive alternative for communities as California continues to grow and demand for water increases. Salt storage, while expensive and often environmentally problematic, should be researched further and new strategies for interim and long-term salt storage and salt disposal should be developed, as the need to close the loop and dispose and sequester salts is becoming more urgent, particularly in inland areas of the state.

Local and regional solutions to salt management can vary significantly, but are generally most appropriate to local and regional scales, unless the planning process in developing those solutions determine that there is a benefit to developing infrastructure at a State level. Therefore salt management should be fully integrated into water management such as through integrated regional water management plans.

Adaptation

A very commonly employed but ultimately unsustainable management strategy is adaptation to increasingly saline conditions. This situation exists in the Tulare Lake

Basin. The basin does not have a reliable natural outlet; so in the absence of some mechanism to remove and dispose salts, salt imported into the basin in irrigation water, in soil amendments, for water softening and for other purposes, remains in the basin. The Water Quality Control Plan for the Tulare Lake Basin recommends that a drain be constructed to remove the excess salts from the basin to begin to correct the problem. This option is not being pursued at this time so the plan also includes a strategy of controlled degradation to extend the beneficial uses of the water in this basin and the environmental, economic and social infrastructure those uses support, for as long as possible. The monitoring network needed to track groundwater salinization in this area has never been developed. With this management approach, at some point in the future beneficial uses will be impacted. Some land in this basin has already been abandoned due to salinization. Additional discussion of land retirement is provided in Chapter 29, Other Resource Management Strategies.

Unlike the crisis scenarios California routinely prepares for, chronic water quality problems like increasing salinity do not trigger overnight evacuations or mobilize teams of emergency personnel, and the media rarely picks these up as newsworthy until it is too late to avoid problem impacts. There is no single solution that can be implemented once to make the problem go away. Salinity generally shows up in localized areas, it expands slowly and its effects are usually incremental rather than event-based. Salinity impacts can be measured as yearly reduction of crop revenues and farmable land, lost jobs, higher utility rates, reduction of community growth potential, loss of habitat, premature corrosion of equipment, and in lost opportunities.

But the salt management news is not all bad in California. Of significant note is the adoption by the State Water Resources Control Board of its 2009 Recycled Water Policy, which includes a requirement that local water and wastewater entities, together with local salt/nutrient contributing stakeholders, prepare salt and nutrient management plans and that those plans be completed and proposed for adoption by the Water Board within five years. The State Water Board also committed to seeking state and federal funds to cost share in the preparation of these plans (see also Chapter 11 Recycled Municipal Water Resource Management Strategy in Volume 2). In addition, the case studies in this chapter illustrate types of approaches currently being used to address problem salinity in various parts of the state. They range from a solution developed by a local stakeholder to address a local salinity issue, to salinity management spurred by regulatory action to address non-point source pollution in a small watershed, and finally to collaborative efforts between regulators and stakeholders to develop and implement regional plans that encompass multiple salinity sources and an array of management options. CV-SALTS, showcased in Case Study 3, is a regional collaborative salinity management effort that will have spillover benefits for areas beyond the region.

Potential Benefits of Salt and Salinity Management

Sustainable salt management in any hydrologic region in California protects water resources that may be serving multiple regions in the state. For example, salinity control

in the Sacramento Basin may have a relatively small direct benefit in this watershed, which normally receives high rainfall and therefore usually has adequate dilution flows to maintain salinity at acceptable levels. But Sacramento River water is not only used in the Sacramento Basin. Reducing salt loads in tributary rivers to the Delta could provide a significant benefit to those receiving water through the California Aqueduct (much of Southern California) and the Delta-Mendota Canal (much of the San Joaquin Valley), in terms of higher quality drinking water, avoided costs, continued ability to produce food and fiber, habitat maintenance, and reduced pre-treatment costs for industries requiring low salinity water supplies. Because the San Joaquin River is more saline than that of the Sacramento, the San Joaquin watershed will likely respond more dramatically to effective salinity management. Research, planning, monitoring and stakeholder collaboration will help water managers identify salt management's "low-hanging fruit": those watersheds and basins where salt management will yield the biggest improvement for the broadest geographic area for the lowest cost in the quickest time.

Water from the Colorado River serves several states, including California, and the river carries a significant load of salt. Reducing salt inputs in the upper watershed would, therefore, be beneficial to downstream California water users. California may have little ability to control salt loads imported into the state through the Colorado: typically, accepting water means accepting its salt load and the responsibility for managing any problems that salt load will contribute to in the receiving basin. But the benefits of reducing the salt imported into parts of the state where opportunities for export, treatment or storage are limited are significant enough that upstream salt load reductions are worth pursuing. Any time salinity treatment can be avoided there will be significant energy savings benefits as well.

Salt management does not simply reduce the salt loads impacting a region; it can also improve water supplies. Climate change will undoubtedly alter the way California manages water, and altered weather patterns will likely impact the volume, location and timing of available low salinity flows in many, if not all, parts of the state. Sustainable salt management is therefore a key component of securing, maintaining, expanding, and recovering usable water supplies. Recovered water supplies would include recycled wastewater and brackish water desalination projects. Some water authorities in Southern California utilize both strategies.

The issues related to recovering usable water supplies are further discussed in Chapter 11, Recycled Municipal Water resource management strategy. The local benefits of sustainable salinity management mirror the statewide benefits: securing and, in some cases, improving the reliability of the water supply and restoring and maintaining beneficial uses of water within the basin.

There are significant costs that can be avoided by managing salt today. In a recently completed study, a State Water Board study team found that Central Valley salinity accumulations are projected to cause a loss of $2.167 billion in California's value of goods and services produced by the year 2030 (Howitt, et al., 2008). Income is

Box 18-4 Case Study 3: We're All in this Together: Regional Collaboration

Once upon a time, the Santa Ana Basin was primarily an agricultural area and a large percentage of the state's dairy farms were located here. A lot of dairies remain, but the former agriculturally based regional economy is now dominated by industry, urban development, and tourism (Disneyland is only one of the attractions the region is famous for). Groundwater salinity threatened this prosperity.

Regulatory limits were established that would protect the aquifer but which could have had the side effect of stopping growth and development in the area. Understanding the limits of the regulatory process, a group of stakeholders approached the Santa Ana Regional Water Quality Control Board (Santa Ana Regional Water Board) with a plan to conduct the studies needed to determine what was going on in the watershed at a more detailed level and come up with an alternative strategy for dealing with salinity in the basin. The Santa Ana Regional Water Board agreed to work with the alternative, and the group began to pursue management actions and construct facilities to deal with the problem. The local water authorities formed a Joint Powers Authority to coordinate salinity management efforts, the Santa Ana Watershed Project Authority (SAWPA). The group has constructed a brine line to remove salt from the basin and trunk lines connecting to the main brine line (the Santa Ana Regional Interceptor or SARI line). Member districts operate groundwater desalters (treatment and recharge facilities) to reclaim the degraded aquifer. SARI line users pay a fee to remove salt from the basin based on the volume of wastewater they discharge to the line.

Salinity also threatens the long-term reliability of water supplies in the Central Valley Region. Valley regulators and stakeholders initiated a collaborative salinity management effort modeled on the SAWPA experience, only on a grander scale. The effort has been strengthened by recent requirements from the State Water Board to develop regional salt and nitrate management plans. The Central Valley region is comprised of three major basins and covers a 60,000 square mile area, extending from the Tehachapi Mountains in the south to the Oregon border in the north.

CV-SALTS (Central Valley Salinity Alternatives for Long Term Sustainability) is an initiative to address salinity throughout the region and Delta in a comprehensive, consistent, and sustainable manner. Working in partnership with the State Water Board, CV-SALTS will be the vehicle used to review and update the Water Quality Control Plans for the Sacramento and San Joaquin River Basins, the Tulare Lake Basin, and the Delta Plan in regards to salinity and nitrate management. The effort encourages stakeholder-regulator collaboration so that management of saline discharges can be accomplished more economically, more effectively and more sustainably (success measured not only by permit compliance rates but also by quantifiable improvements in the watershed's salt balance. Like the SAWPA effort, CV-SALTS will encourage and work with stakeholder-initiated actions that the Regional Water Boards are unable to require but which will make it possible to achieve and maintain sustainable salinity management in the region.

Several working bodies are currently involved in the CV-SALTS initiative. The Water Boards provided the initial impetus for the effort and will continue to play key advisory roles.
A Leadership Group, made up of upper management from State, federal, and local governments; nongovernment, environmental, social justice, and industry organizations; and top researchers in the field convenes annually to review progress. Committees made up of policy group members, their designees, and interested parties serve as technical advisors, conduct outreach, review economic studies, and coordinate efforts. The Central Valley Salinity Coalition recently formed to secure and manage funding for key preliminary work. For more information on the CV-SALTS committees or the Central Valley Salinity Coalition, contact the Central Valley Regional Water Quality Control Board.

expected to decline by $941 million, employment by 29,270 jobs, and population by 39,440 persons because of the increase in commercial operating expenses incurred by water supplies that have higher salinity concentrations. Irrigated agriculture, confined animal operations, food processors and residential water users were included in the study. Potential benefits of implementing a Central Valley salinity management program are estimated at $10 billion. Similar studies have been performed in other parts of the state (see reference section) and all indicate that proactive salt management is economically beneficial.

Potential Costs of Salt and Salinity Management

It is extremely difficult to estimate the cost of sustainable salt management in California as an isolated statewide strategy. Ideally, salinity control should be (and often is) incorporated into some broader effort to protect or expand water supplies, optimize water use, offset land subsidence, protect fisheries or store water for future use. Salt management methods vary in effectiveness and cost, depending on the volume and concentration of salts, salt type, other materials present, the desired salt concentration after management (dependent on water use) and the type of management strategy used (prevention, salt input minimization, salt removal at the end of a process, etc.). A 2007 study illustrates the wide range of costs that a single industry might face in dealing with salt management. Rubin, Sundig and Berkman (2007) investigated the cost of managing TDS at food processing plants and found that costs for removing dissolved solids (TDS) by various means ranged from $258 per ton (deep well injection of collected untreated effluent) to over $8,000 per ton (end of pipe effluent treatment). While cost variability is high, multiple salt management options are necessary because the least-cost salt management option appropriate for a given area may be inconsistent with sustainability when considered in a broader context of local, regional or statewide salt management, energy consumption, water availability or other resource issues.

Major Issues Facing Salt and Salinity Management

Although the local impacts of salinity have been severe in certain parts of California such as the Salinas Valley, the Tulare Lake Basin, and the Lower San Joaquin River Basin, salinity has not historically been a high profile issue to the general public in California. Water Plan Update 2009 marks a paradigm shift in California's thinking. As a society, we increasingly recognize that high quality water is a limited resource; that once salinity concentrations become excessive, the available technically feasible recovery options are likely to be very expensive; that adaptation to increasing salinity is an interim measure at best; and that water quality protection is more cost effective and has a greater chance of success than water quality remediation.

Understanding the need for salt management is only a first step. California faces some major challenges to sustainable salt management.

Urgent Needs (Loss or Impending Loss of Beneficial Use)

1. Each hydrologic region has its own priorities and limitations on the resources available to address those priorities. A few of the common, ongoing, and emerging threats are listed below.
   - **Nitrates.** Dairy waste management, septic systems, and fertilizer use can all contribute to groundwater degradation by nitrate. Excessive nitrate salts in groundwater is a human health issue. Excessive nutrient salts in surface water can spur explosive, unwanted algal growth that not only impacts aquatic life but also interferes with recreational and commercial use of water bodies.
   - **Seawater intrusion.** Seawater intrusion into the Delta has a significant impact on the quality of water exported from the Delta. Coastal aquifers are at risk of seawater intrusion when more fresh water is withdrawn than can be recharged. Aquifers and surface water are vulnerable to sea level rise and seawater brought in by storm surges that may increase in intensity or frequency as a result of climate change. Seawater intrusion threatens drinking water and water used for irrigation.
   - **Soil and groundwater salinization.** Salinization occurs when salts are allowed to accumulate over time in soil or groundwater. Soil salinization results in a loss of soil productivity due to a chronically unfavorable balance of salt and water in the soil profile. Groundwater salinization results in the loss of utility of an aquifer, meaning that the water no longer supports municipal or agricultural use. Both processes are virtually irreversible. Although some communities reclaim brackish water at great expense, most California water users cannot afford to do this. Despite contributing $31.4 billion to California's economy in 2006, several of the most productive farming regions of the state (including the Imperial, Salinas and San Joaquin Valleys) are vulnerable to soil and/or groundwater salinization.
   - **Reduced availability of fresh water flows.** In some regions, dilution with low salinity water is the primary means used to manage salinity in California. Dilution in the right place may provide some side benefits due to increased flow (supporting aquatic life for example) but more often, water used for dilution is water that is unavailable for other purposes at other times.

Less urgent, but equally important

2. Salt management has not kept up with emerging salt problems in many parts of the state. As a general rule, salt management has been reactive rather than proactive in California: problem salinity emerges and a plan is formulated to deal with it; or problem salinity is anticipated and a plan is formulated but the plan is incompletely implemented or is not flexible enough to adjust to changing conditions, like ecosystem or other water quality priorities. Sustainable salt management will require a more concerted, coordinated, proactive planning effort than most regions of the state and most California communities have been able to achieve to date. This planning should be integrated with other water management alternatives as it could result in efficiencies and cost reduction and should be included in integrated regional water management planning efforts.

3. Funding to support salt management planning, project development, project operation and maintenance and salinity monitoring has been absent or insufficient in some parts of the state. With very few exceptions, public funding dispersed through grants or loans to agencies and organizations has excluded or severely limited funding for planning efforts. Salt management on the scale needed for sustainability in California will require a great deal of coordinated planning at the local and regional levels.

4. Grants and loans targeting project development and operation also often fail to serve salt management, since the programs are usually competitive and award caps may be set to favor multiple small projects over a smaller number of larger, coordinating projects. This strategy is effective for some purposes (for example, funding irrigation efficiency improvements on multiple farms across a large geographic area), but may be counterproductive for salt management, which is often more cost-effectively achieved at a sustainable level through community-, watershed- and regionally-scaled efforts (see Case Studies 1 & 2 for examples).

5. Project maintenance and closure is often overlooked in budgeting for salt management. But as with the case of the incomplete San Luis Drain (see #7(b) below), the unforeseen environmental consequences of incomplete or abandoned salt management projects can result in greater hazards than if the project had never been undertaken. Sustainable salt management will need sufficient funding to ensure that salt management projects are maintained and closed properly, and adapt to unforeseen additional environmental issues. Timely and adequate investments in salt management will ensure that salt control projects do not exacerbate existing salt conditions.

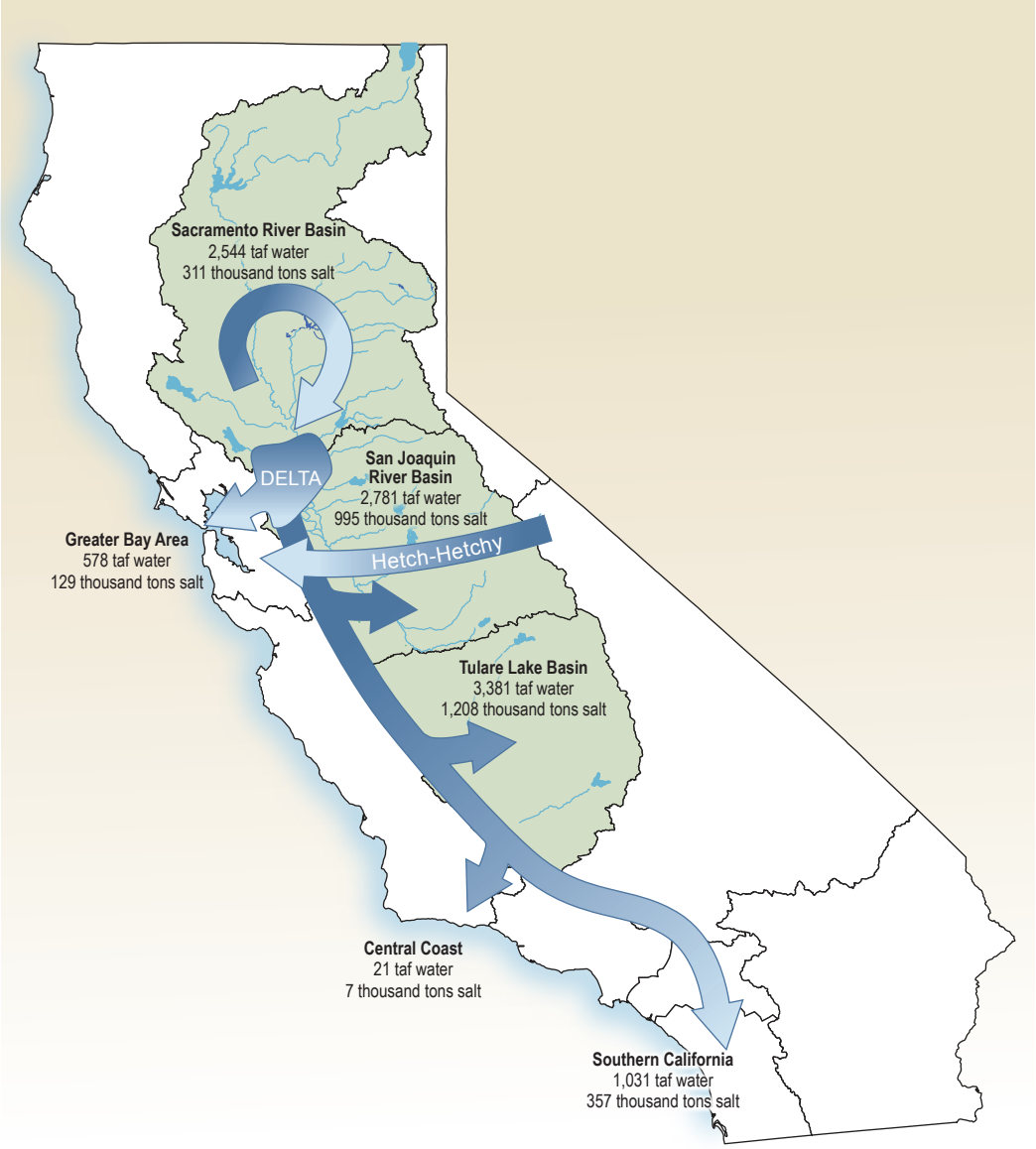
6. Salinity monitoring is under-funded and insufficiently coordinated, and provides inadequate coverage of the salt situation in most regions. Monitoring has historically been under-funded; however, coordinated monitoring is the only way to assess salt impairment, track the rate of salinity degradation or improvement, and determine the effectiveness of salt management actions.

7. Effective salt management may be constrained by federal, State and local policies crafted to serve other needs. This is a similar problem to the funding issues discussed previously (#3, above). Very few policies were developed with salt management in mind. As a result, water use and reuse, prioritization of resources, pollutant control, land use, and habitat management policies, to name a few, may be inconsistent with optimal salt management. Water management decisions have historically been driven primarily by water use efficiency policies, often without any consideration of the salinity issues. Consumptive use of water never results in the consumptive use of the water's total salt load. As California uses water more efficiently, supplies will tend to become more saline unless practices and policies are intentionally implemented to maintain salinity at acceptable concentrations. Compromises between efficiency and quality will likely be needed to ensure a sustainable water supply for future generations.

8. Environmentally and economically feasible options for sustainable salt collection, storage, and disposal do not exist for many parts of the state. Supporting beneficial uses when water is becoming increasingly saline often means that salt must be harvested from the water periodically and disposed. Treatment technologies like reverse osmosis or distillation generate a highly saline solid or liquid waste product. Some areas, such as the Santa Ana Basin, have conveyance channels that take brine from inland areas to the ocean, where it mixes with the salt already there; but California's interior valleys don't have this option. A few facilities use deep-well injection to sequester saline wastewater, and some areas use lower-tech solutions such as evaporation basins to isolate and store collected salt, but both of these alternatives are expensive and can only be used in areas where the geology and soil structure support this type of management. Also evaporation basins have environmental impacts requiring mitigation. Other areas are investigating strategies such as Integrated Farm Drainage Management, which applies water to progressively more saline-tolerant crops, ultimately disposing the remaining drainage in a solar evaporator but these systems have not been tested at a scale needed for regional salt management. Some saline discharges cannot be managed feasibly, sustainably or economically with the management tools currently available.

9. Salinity problems often stem from decisions and actions taken elsewhere, but the costs to manage salt are generally borne by the receiving basin, watershed, community, or individual water user. Salt problems are rarely attributable to a single cause, but rather reflect a suite of decisions, conditions, conflicting water needs, and shifting State and local priorities. Problem salinity in California, as in other parts of the country and other parts of the world, can often be traced back to decisions that seemed like a good idea at the time but that did not take into account the long-term impacts of salinity. Local salinity problems often are not solely due to local decisions or conditions. The most significant example of this is the operation of the State and federal water projects, which move water and the associated salt loads from one basin to another around the state in order to meet water supply needs while operating to Delta water quality objectives set by the State Water Board. (Figure 18-2). A few additional examples follow.
   - Hetch Hetchy and Pardee reservoirs serve as a water supply for San Francisco and East Bay Municipal Utility District respectively, diverting high quality water supplies from their basin of origin. These flows would otherwise assist in salt management by diluting the concentrations of salts downstream.
   - Planning for drainage facilities in the San Joaquin Valley began in the mid-1950s. Drainage service was initially considered at the time the US Bureau of Reclamation (USBR) first studied the feasibility of supplying water to the San Luis Unit. In 1960, Congress enacted Public Law 86-488 authorizing construction of the Unit, including an interceptor drain discharging to the Sacramento-San Joaquin Delta. Between 1975 and 1979 a joint State-federal team, the San Joaquin Valley Interagency Drainage Program, was formed to find an acceptable solution to San Joaquin Valley drainage problems, eventually

Figure 18-2 State and federal water projects



recommending that a drain be completed to the Delta, terminating near Chipps Island.

- As a result, USBR initiated a San Luis Unit Special Study to fulfill requirements for a discharge permit from the State Board for a federal-only drain. By 1975, an 82-mile segment of the San Luis Drain (ending at Kesterson Reservoir) had been completed and 120 miles of collector drains were constructed in a 42,000 acre area of the northeast portion of Westlands Water District. In 1983 the discovery of embryonic deformities of aquatic birds at Kesterson Reservoir significantly changed the approach to drainage solutions in San Joaquin Valley. Because of the high selenium (Se) levels found in the drainwater and its effects at Kesterson Reservoir, the San Luis Unit Special Study was suspended. In 1985, following a Nuisance and Abatement Order issued by the State Water

Board, discharges to Kesterson Reservoir were halted and feeder drains leading to the San Luis Drain were plugged.

- The San Joaquin Valley Drainage Program (SJVDP) was formed in 1991 by the US Secretary of the Interior and the Governor of California in response to issues at Kesterson Reservoir. This joint federal/State effort was established to develop solutions to drainage and drainage-related problems. While the initial efforts looked at all possible solutions, a policy decision in 1987 limited studies to In-Valley drainage management measures based on a recommendation from a citizen's advisory committee consisting of water users, environmental advocates, and public interests.
- The SJVDP's final report (SUTC, 1999) recommended an in-Valley solution that included source reduction, drainage reuse, land retirement, evaporation basins, groundwater management, San Joaquin River discharge, and institutional changes. This report provided a strategy for managing salts through 2040 and stated that eventually salts may need to be removed from the San Joaquin Valley. In the meantime, the Barcellos Judgment directed USBR to develop, adopt and submit to Westlands a plan for drainage service facilities by the end of 1991, leading to preparation of the "San Luis Unit Drainage Feature Re-evaluation Preliminary Alternatives Report" and the related Draft EIS in December.
- An additional lawsuit concluding in 2000, ordered USBR to re-evaluate this report, resulting in the "San Luis Drainage Feature Reevaluation Plan Formulation Report" in 2002 and Draft EIS in 2005 (USBR, 2002, 2009). The Plan identified the In-Valley Disposal/Water Needs Land Retirement Alternative as the proposed action to provide drainage service based on cost, implementation, and other environmental information. In May 2003, the Westside Regional Drainage Plan was developed as a collaborative effort between the San Luis Unit water districts and the San Joaquin River Exchange Contractors Authority to provide drainage relief in portions of the Unit and adjacent areas (SJRECW, et al., 2003). The Westside Regional Drainage Plan is currently being implemented by its proponents and with the assistance of state and federal funding.
- Los Angeles Basin biosolids are exported and applied to land in Kern County. From a salinity standpoint, salt is being redirected to a basin that is already under salt stress.
- In Southern California, only about half of the region's salt comes from local sources. The rest is brought in with imported water. The Colorado River Aqueduct constitutes Metropolitan's highest source of salinity, averaging about 700 mg/L TDS. This leads to salt scale problems for indoor plumbing appliances and equipment at homes, business and industries, which can also contribute to a consumer choice to install water softening equipment, exacerbating the overall problem.

These examples illustrate California's need for long-term planning to deal with the ultimate disposal or long-term sequestration of salt and equitable distribution of salt management costs. Salt disposal and re-location is not simply a local engineering

problem, but may potentially pose economic, social justice or environmental problems for the state.

California's communities, watersheds and regions can only achieve a salt balance if the salt leaving the area equals or, in the case of basins already out of balance, (which includes most agricultural areas) exceeds the amount taken outside of the area. The state's "plumbing"—the natural and constructed conveyance systems that move water and drainage around the state—is not optimized for salt management. It may not be possible to achieve sustainable salt management solely through conveyance system changes, but studies should be conducted to quantify the benefits of optimizing conveyance systems for the additional purpose of salt management.

Recommendations to Promote and Facilitate Salt and Salinity Management

Recommendation to address urgent needs

1. Stakeholders in areas impacted by saline elements at levels that pose a threat to human health (for example, high nitrate) should without delay seek to identify sources, quantify the threat, prioritize necessary mitigation action and work collaboratively with entities with the authority to take appropriate action. Local solutions should be sought first, as these can be implemented more rapidly than those imposed by State or federal authorities. All stakeholders affected by nitrate, seawater intrusion, soil or groundwater salinization or loss of fresh water flows should address salt management through an expedited combination of:
   - adequate funding
   - monitoring to identify the location
   - extent and magnitude of the salt problem
   - planning to incorporate the salt management elements addressing the urgent needs into a community-, watershed- or regionally-scaled management plan
   - policy changes where needed, and
   - collaboration with other interest groups to optimize resources and effectiveness

Each of these elements is addressed separately in more detail below.

Recommendations to address longer-term and ongoing needs

Planning

2. The California Department of Water Resources (DWR) and the US Bureau of Reclamation (USBR) should actively participate in the Central Valley Salinity Alternatives for Long Term Sustainability (CV-SALTS) to develop regional salinity management plans that would include their respective water projects. (Salinity

management plans are salt management plans. Some organizations use one appellation and some use the other. CV-SALTS uses "salinity management plan.")

These regional plans should include:

- An assessment of salt sources, loads, and timing
- An assessment of conveyance flexibility to minimize exportation of salts
- A regional implementation strategy, which could include offsetting/reducing salt loads relocated to salt-stressed interior basins as a result of water project operations. For example, USBR and the Central Valley Regional Water Quality Control Board entered into a Management Agency Agreement in December 2008 to address salinity brought into the San Joaquin Basin via the Delta Mendota Canal. From 2008 - 2010, USBR will implement its Action Plan to quantify offsets from current mitigation projects and continue to implement existing projects.
- A funding strategy that supports the implementation strategy
- A stakeholder participation process to increase the likelihood of achieving plan goals and to ensure transparency in project planning and implementation
- A monitoring program to track the success of the implementation strategy
- An adaptive management strategy that should ensure the plan can be modified to respond to drought, emergencies, climate change, and other changes appropriately

3. Also, over the next 5-7 years, federal, State and local entities with planning authority should review their planning documents (integrated regional water plans, basin plans, general plans, etc.) for consistency with sustainable salt management, making revisions where necessary. Plans serving areas where salt accumulation in groundwater is currently unavoidable should address options for extending the life of the aquifer, including, but not limited to, source control strategies and construction of salt disposal or long-term storage facilities. These plans are living documents, so salt management sections should be updated in accordance with salt management actions that have been taken (or in response to expanded salinity problems due to action not taken) since the previous review. (See also Recommendations 4 through 8, 11, and 12.)

Funding

4. Salt management is a complex issue that has no easy solution and should require diligent attention on an ongoing basis, so California should fund salinity management through multiple mechanisms. Options the State should consider include but are not limited to:
    a. Collect a salt fee on wholesale water deliveries to fund mitigation of the impacts of imported and displaced salts.
    b. Collect an annual salt fee for water rights permits to implement mitigation for lost dilution flows, environmental salinity impacts and salinity impacts to other water rights holders.

c. Collect a salt surcharge on water diversions within adjudicated basins to provide funding for projects designed to restore a salt balance in the basin.
d. Collect a salt fee on transfers of surface water or groundwater that adversely affect the salt balance in the basin of origin to fund mitigation actions.

5. The State should review its funding guidance and policies for consistency with sustainable salt management and make revisions where necessary. Specifically:
    a. Grant and loan programs (including Prop. 84) should address salt management differently than other constituents, favoring projects that coordinate with a regional salt management plan and are supported by the entities maintaining the salt plan.
    b. When not explicitly prohibited by statute, public funding proposal solicitations should welcome projects with community-, watershed-, and regional-scale planning (specifically salt management planning) and water quality monitoring components.
    c. Award caps should be consistent with implementation of community-, watershed- and regional-scale salt management projects.
    d. All projects receiving State money for salt management should be required to follow appropriate quality assurance protocols and submit salt data to a publicly accessible database.
    e. All salt projects receiving public funding should be required to provide the awarding agency with an assurance that sufficient funding should be available to maintain the project during its life and close the project in an environmentally acceptable manner at its termination based upon what can be foreseen at the time of project proposal.

6. The federal government should ensure that all federal facilities are contributing their fair share to mitigate federal contributions to salt imbalances in California's communities, watersheds and regions and participate in regional salt management efforts where appropriate.

7. Business, industry, agriculture, development and the general public should contribute financially to sustainable salt management. Several organizations representing water providers and wastewater treatment operators recently offered to fund development of regional salinity and nutrient management plans around the state. Californians should be paying for salt management either reactively as rates increase, equipment wears out prematurely, food costs soar (loss of farmland means higher transportation costs for imports), fish and wildlife habitat is lost and business and development opportunities disappear as operations leave the area for states with more favorable water conditions; or proactively, through adequate, continuous funding of sustainable salt management. With so much at stake on a statewide, community and personal level, funding for salt management cannot be solely a State or federal responsibility. (See also Recommendations 8 and 12.)

Monitoring

8. Federal, State, Tribal, local, non-government and private stakeholders should work collaboratively to fund, develop and operate a monitoring network or an array of compatible networks capable of identifying emerging salinity problems and tracking the success of ongoing salinity management efforts where such networks do not already exist. Using the model of the Pesticide Use Reporting program, continuous funding for operation and maintenance of these networks might be made possible through a mil tax (1 mil = $0.0001) on salt–containing products sold in the state (fertilizers, detergents, personal care products, water softener salts, processed foods, etc.), since many of these salts may end up in our wastewater treatment plants, ultimately discharged to groundwater or surface streams. New or expanded networks should build off of and remain compatible with existing relevant statewide monitoring programs such as the Surface Water Ambient Monitoring Program (SWAMP) and Groundwater Ambient Monitoring and Assessment (GAMA) program. Data should be made available to the public through a web-based user interface such as the Integrated Water Resources Information System (IWRIS). (See also Recommendations 2, 3, 11 and 12.)

Policies

9. Over the next 5 years, entities with water policymaking authority should review existing policies, including those related to water use efficiency and funding of water projects, for consistency with sustainable salt management. Revisions should be made where necessary to ensure consistency with long-term sustainability objectives. Effective salt management is not a stand-alone strategy, but should be integrated with other strategies. Every water use, water reuse, and waste disposal decision should include consideration of how the decision may affect the local and regional salt balance. Projects that propose to introduce saline water that may eventually mix with groundwater should be evaluated in the context of the basin's assimilative properties and California's anti-degradation policy. (See also Recommendations 11 and 12.)

Salt storage and other research and implementation

10. Additional options for salt collection, salt treatment, salt disposal and long-term storage of salt should be developed. University researchers should work with regulatory agencies and stakeholders to identify environmentally acceptable and economically feasible methods of closing the loop on salt for areas of the state that do not currently have sustainable salt management options. Funding for this sort of research should be prioritized to ensure that areas with the greatest needs (i.e. high salt and few or no feasible management options) are targeted first. (See also Recommendations 2 through 7, 11 and 12.)

Movement of Salts with Water

11. The movement of salts with water should be acknowledged and mitigated as appropriate. Mitigation could involve ceasing the activity that is causing the impact or provision of financial assistance to help the impacted community deal with the problem on an ongoing basis, or mitigation might take some other form as agreed to by the parties dealing with the salt impact and those causing it. (See also Recommendations 2 through 9.)

Salt balance

12. Where appropriate, State and federal water agencies with the necessary expertise and authority should implement projects that assist the state's communities, watersheds and regions in achieving a sustainable salt balance. Public interests should work with industry, environmental interests, agriculture and other stakeholder groups to develop both long term and interim salt management projects so that salts are safely collected, stored and managed over the short term and disposed in an environmentally acceptable manner over the long term. Options that should be considered include but are not limited to:
    - Avoid/minimize salt importation. Additional discussion of avoidance/minimization of salt importation is included in Chapter 4, Conveyance Delta resource management strategy.
    - Upgrade existing conveyance structures, and if planning efforts determine that new structures are warranted, invest in new structures to safely collect, transport and dispose of salts. Additional discussion of conveyance is provided in Chapter 5, Conveyance Regional and Local resource management strategy.
    - Invest in research and development of environmentally acceptable means of storing salts for extended periods (decades) and sequestering salts (100+ years). Research should include identification of areas within the state where such facilities can be sited with the least environmental impacts.
    - Additional research into more feasible means of utilizing collected salts should be encouraged.

    (See also Recommendations 2 through 7, 10 and 12. For additional discussion of resource management strategies that have benefits to salt and salinity management, see the chapters Agricultural Water Use Efficiency, Matching Water Quality to Use, Land Use Management and Planning, and Recycled Municipal Water.)

Collaboration (Recommended for all recommendations)

13. All entities that make decisions with a bearing on salt management should be participating in regional salt management planning, monitoring and implementation projects. Effective and sustainable salt management decisions rest in the hands of a wide range of water managers, regulators, facility operators, policy makers, landowners and other stakeholders in any given watershed. These entities should strive to coordinate their efforts where possible in order to utilize resources

efficiently, develop regional solutions to regional problems, optimize funding opportunities and achieve a salt balance in the basin as quickly as possible.

14. Salt moves with water; therefore, effective salinity management should address the routes water takes within and between basins. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) is an initiative aimed at developing and implementing sustainable regional salinity management plans for the Delta and Central Valley regions. Because water operations in the Delta and Central Valley and the beneficial uses the operations support are critical to the state, policy makers and stakeholders should support and participate in the CV-SALTS effort. (See Case Study 3). Salinity stakeholder groups should conduct outreach aimed at educating specific target audiences with the ability to influence salinity decisions (Legislature, interest groups, general public, etc.) about the need for sustainable salinity management.

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