Appendix A: Summary of Reviewed Literature
Conservation Potential of Salinity Mitigation Strategies (SCSC 11-02)

1. **Aquacraft, Inc. California Single-Family Water Use Efficiency Study, June, 2011.**

   The California Single Family Home Water Use Efficiency Study was prepared by Aquacraft in June 2011. The primary goal of this study was to assist in identifying how much potential remains for conservation savings from both indoor and outdoor conservation efforts within single family households. This study showed that the conservation potential remaining in the system is primarily from outdoor uses and is significant. The three key parameters for modifying outdoor use included the irrigated area, the water demands for various plants in the landscape and the percent of homes in the population area that are over irrigating. This study showed that 42% of all homes were over irrigating. The study identified indoor water use by household for each water device such as clothes washers, faucets, toilet flushing, etc. However, water softeners were not specifically identified and could show up in the monitoring as a leak. The study recommended that additional studies and criteria be established to identify home RO devices since 7% of homes within the study appeared to have “leak- like” events which constituted approximately 100 gpd or more within the study area alone. This study provides good statistics on the water use within the typical household for various devices.

2. **Australian Golf Course Superintendents' Association, Turfgrass Tolerance to Salinity, 2011.**

   High levels of soluble salts in the turf root zone are detrimental to most turf grasses. Excess salts can affect growth by osmotic inhibition of water uptake (physiological drought). Other effects can include reduced top growth, and reduced nutrient uptake; root biomass may increase adaptively to improve water-absorbing ability. Sodium (Na) and chloride (Cl) reduce growth by interfering in photosynthesis (also noted by Harivandi et al. 1992). Salinity affects different species in different ways and the effects can vary according to the age of the plant. Effects are generally greater at germination and planting than in the mature plant. Salinity tolerance is related to the plant species’ ability to reduce sodium chloride (NaCl) uptake.

   It is essential that the golf course manager have a good understanding of the complete soil/turf/drainage system to ensure long-term sustainability.

   If high salinity water is the only water available, several management techniques can be used to minimize salt damage. Management techniques include: establish salt-tolerant species and varieties, construct the greens and tees using high drainage rate sands and include a good subsoil drainage system to ensure leaching, ensure irrigations are sufficient to leach salts out of the root zone and prevent accumulation, without leaching pollutants into groundwater. In addition, the following practices can be used to improve irrigation efficiency: evaluation of the performance (mechanics of the system, sprinkler uniformity) and management (actual water applied vs demand) of the irrigation system on a regular basis.

   Leaching requirement=ECiw (EC of irrigation water) - ECdw (EC of drainage water). Assume that the concentration of the drainage water is the same as that of the saturation extract (ECe) at the bottom of the root zone (which depends on the species). So if the leaching requirement is 33-66%, the amount of irrigation required is 33-66% greater than if low salinity water is used (Dickey: questionable calculation result).

3. **AWWA, 2013 Water Rate Survey, California-Nevada Section, 2014.**

4. **AWWA Research Foundation, WateReuse Foundation, Characterizing and Managing Salinity Loadings in Reclaimed Water Systems, 2006. (T:\071\NWRI Salinity Mitigation Study\Literature\Temp\WateReuse 2006 Salt Loadings in Reclaimed Water)**

   This study took an in-depth comprehensive look at the problem of salinity in recycled water on a national level. The study included a literature review on sources of salinity to wastewater, constraints to using recycled water, recycled water regulations and developed salt balances for sewersheds for five utilities. A Water Quality model (WQ Analyst) was developed and the annualized cost of potential salinity mitigation practices was determined using an economics model. The study identified the main contributors of salinity to wastewater include human excretion, grey water, self-regenerating water softeners, swimming pools, industrial and commercial and water and wastewater treatment. Relevant to the NWRI Salinity Mitigations Study, this study found that self-regenerating water softeners were a significant contributor to the wastewater for three of the study areas (33.3% of 22.7 mgd, 29.3% of 6.86 mgd, 6.2% of 10.3 mgd and 24.1% of 2.35 mgd) (Table ES.1). The water softeners contribution was evident since the spikes occurred in the early am hours when softeners are recharged, the spikes were dominated by NaCL and the were almost exclusively residential neighborhoods with no commercial or industrial discharges. This study provided the contributions of salinity based on the average efficiency of the water softeners and market penetration. This study offers valuable information on softener penetration, costs of RO treatment, etc. and is a good reference for the NWRI Conservation Potential of Salinity Mitigations Strategies Study.

5. **Ayers, R.S. Ayers, R.S., and D.W Westcot. 1985. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29. Food and Agriculture Organization of the United Nations, Rome.**

6. **Battelle Memorial Institute, Final Report Study on Benefits of Removal Of Water Hardness (Calcium And Magnesium Ions) From A Water Supply By D. D. Paul, V.V. Gadkari, D.P. Evers, M.E. Goshe, and D.A. Thornton, Not Dated.**

   This study looked at the impacts of hard water, specifically calcium and magnesium, on household appliances including varying types of water heaters (gas and electric), showerheads, low flow faucets, dishwashers, and clothes washers. While this reference was not specifically relevant to this study, it showed that household appliances operate more efficiently when utilizing softened water and less energy was consumed with the increase in efficiency. This study concluded that there are environmental benefits to the use of water softeners because the higher efficiency results in less energy consumption and hence, lower energy costs. However, the study did not include the cost of the purchase of the water softener itself, maintenance cost of the softener, or the cost of the energy to run the softener. Not a relevant study for the NWRI Salinity Mitigation Strategies Study.

7. **Bender, Gary and Ben Faber. Irrigation Book 2, Chapter 1, 2011.**

   Salts reduce avocado yield by making it difficult for roots to extract water. Sodium may displace calcium and magnesium ions leading to deterioration of soil structure and poor water retention. High concentrations of salts may facilitate the uptake of ions the plant might otherwise exclude, and interfere with metabolism of the plant. Avocado specifically has problems with chloride, sodium, and sometimes boron.

   Avocado is one of the most sensitive tree crops to TDS. The chloride ion is specifically toxic to avocado.

During a 5-year experiment with 100% reclaimed water, yield was reduced 40% compared to yield with 100% potable district water. Adding 40% extra reclaimed water still reduced yield 27% compared to 100% district water. A 50/50 blend of reclaimed/district water reduced yield 27% compared to 100% district water (Bender and Miller 1996). Under-irrigation, complicated by the accumulation of salts in the soil due to inadequate leaching, is one of the leading causes of poor yield in avocado groves. The use of saline well water, saline surface water, or reclaimed water also reduces yields significantly and may not be corrected with leaching. Avocados are challenging due to shallow feeder root systems (90% of feeder root length is located in upper 8-10 inches of root zone soil).

Salinity management is essential and is inter-twined with irrigation scheduling, but it is not given enough attention from growers. Very few growers do soil samples to check salt accumulation. Using high quality water is the best option. Leaching is not well-researched in avocados, but growers should leach every irrigation by adding extra water above the 100% ET requirement, depending on the salinity of applied water and the soil. Other strategies include: soil monitoring, water blending, irrigation frequency, rootstocks, mulches and manures, monitoring the sodium adsorption ratio.

Under-irrigation, poor leaching, and the use of saline well water, surface water, or reclaimed water are major causes of poor yields in California. Avocados are sensitive irrigating with saline water of an EC 1.2 (Dickey: about 770 mg/L TDS) would reduce yield by 10% (assuming leaching fraction of 10%) and a yield reduction of 50% with and EC of 2.4 (assuming leaching fraction of 20%; Dickey: 1540 mg/L TDS). Growers of Avocados should leach during every irrigation by adding extra water above 100% of ETc (Dickey: minus effective rainfall) requirement (10% extra for district water, higher for reclaimed water). Manage salinity blending, use high irrigation frequency (to keep salts in solution), switching from manure to green waste (Dickey: i.e., compost as fertilizer), and managing your Sodium Adsorption Ratio (Dickey: SAR, an index of cation balance).

8. **Bookman-Edmonston Engineering, Inc. (July 1996 - June 1999). Salinity Management Study, Section 1 through Section 5, Final Report. Los Angeles: USBR I MWD.**

Completed in 1999 for the Metropolitan Water District of Southern California and the U.S. Bureau of Reclamation by Bookman-Edmonston Engineering, this work is a report summarizing the detailed data found in the Technical Appendices 1-13.

This was a two and a half year comprehensive technical study evaluating the overall impacts of total dissolved solids/salinity on Southern California. The study found that the sources of salinity are half imported water and the other half comes from local sources. The Colorado River Aqueduct (CRA) constitutes Metropolitan Water Disrict's (MWD) highest source of salinity (average 700 mg/L total dissolved solids [TDS]). The California State Water Project (SWP) provides an average of 250 mg/L TDS on the East Branch and 325 mg/L TDS on the West Branch. These sources can be used to blend with CRA water. Local sources include naturally occurring salts, salts added by urban users, infiltration of brackish groundwater into sewers, irrigated agriculture, and confined animal feeding management practices. Urban use salt contributions to wastewater range from 250 - 400 mg/L TDS or more in some regions. Hardness comprises about 1/2 of the CRA salt load and causes troublesome scaling problems to indoor plumbing appliances and equipment at home, businesses, and industries.

MWD estimates that $95M/year of economic benefits would result if the CRA and SWP waters were to simultaneously experience a 100 mg/L reduction in salt content over their historic average. About the same amount of impacts would result if imported salinity increased by 100 mg/L. Primary impact categories include: residential, commercial, industrial and agricultural users, groundwater and recycled water resources, and utility distribution systems.

Benefits of reduced salinity include improved use of local groundwater and recycled water, and reduced costs to water consumers and utilities. This report recommends a goal to maintain a salinity level of 500 mg/L. This is challenging when in drought conditions and water demand is high and there is less SWP water available for blending.

Technical Appendix 5 is relevant to the work that will be performed under the NWRI Salinity Mitigation Strategies Study and is discussed below.

9. **Bookman-Edmonston Engineering, Inc. (July 1996- June 1999). Salinity Management Study, Technical Appendices 1 – 13, Los Angeles: USBR I MWD.**

Technical Appendix 5 of the Bookman-Edmonston Salinity Management Study is a report on the economic impacts of salinity, titled “Economic Impact of Changes in Water Supply Salinity and Salinity Economic Impact Model Final Report” from June of 1999. This report details the model developed by Bookman-Edmonston (BE) and demonstrates how the economic impacts of increased salinity are calculated. Total Dissolved Solids TDS is the measure of salinity used. The model is an update of the U.S. Bureau of Reclamation’s (USBR) 1988 model and covers the salinity impacts of both the State Water Project (SWP) and Colorado River Aqueduct (CRA) water to residential, commercial, industrial, agricultural, groundwater, water recycling, and water treatment and distribution facilities in the Metropolitan Water District of Southern California’s service area. The service area is divided into 15 sub-areas to reflect the different water supply and impact conditions.

In general, a mathematical function is developed to model the physical impacts of increased salinity on a particular sector for a particular region. An economic cost is then applied to the physical function to get an equation for the economic impact of salinity for that item. Key input variables include population, households, plumbing fixture statistics, water supply and use characteristics and agricultural production data.

Not all of the economic impacts calculated in the report are due to increased salinity; many are due to water hardness and other constituents. In order to simplify the model, changes in TDS were used as a proxy for all other impacts as there is an assumed linear relationship between salinity and these other factors.

The model calculates the value of an incremental change in TDS from a baseline and only totals the direct economic impacts. A hypothetical example of a 100 mg/L decrease in TDS for the overall system leads to an annual economic benefit of about $95 million for Metropolitan’s service area. The report also presents the economic impacts of increases in salinity for each of the main water sources individually.

This work will be very helpful in the current NWRI study. It provides a baseline of salinity effects and economic impacts. The shortcomings for our work are primarily two. First, there is little information on increased water use specifically for the primary focus of the NWRI study which is focused on the additional water use required for large landscape and water softeners due to salinity. Second, this study is 14 years old and the data supporting it are as much as 20 years old. Development patterns, building technologies and household appliances have changed radically since the original data was gathered.

10. **Brown, Paul and Jim Walworth, University of Arizona, Arizona Cooperative Extension, Factors Contributing to Development of Salinity Problems in Turf, August 2010.**

The consequences of excess salinity can include poor turf performance, reduced water infiltration (Dickey: this is due to poor cation balance [excessive Na], not salinity per se), and the appearance of a new turf disease, rapid blight. The two main causes of high salinity are inadequate leaching and inherited (Dickey: water supply) salinity. When water supply is insufficient, salinity levels rise and turf performance and/or soil structure declines (Dickey: structural decline should not be related to drought).

There is a well-established body of literature that quantifies the amount of leaching required based on water quality and salinity tolerance of turf grass species (e.g., Ayers and Westcot 1989, Mass 1984, Carrow and Duncan 1998). For most species, an additional three to six inches on water in excess of ET is required on an annual basis.

Increasing the amount of water available for turf irrigation is one means of addressing salinity-related problems. Future water duties (depth of water allocated for irrigation) should be revised to incorporate this additional water need. In the interim, there are two options: applying the leaching allotment or blending with higher quality water. Other options include capturing runoff, improving irrigation application uniformity, and improving infiltration

11. **Brummer, Joe, Colorado River Salinity Control Program, Preliminary Salinity Damage Assessment for Golf Courses and Other Turf Areas, January, 2010. Draft**

The use of water softeners, low flush toilets, low flow showers, etc. has led to less dilution of salts in domestic wastewater. Return flows to recycled water systems have therefore, become more concentrated.

Golf course industry experts (chemists, turf breeders, salinity experts, agronomists, and soil scientists) report increasing turf damage due to salinity of irrigation water supplies. The Salinity Management Guide of the Water Reuse Foundation reports an increased likelihood of salinity damage from irrigation water with 450 – 2000 mg/L TDS, and a high probability of salinity damage when water exceeds 2000 mg/L. Effects on golf courses have a major impact on revenue and secondary tourism. Other impacts include turf replacement costs, soil remediation measures, water treatment measures, cost of leaching water, cost of rapid blight control, capital costs for drainage systems, increased maintenance, lost revenue from lost play times.

Current management trends include: better drainage and irrigation infrastructure, improved variety of turf grasses, more knowledgeable superintendents and greens keepers, use of reclaimed municipal wastewater or marginal well water (that is not suited for municipal use), high tech soil and water salinity sensors, use of desert landscapes, use of RO units and water blending hardware, decreasing turf areas.

The city of Scottsdale is expanding its reverse osmosis plant and eventually plans to place 55 golf courses on blended water (RO, effluent, and other sources). This will provide better water quality. The goal is to reduce sodium content of the blended water to 125 mg/L, which would reduce salinity levels to 600 mg/L TDS. Golf courses are paying for a portion of this expansion ($14M) and are paying a surcharge of $1 per 1,000 gallons of blended water. This should reduce annual salinity damage remediation costs and improve turf conditions; however capital costs need to be considered.

The paper includes a full page list of costs for remedial soil treatment measures and water treatment measures. The paper also identifies lost revenue from high TDS, such as fewer rounds played, lower green fees, and overall reduced revenue.

Golf Course Superintendents Association of America reports that the typical golf course has 115 acres of turf and average water use is 459 AF per year (5 feet/acre). The National Golf Foundation reports that the average course in the southwest pays $107,800 for water, which equals to $937/acre and $233/AF. Based on leaching algorithms, leaching rates and annual costs are identified in the paper, ranging from $6k to $48k depending on TDS. Average cost of AF water: average of courses in southwest: $233; Las Vegas (municipal): $1466; Scottsdale (blended effluent) $250; Tucson (municipal): $435; and TPC Course in Scottsdale 2009: $627

12. California Avocado Commission, Salinity Management of Avocados, Undated.

Depending on the salinity of the irrigation water, generally, aim to use a 10-20% leaching fraction at each irrigation to maintain a root-zone salinity of soil water below EC 2.

The best practices to manage soil salinity and optimize water use include: monitor salt levels, leach effectively, and good cultural practices (salt-tolerant rootstock, low salinity irrigation water, soil leaching, good irrigation practices, proper irrigation equipment, gypsum applications). Also, avoid short, frequent irrigation cycles (because salts are not leached); avoid prolonged saturated soils that leads to root rot. Optimal irrigation requires uniform water application and mass; drip irrigation is not ideal for managing salinity in hot dry weather because it only supports roots in a narrow zone of low EC soil.

13. Carrow, R.N., M. Huck, and R.R. Duncan, Leaching for Salinity Management on Turfgrass Sites, November/December 2000.

The Rhoades method presented in this article provides a good approximation of leaching requirements and is based on the irrigation water salinity and grass salinity tolerance using the threshold EC.

The best option for managing salinity is a continuous, routine maintenance leaching program using an adequate leaching requirement (LR). The most common reason for not applying sufficient irrigation water volume for leaching is underestimating the daily ET requirement for replacement of soil moisture lost by ET, rather than underestimating the leaching requirement (LR) fraction of total irrigation needed.

14. Carrow, R.N, C. Waltz, Turfgrass Soil and Water Relationships, Undated .

This publication is about the relationships between soil, plants, and water, and discusses drought stress symptoms but it does not specifically address salinity.

15. CDM Smith, Memorandum to CV-Salts Executive Committee, Salinity Effects on MUN-Related Uses of Water, July 6, 2012.

The purpose of this memorandum was to summarize the current knowledge regarding the effects salinity and hardness has on the drinking water supply and other domestic purposes and identify and summarize the concerns related to specific ions (sodium, chloride boron, etc.). Provides a summary in terms of regulations, health effects and domestic use effects. Not a significant resource for the NWRI Conservation Potential of Salinity Mitigation Strategies Study.

16. **Characklis, G. W., R.C. Griffin and P.B. Bedient, Measuring the long-term Regional Benefits of Salinity Reduction. Journal of Agricultural and Resource Economics- Western Agricultural Economics Association, 2005.**

This work was published in the *Journal of Agricultural and Resource Economics* by Gregory W. Characklis, et. al. This study considers desalination as a method for salinity management. The authors believe that previous studies reveal that municipalities and urban users incur the vast majority of salinity related damages as compared to agricultural users. They also assert that previous studies also use stepped increases in salinity concentration rather than incremental increases when calculating benefits. They contend that this tends to significantly overstate benefits.

The study area is the Lower Rio Grande Valley in Texas which had a rapidly growing population of almost one million and about 400,000 acres of irrigated farmland at the time of this report. The authors present six scenarios that use different approaches in calculating benefits where the change in salinity and water use is either incremental, step-average or step; if desalination is an option – yes or no; and either a linear or non-linear agronomic-economic relationship. This results in total regional benefits ranging from $176.4M to $703.3M (present value).

The equations used in this study are displayed as net benefits (benefits to muni + benefits to ag) – (cost to muni + cost to ag + damages). For our work, benefits will be calculated in water savings. Useful points:

1) Urbanization will increase benefits of reduced salinity
2) Costs begin in year one, but benefits are incremental over time and care should be taken not to assume constant benefits over time

The relevant information within this study will be utilized for the efforts on the Salinity Mitigations Study. The water use information will be of some use, although landscaping water requirements in this region will obviously differ from Southern California.

A lot of detailed models have evaluated effects of salinity on crop yield and municipal activities (references for each study are included in the paper). Each study found that the bulk of damages (85%) occur in the municipal sector, even though the majority of water use is agricultural.
This paper assumes that salinity increases have a minimal impact on municipal demand, and that the municipal damages accrue as an increase in cost. Specifically, only small changes in demand occur for urban irrigation because turf grass is "unaffected by moderate salinity levels." Damages are considered in three categories: accelerated degradation of equipment/appliances, accelerated degradation of infrastructure, and increased use of tap water substitutes. Algorithms are included to evaluate damages in residential, commercial, and industrial sectors. The paper concludes that desalination is economically preferable when salinity rises above 1,195 mg/L TDS in small municipalities (i.e., around 3 million gallon per day [MGD] treatment facility) and 1,655 mg/L TDS in large municipalities (i.e., around 12 MGD treatment facilities). There would be increases in source water demand and consumption.

Agricultural impacts of salinity include lower irrigated crop yield. Municipal impacts include economic damages related to accelerated degradation of infrastructure and increased use of tap water substitutes.

Benefit estimation (of a salinity management program) requires the calculation of two values: the relative reduction in salinity and the avoided damages. While traditionally viewed as expensive, recent work has found that the reduction in municipal damages through desalination can exceed capital costs when the source water is as low as 1,000 mg/L.

17. **County Sanitation Districts of Los Angeles County, Automatic Water Softener Rebate Program – Phase II: Public Outreach Program, Final Project Report, December 2010**

    This is a report that summarizes the automatic water softener (AWS) residential rebate and outreach program that was launched in 2005 for the Santa Clarita Valley Sanitation District of Los Angeles County (Sanitation District). The program resulted in the removal of over 7,050 AWS from the District's service area and helped to decrease the chloride concentrations in the local recycled water by 50 mg/l. Phase I of the program provided a financial incentive to residents of $100 to $150 to voluntarily remove the AWS from their homes. Phase II focused on increasing the rebate amounts and developing outreach materials. This is a good resource for implementing a successful AWS rebate program and provides a summary of the lessons learned.

18. **Crowley, David, University of California, Riverside, Department of Environmental Sciences, Irrigation and Salinity Management of Avocado, undated.**

    This is a presentation on research that was conducted and introduces new recommended technologies to specifically improve avocado production.

19. **d'Arge Ralph C, Larry Eubanks, Municipal and Industrial Consequences of Salinity in the Colorado River Service Area of California, U.S. Department of lnterior, (1978)**

    This study attempted to measure the economic losses associated with variation in the mineralization of water delivered to households. The losses were measured for water heaters, galvanized pipes, brass faucets, dishwashers, washing machines, and garbage disposals. A statistical analysis comparing the lifetimes for the household appliances and materials was performed for the San Fernando Valley, Costa Mesa-Newport Beach and Long Beach, California. Each location was also divided into socio-economic units based on median home values, rent, number of persons per household, etc. It was estimated that the economic losses for a typical Los Angeles household ranged from $620 to $1,010 in present value terms for an increase in TDS from 200 to 700 mg/l. Utilizing rough extrapolation, damages utilizing the higher salinity Colorado River water rather than State Project water results in an estimate of approximately $70 to $115 million annually. This report claims that a reduction in TDS in the Colorado River water would lead to a cost savings of approximately $14 million per year in present value terms. This estimate does not include other household savings such as purchases on soaps and detergents nor the advances in water softening devices that decrease the physical damages to household items. It also does not take into consideration the cost of water softening devices or the purchase of salt. This study is not directly relevant to the NWRI Salinity Mitigations Study in that it does not provide information on water savings from lowering the salinity.

20. **Dickey, John, PlanTierra, Personal Communication, 2014.**

    Impacts of salinity to irrigated systems that are most often cited reductions in soil quality brought about by inadequate removal of salt from the root zone, which in turn affects plant growth. The nexus with water supply is the process of salt removal, which is almost exclusively with excess applied water and precipitation (see later discussion of leaching). In general, more applied water is required to remove a greater mass of salt. The mass of salt that must be removed depends on 1) how much is being added, and 2) the sensitivity of the plants, and thus the salt concentration that must be achieved in the root zone. The sensitivity of landscape and agricultural systems in the region is therefore central to the question of whether and how reductions in imported water supply salinity could feasibly influence volumes of applied water. The other major determinant of how applied water amounts can be influenced by applied water salinity lies in the extent to which irrigation practices accurately reflect leaching requirements. Irrigators must respond to more dilute water by reducing leaching requirements for water conservation to be realized. See the later section on water management.

Increasingly, there are viable techniques to help guide irrigation decisions at the landscape level, allowing irrigators to understand not only average conditions in irrigated areas, but also to locate and diagnose variability. These include ground-based remote sensing to assess soil salinity (previously discussed), as well as aerial and satellite based sensors. The diversity, as well as the spatial and temporal resolution of these data, and our capacity to interpret them, have all increased. At the same time, their cost relative to other costs (for example, of water) has generally declined. For example, estimates reference evapotranspiration have historically been based on climatic parameters. We then estimate landscape ET with the help of coefficients. Actual ET can also be measured by observing the energy balance at the surface of the earth, something that can be done by satellite. The same imagery provides indices of plant stress, soil wetness, and weed infestations, all with comparable spatial richness. Delivery of these types of data, along with interpretations and recommendations that follow from them, is now greatly facilitated in web-based services that resemble the Google Earth interface. These images and estimates are far more detailed (spatially) so that irrigators can identify and manage problem areas and the rest of the landscape in distinct and appropriate ways. Sensing of soil salinity from above ground is analogous. Electromagnetic properties of salt, water, and soil allow this to occur, resulting in detailed maps of salinity. This complements and greatly enriches knowledge gained from more cumbersome and therefore more limited information from soil samples taken at specific points in the landscape. Since the objective of irrigation is to manage soil moisture and salinity in a manner that benefits the desired plant community, and to do so in a time- and water-efficient manner, the more detailed knowledge provided by these tools presents an as-yet lightly tapped opportunity.

21. Dickey, J.B. 2014. Blended Water Suitability and Use for Irrigation. Presentation to landscape irrigators for Santa Clara Valley Water District and South Bay Water Recycling. Unpublished. http://santaclaraca.gov/modules/showdocument.aspx?documentid=8871

The Santa Clara Valley Water District is bringing a reverse-osmosis polishing stage of wastewater treatment online. Water produced is mixed with 725 mg/L TDS recycled water to produce a 500-mg/L-TDS blend. While the higher salinity was considered manageable, ease of management and the opportunity to reduce leaching, especially for sensitive plants (e.g., about 5% savings in peak months for redwoods) were cited as advantages to landscape irrigators.

22. Environmental Protection Agency, Notification of Intent to Develop Draft Efficiency and Performance Specifications for Cation Exchange Water Softeners, November 8, 2010.

The Environmental Protection Agency (EPA) is looking for information to help develop and support a specification for water-efficient, high-performing cation water softeners. Federal standards do not currently regulate water use or performance of water softeners. There is however, an industry standard for Residential Cation Water Softeners that some states have adopted as part of their plumbing code for manufacturers wishing to obtain the Efficiency Rating. NSF/ANSI 44 is a basis for the water efficiency and performance requirements, however, supplemental performance factors have been identified that need to be developed in order to support a draft specification. Water efficiency of water softeners is defined by NSF/ANSI 44 as the amount of water used during the regeneration process per 1,000 grains of hardness removed during the exchange cycle. Salt efficiency is defined as the amount of hardness that can be removed by each pound of salt added to the system. The voluntary salt-efficiency requirement of NSF/ANSI 44 is 3,350 grains of hardness removed per pound of salt. WaterSmart determined that salt efficiency is an important measure of performance for two reasons: it could reduce the operating costs for the end users and it could decrease the amount of sodium discharged into the septic or municipal recycled water system.

23. Hanson, B.R., Stephen R. Grattan, Allan Fulton, Agricultural Salinity and Drainage, 2006.

Updated and much expanded list of crops, classed by salt sensitivity. Also contains quantitative measures of yield impact by increasing salinity. (Dickey: Ornamentals are generally judged to be economically impacted at what amounts to a 50% yield reduction, where economic impact to agricultural crops is generally recognized when yield reductions are in the range of 5% or less.)

24. Harivandi, M.A., Evaluating Recycled Waters for Golf Course Irrigation, 2004.

Most waters of acceptable quality for turf grass irrigation are 200 to 800 ppm soluble salts (mg/L TDS). Soluble salts above 2,000 ppm may injure turf grass (this level can be tolerated by some species, but the soil needs good permeability and subsoil drainage). This publication provides a table with tolerable ranges in salinity and other soil parameters.

25. Harivandi, M.A., Interpreting Turfgrass Irrigation Water Test Results, 1999.

This publication is a guide for understanding water quality test results and not relevant to this study.

26. Howitt, Richard, et al., The Economic Impacts of Central Valley Salinity, University of California, Davis, Final Report to the State Water Resources Control Board Contract 05-417-150-0, March 20, 2009.

The goal of this study was to measure the economic impacts of increased salinity in the Central Valley to the year 2030. The study assumed that there was no change in current policy and, the economic impacts represent taking no action. The study results showed that if salinity increases at the current rate until 2030, the direct annual costs will range from $1 billion to $1.5 billion. Total annual income impacts to California will range between $1.7 billion to $3 billion by 2030. The income impacts to the Central Valley will range between $1.2 billion and $2.2 billion. The production of goods and services in California could be reduced from $5 billion to $8.7 billion a year. The Central Valley output reduction would range between $2.8 billion to $5.3 billion. There is an additional $145 million per year of non-market costs. In terms of job losses the increase in salinity by 2030 could cost the Central Valley economy 27,000 to 53,000 jobs. California could lose 34,000 to 64,000 jobs. This resource provides an in-depth break down of the economic impacts to agriculture, animal production and each industry as salinity increases. The authors note that some of the shortfalls to the projections lies in the lack of information on the physical parameters of salinity accumulation. Variability of salinity is the basic water supply is not well documented and consistent throughout the valley producing a wide range of salinity and economic impacts over the different regions. The authors recommend that additional research should be conducted on the hydo-geology prior to updating the economic impacts. Other factors affecting the economics include the uncertainty of the types of crops that will be grown due to the scarcity of water supply in the future, change in climate, salinity accumulation, and urban growth affecting land availability.

27. **Hunt, Andrew A., Trickle-Down Effect: How Water Filters & Softeners are Evolving. Consumer Digest, July 2012, Retrieved from www.consumersdigest.com**

This article primarily discusses the reasons why so many consumers are utilizing water filters. It states that municipal water supplies have more contaminants than ever before and the water filter companies are responding to those concerns. The primary contaminants discussed in this article are the changing trend, due to the Environmental Protection Agency's regulations, that municipalities are switching to chloramine, a combination of chlorine and ammonia and critics say that it is linked to respiratory and skin ailments and is toxic to fish. Water softener manufacturers will respond by changing their carbon formulation to remove chloramines. This article also discusses the research that is currently underway by water softener manufacturers to remove pharmaceuticals from drinking water but estimates that it will be 10-20 years before standards are developed due to the thousands of different chemicals in the water. According to a 2011 World Health Organization Report, there are two devices that remove pharmaceuticals, nanofiltration and reverse osmosis. Nanofiltration devices start at about $300 ($150 for replacement filters) and reverse osmosis start at about $200 ($125 for replacement filters). There is a rise in the use of water filtration bottles and they use the same technology that's found in the faucet-mounted and pitcher water filters and utilize carbon to remove chlorine and resin beads to remove heavy metals and sediment. Water softener manufacturers are getting into the water filtration business and have introduced hybrid models that filter water to improve the flavor of heavily chlorinated water and remove minerals such as calcium and magnesium and reduce the barium and radium which softens the water. These models use granular activated carbon pellets that are added to the resin beads that soften the water. Like other carbon-based filtration systems, the GAC pellets in the resin bed need to be replaced every six months at a cost of $14-$28 per year. Hybrid water softeners can last about 6-10 years until the carbon pellets need to be replaced and the resin beads need to be repacked. Prices start at around $200 to replace the carbon pellets and replace the resin beads. The cost of the hybrid models start around $749 for the Kenmore Hybrid Elite which is approximately $200 more than the Kenmore model that does not filter water also. The article states that the hybrid models are effective if all you are looking to accomplish is removing the chlorine taste and softening but not as effective if you need to reduce metals or other substances in addition to softening. Culligan has also launched a high efficiency water softener line starting at $2,500 that has sensors that measure how much of the softening resin bed has to be regenerated and measures out only enough salt to clean the resin beads. Sensor technology in water softeners isn't new but having an electronic sensor in the resin bed is unique to Culligan and can save about $80 in salt over the life of the unit compared with other softeners that use traditional regeneration. A wireless control pad is available for a monthly charge of $25-$35 that allows the consumer to keep track of daily water usage and generation rates.

There are several water softener manufacturers, HydroNovation and Rainsoft, that are developing water softeners that don't rely on salt for regeneration but use deionization technology instead. The advantage to using the deionization technology is not only does is it a salt-free softener, it will perform well even if water quality changes and you don't have to worry about replacing your water softening system when the water composition changes or if and when the laws against traditional water softeners that utilize salt become more restrictive. As of the writing of the article, a price had not been set on either device. These devices will need service to change the filter in the HydroNovation product, estimated at $17 and the Rainsoft will require a service call from a local dealer every year to do a descaling rinse at a cost of $50-$75.

28. Inland Empire Utilities Agency, Salinity Characterization Study for the Carbon Canyon Water Recycling Facility, October 2006.

This study conducted in 2004 was initiated to identify the sources of salinity entering the Carbon Canyon Water Recycling facility (CCWRF) owned and operated by the Inland Empire Utilities Agency (IEUA). The study had a specific focus on the contribution of salts from the residential use of self-regenerating water softeners. The results of this study were utilized to implement a pilot program for the replacement of existing older and less efficient self-regenerating water softeners used by residential customers in 2007. When raw water is treated to create potable water supplies, the treatment process adds an average of 50 mg/L. The potable water is then used for residential, industrial, and commercial activities, which adds an additional 200 – 400 mg/L from household activities including self-regenerating water softeners, and commercial and industrial discharges. The wastewater treatment process then adds another 50 – 65 mg/L of TDS. Depending on the combined market penetration and model efficiency, self-regenerating water softeners contribute an average TDS of 30-120 mg/L. A national study of six wastewater agencies and their service areas, completed by AwwaRF (2006), found that between 7% and 31% of the serviced households used water softeners and that 33%-66% were self-regenerating models. Results from the IEUA study found that approximately 11% of the households within the IEUA service area used water softeners and approximately 9% use the self-regenerating type. The study found that approximately 157 mg/l or 32% of the overall TDS concentration in the CCWRF recycled water was due to residential indoor water use and 25 mg/l or 5% was from the use of self-generating water softeners. The industrial sector was the smallest source of contribution , contributing 8 mg/l or 2% of the overall TDS concentration. However, it should be noted that a large portion of the industries within IEUA with discharges in excess of 550 mg/l TDS connect to the Santa Ana River Interceptor Brine Line to keep the high TDS sources out of the regional water system. During 2006-2007 IEUA implemented a pilot water softener salinity reduction rebate and public education program to test the efficacy of reducing TDS in wastewater discharges. A key finding was that owners of self-regenerating water softeners were unwilling to remove their units regardless of the salt impacts on recycled water and other issues. However, they were willing to take steps to reduce the salt released by their water softeners.

29. Insights & Solutions, Inc, Survey of Water Softener Penetration into the Residential Market in the Phoenix Metropolitan Area. U.S. Bureau of Reclamation, 2004.

The central Arizona Salinity Study identified and quantified the sources of salt entering the wastewater treatment plants in the Phoenix Metropolitan Area specifically from water softeners. 2,453 households were screened that included 1,392 households in established areas of Phoenix, Mesa, Tempe, Glendale and Scottsdale and 1,061 households in new areas of north Scottsdale, south Phoenix, Glendale and east Mesa. The survey concluded that residents are equally concerned about water quality and water availability and less concerned about costs. Residents in established areas were more concerned about water quality but less concerned about availability than those in the growth areas. Opinions on water quality were not measurably different between those owning water softeners than those that don’t. Eight out of the ten households interviewed state that they utilize water softeners primarily to reduce water hardness and not to remove contaminants. Twenty five percent of all homes surveyed had a water softener and water softener penetration was much higher in the new growth area where four in ten had water softners. Reverse Osmosis systems followed the same pattern. It was also found that water softener and RO system ownership significantly increased with income and newer homes tended to come equipped with water softeners. About one third of those with water softeners have someone else maintain them and most households add approximately 40 lbs of salt per month in the form of sodium chloride

(1.63 to 1) compared to potassium chloride.

30. **International Bottled Water Association, (2012). U.S. Consumption of Bottled Water shows significant Growth increasing 4.1 percent in 2011, May 2012.**

A summary of the study conducted by the International Bottled Water Association in conjunction with Beverage marketing that found that the use of bottled water had increased by 4.1 percent since 2010. 9.1 billion gallons of bottled water was consumed in 2011 as compared to 8.75 billion gallons in 2010. It is estimated that every person in America consumed an average of 29.2 gallons of bottled water in 2011.

31. **Irrigation Training and Research Center (ITRC). 2003. Crop and soil evapotranspiration for water balanaces and irrigation scheduling/design. ITRC, San Luis Obispo, CA. http://www.itrc.org/reports/pdf/californiacrop.pdf**

32. **Kopec, David M., Ph.D., Managing Turf with Effluent Water, Undated.**

This paper presents how to establish good soil drainage and how to calculate the amount of salt in both the effluent water and the soil to determine the leaching fraction needed to prevent soil salt buildup. This paper also discusses the nutrient levels, pH and other parameters to consider when using primary, secondary and tertiary treated water.

33. **Letey, J. , G.J. Hoffman, J.W. Hopmans, S.R. Grattan, D. Suarez, D.L. Corwin, J.D. Oster, L. Wu, C. Amrhein, Evaluation of soil salinity leaching requirement guidelines. Agricultural Water Management 98 (2011) 502–506.**

The scientific literature documents a number of recent, important changes in the manner in which leaching requirements can, and in some cases should be determined. Innovations and updates cover a range of methodology. Some pertain to new knowledge about how plants respond to salinity. For example, the notion of a fixed 40-30-20-10 proportion of uptake in four root-zone intervals of equal thickness was always understood as a simplification. However, it also turns out to be systematically conservative relative to salt impact on plants. This is because, when water at deep layers of the root zone becomes saline (relative to a plant's sensitivity), most plants will increase the proportion of water taken up from shallower layers, if water is made available near to the surface by irrigating. The actual vertical distribution of uptake and impact under these conditions is more exponential than linear, greatly reducing the influence of root zone salinity on the plant. Another update entails better characterization of temporal fluctuations in root-zone conditions (for example, between irrigation events), and of spatial distribution of salinity (for example, in response to drip as opposed to surface irrigation). Once characterized, this richer picture allows for modeling that takes account of real field conditions more completely. These models often pick up times and places where salinity does affect plants, without overly generalizing the breadth of impacts. Older methods of setting target salinity levels and leaching requirements, while outmoded in the literature, remain in widespread use. Conservatism can be appropriate in the sense that a margin of safety, when needed, is useful. However, systematically conservative management beyond these legitimate margins presents opportunities to conserve water and/or to better cope with delivered salt.

34. **Metcalf & Eddy, The Economic Value of Water Quality, Research and Development, Report No. 779. U.S. Department of Interior, Office of Saline Water, January 1972. In paperback form.**

This study developed correlations between water quality and costs for both residential and

commercial and industrial customers. Research found that the primary water quality parameters that affect residential user costs are TDS, hardness and chloride ion concentration . These affect residential user costs by: TDS affects bottled water purchases; soap and detergent costs and the cost of softening are functions of hardness in the water; and high chloride content and the corrosivity affects the frequency of water heater replacement. The other factor affecting residential costs are the family size. No significant correlations between residential costs and water quality were found for damage to clothing, dishes, glassware, lawns and plants;, plumbing repair or replacement. The costs primarily affecting commercial and industrial users were directly related to softening costs versus hardness, internal chemical treatment, ion exchange and process costs such as filtration required due to hardness. The relationships and equations developed for this study may be of some use in the Conservation Potential of Salinity Mitigation Strategies Study and will be revisited as we move through the next tasks. However, the costs presented in this study are outdated and will need to be revised.

35. **Metropolitan Water District MWD, Association of Groundwater Agencies AGWA, Southern California Alliance of Publicly Owned Treatment Works SCAP. (January 1999).** ***Salinity Summit.*** **Pomona, California: Metropolitan Water District MWD.**

MWD committed to a long-term policy of an average annual TDS of 500 mg/L. Achieved by a number of actions that fall into four broad categories: imported water source control, distribution system salinity management actions, collaboration with other agencies, and local salinity management actions.

36. **Miehls, Alea , James H. Baird, Donald L. Suarez, Catherine Grieve, and David Crowley, Irrigation Requirements for Salinity Management on Ryegrass Turf, University of California, Riverside, U.S. Salinity Laboratory USDA-ARS, Riverside, 2011.**

Use of saline irrigation water is inevitable in the arid southwestern US. In this study, the authors combined the line-source method of generating a continuous distribution of saline (4.6 deciSiemens/meter [dS/m]) and potable irrigation water with different quantities of water at 140, 120, 100, and 80% reference evapotranspiration (ETo). Preliminary results of this study indicate that turf grass can be irrigated with high-salinity recycled water, provided it is managed properly. Thus far, it appears that irrigation replacement of 100% < ETo < 140% is needed to maintain color and quality of perennial ryegrass during the summer months in an inland Mediterranean climate list Riverside, CA. Irrigation at higher regimes resulted in waterlogged conditions that adversely impacted turf stand density and ability to mow or walk the area.

37. **Miehls et al. 2012. Leaching Requirements for Turfgrass Salinity Management and Water Conservation.**

Turf grass plays an important role in the landscape and in the lives of Californians. However, turf grass demands a significant amount of water, especially cool-season species like tall fescue and perennial ryegrass. Water conservation on landscapes, including turf grass, is a must in California and in other arid regions of the country. The preliminary results of this study substantiate the use of recycled water on turf grass (for conservation of potable water), provided that salinity management practices are implemented (adequate drainage, appropriate species, proper cultural practices, and adequate leaching).

38. **Milliken, G. J., Lohman, L. C., & Dorn, W. S. (February 1988).** ***Estimating Economic Impacts of Salinity of the Colorado River.*** **Milliken Chapman Research Group. Littleton, Colorado: U. S. Department of Interior, Bureau of Reclamation.**

This report was performed by the Milliken Chapman Research Group for the USBR. The purpose of the report was to update previous studies on the economic damages from salinity in the Colorado River, to develop a computer model to estimate current and future damages and to determine areas of damage that had not been included in earlier work. The authors of this study noted the following limitations placed on their research:

A. only direct damages were to be considered;
B. only damages within U.S. borders were to be considered;
C. damages could not be separated as to ion composition or other constituents of the water; and
D. a basin-wide perspective was to be maintained.

In addition to these limitations, the authors noted that time and budgetary constraints further impacted their work. Two baseline TDS levels were used, 334 mg/L, the Colorado River's natural TDS level and 500 mg/L, the EPA secondary drinking water standard.

Damages to agriculture were limited to reduction in yield, although the authors acknowledged that other additional costs to agriculture may be incurred due to increased salinity. Damages to households were based on useful life data from previous studies. Regression analysis was used to develop formulas and curves over the study TDS range. Business and commercial uses, but not industrial uses, were included in these damage estimates. Damages to water/wastewater utilities were based on useful life and replacement costs. Damages to utilities from government regulation were calculated based on costs incurred by utilities to meet these requirements. Both capital and O&M costs were estimated. The authors found that insufficient data were available, but used water quality criteria data from previous studies to estimate damages to industrial water users.

The authors note that the quality of the inputs in their work are better than in previous studies, but note that over time, better data would likely be available. Additional research performed since this work was done and improvements made to the model will be beneficial to the work being done by the URS team.

39. Mitra, Sowmya, Managing salts in soil and irrigation water, Golf Course Management, January 2001.

Golf course superintendents should develop an integrated salt management program including the following strategies: using or adding a soluble source of calcium in the soil, increasing soil aggregation to improve aeration and infiltration, leaching excess salts and displaced sodium, applying foliar nutrients to replenish leaching-out nutrients.

40. Miyamoto, S., et al. , Improving Permeability and Salt Leaching in Irrigated Sports Fields: Exploratory Testing, Texas AgriLife Agricultural Research and Extension Center at El Paso, February, 2008.

This study focused on evaluating various mechanical means of improving soil permeability for enhancing salt leaching. The most significant reduction in soil salinity was found when stratified silty clay was either inverted to the new profile sequence of loamy sand over the fractured silty clay clods or mixed with the loamy sand layer below. Replacement of clays with sandy soils in a corrugated surface to permit lateral drainage also was highly effective in salt leaching in deep clay. The primary goal of soil improvement activities is to improve soil permeability, water movement, and salt leaching, and it must be accompanied by appropriate turf management. In addition, there's a need to examine existing codes and specifications for construction of new fields for improved salt leaching.

41. National Water Research Institute, Salinity Management Study Update Workshop. Fountain Valley, California,: Southern California Salinity Coalition, March, 2013.

This documentation was drawn from the Southern California Salinity Coalition Workshop to gain insight into challenges and potential solutions. This was undertaken as part of the "Salinity Management Study Update" which has four key objectives. For our work, Objective 2: Update Economic Impact Model" is relevant. The key recommendations of the workshop related to the economic models were the following:

- Consider the leaching fraction costs (using more water) and the value of farms lost.
- Consider the scaling impact of dishwashers.
- Evaluate the crop yield impact functions.
- Provide an economic analysis for recycled water; surveys may indicate that the public will support non-potable water supplies due to increased potable water supply costs.

It is not clear from this document what has been accomplished thus far. The project team will consider these recommendations to the extent possible within the scope of our work.

Based on a workshop survey, the top strategies to manage salinity include blending and source control. Brine lines and wastewater effluent ocean outfalls were identified as key components of source control and the lack of brine lines was seen as major challenge to brine disposal. It was noted that even though certain strategies in the 1999 Salinity Management Study has been successful (like source control of imported supplies) salinity is slowly beginning to increase in Southern California.

Key actions for next steps to address salinity management include expanding the salinity impact considerations in the BOR Salinity Economic Impact Model update. Specifically, consider the leaching fraction cost (using more water) and the value of farms lost; consider the scaling impact of dishwashers; evaluate crop yield impact functions; and provide an economic analysis for recycled water.

This study stipulates that a 10 to 20 percent leaching fraction is generally used for avocado irrigation and leaching is expensive. On 100 acres, farmers spend $84k extra per year to leach

42. Prairie, James R., US Department of the Interior, Bureau of Reclamation, Presentation on the Economic Benefits of the Salinity Control Program, April 2, 2009.

This is a presentation on the benefits of the salinity control program. It shows the water quality in terms of TDS for 2008, 2011 and projects 2030 at Hoover Dam, Parker Dam and Imperial Dam and the corresponding economic damages based on the TDS levels. This presentation shows that the economic damages from salinity are decreasing due to the implementation of the salinity control program.

43. Public Policy Institute of California, Lawns and Water Demand in California. Volume 2, Number 2, July 2006.

44. Qian, Yaling, Salt Tolerance Should Be Considered when Choosing Kentucky Bluegrass, Turfgrass Trends, June, 2003.

This paper focuses on seed germination, temperature, and stress, rather than irrigation practices. Salt tolerance needs to be considered when choosing Kentucky Bluegrass. Many cultivars of Kentucky bluegrass are relatively salt tolerant and should be carefully selected for saline sites. Salinity affects the temperature window for seed germination (as salinity rises the temperature window decreases).

45. Ragan, Guy E. Carole Makela, Robert Young, *Improved Estimates of Economic Damages from Residential Use of Mineralized Water.* Fort Collins: U.S. Geologic Survey USGS DOl, Colorado State University, (August *1993).*

This study analyzed the economic damages from using high TDS water on household appliances utilizing data from random mail surveys obtained from the Arkansas River Basin in Southeastern Colorado. The purpose of this study was to develop improved techniques for measuring the damages to households from salinity in residential water supplies and test the techniques on a significant case study region in the Arkansas River Basin in Southeastern Colorado where TDS ranges from 200 mg/l to 3500 mg/l. It also summarizes and critiques information from previous studies on this topic and how findings differ and why. This study is not relevant to the NWRI Salinity Mitigations Study as it does not discuss the water savings nor economic savings realized specifically on water softeners nor landscape irrigation from lowering the salinity.

46. Rhoades, J.D., S.M. Lesch, R.D. LeMert, and W.J. Alves, Assessment of Salinity and Irrigation/Drainage Practices, undated, Retrieved from USDA Agricultural Research Service:www.ars.usda.gov/Research/docs.htm?docid=10323

The achievement of efficient irrigation and effective salinity control requires periodic information of soil salinity levels and distributions within the crop root zones and fields of irrigated lands. This allows an inventory of soil salinity conditions, an assessment of the adequacy of leaching and drainage, and provides a guide to management practices. Monitoring soil salinity is complicated by its spatially variability of edaphic factors (soil permeability, water table depth, salinity of perched groundwater, topography, soil parent material, and geohydrology), management induced processes (irrigation, drainage, tillage, cropping practices), and climate-related factors (rainfall, temp, humidity, and wind). A rapid field-measurement is needed that accounts for spatial variability in these factors, is systematic, and is capable of proving changes or differences in an area's salinity over time. Two systems are described: the Mobile Four-Electrode Sensing System and Mobile Electromagnetic Sensing System. The technology packages described in this poster paper represent a major breakthrough in our ability to rapidly and accurately assess soil salinity in irrigated lands. Results indicate that much of the apparent chaos in the spatial pattern of soil salinity in irrigated lands is man-induced and can be explained in terms of deterministic processes caused by management practices (irrigation, drainage, cultivation, and tillage).

47. Santa Clara Valley Water District, Water Softener Pilot Program Proposition 13 Urban Water Conservation Program Grant Proposal, 2002.

Grant application for $60,000 to the California Department of Water Resources under the Proposition 13 Urban Water Conservation Program. Santa Clara Valley Water District (SCVWD) proposes to study the outreach program and incentives necessary to encourage existing water softener users to either replace their older water softener devices for newer and more efficient water softener technology, remove their existing water softener for a non-regenerating water filter or replace their older water softener with one using centralized off-site regeneration. This study also proposed to provide outreach to distributors of water softening technology on rebates available serve as an educational tool to inform existing water softener users of the effects water softeners have on water quality. The primary benefits of this program are to include: replacement of old water softeners resulting in a reduction in water demand, reduce TDS, detergents and other cleaning compounds introduced into the wastewater treatment system. A summary report will be prepared that quantifies water savings, wastewater volume savings and wastewater reduction in TDS.

48. Santa Clara County Residential Water Use Baseline Survey, Final Report, August 2004

This study surveyed single and multi-family residences in Santa Clara County to determine the distributions of water-using appliances, fixtures and landscapes in the residential sector. The study also assessed Santa Clara County residential customer knowledge and attitudes about water use and conservation. While this study focused on all indoor and outdoor fixtures and appliances, for the purposes of the NWRI Conservation Potential Study, we will focus only on the finding of the water softener and home water treatment aspects of the study. Utilizing both telephone and on-site surveys, this study found that 17% of Single-Family households and 3% of multi-family households had water softeners installed.

49. Santa Clara Valley Water District Pilot Water Softener Rebate Program, Final Report prepared for California Department of Water Resources, May 2006.

This report is a follow up to the Grant proposal previously discussed. The purpose of this program was to test the effectiveness of utilizing financial incentives through rebates to promote the replacement of timer based water softeners with more efficient models such as the Demand Initiated Regeneration (DIR) or no-salt filters. This rebate program resulted in the replacement of 400 water softeners at $150 per household. The water savings realized were estimated at 1.3 million gallons per year and the salinity reduction was estimated at approximately 240,000 pounds. The average savings for wastewater treatment due to the reduction in water use was estimated at $400/A-F but did not include the savings realized from the reduction in salinity in the wastewater. The customers savings included a reduction in water use and salt use which resulted in an annual savings of approximately $84 per year per customer. A benefit-cost(B/C) analysis was performed for both the participants and the SCVWD. The b/c ratio for participants was calculated to be 2.08 indicating that this program was very beneficial for participants. The b/c ratio for SCVWD was 0.45 indicating that this program was not beneficial for SCVWD. However, there were a number of quantifiable and non-quantifiable benefits excluded from the b/c calculations; the two quantifiable calculations that were excluded included the reduction in wastewater treatment costs due to the reduction in water use as well as the overall reduction of TDS, sodium and chloride concentrations in the recycled water. The other benefits that were excluded included the reduction of demand for imported water, and reduction of TDS, detergents and other cleaning compounds discharged to the sewer.

The information from this study will be beneficial in the identification and implementation of potential cost effective water saving approaches.

50. Santa Clara Valley Water District, Commercial, Institutional, and Industrial (CII) Water Use and Conservation Baseline Study, Final Report, February 2008.

The primary purpose of this study was to better understand what the water uses within the District to assist in targeting water efficiency program efforts. Through this study, the District sought to determine the prevalent types of water-using fixtures and appliances and characterize water using behaviors of selected nonresidential customer groups. The information contained in this report in terms of relevance for the NWRI Salinity Mitigation Study, was not pertinent. The most relevant information was that forth three percent of all the establishments within the SCVWD service area reported using some type of water purification equipment with the highest numbers in hospitals, nursing care facilities and semiconductor manufacturing facilities. The most common types of water purification equipment reported were water softeners (24 percent) water filters (20 percent) and deionization/on exchange units (11 percent).

51. **Shalhevet, Joseph, Institute of Soils, Water and Environmental Sciences, The Volcani Center, Bet-Dagan, Israel, Salinity and Water Management in Avocado, Undated.**

Avocado is the most salt-sensitive crop among fruit trees, yet its response to water shortage is mild and it exhibits great variability in results. The class A pan factor (Kp) ranges from 0.42 in June to 0.61 in October. Avocados absorb most "consumptive use" (CU) water from shallow depths (60 cm). For heavy textured soils, this can be 95% of CU, and for medium textured soils 80%. The most prevalent irrigation method is drip or micro sprinkler, which results in only part of the soil volume being wetted.

52. **Shubnum, Tariq Khalidi, Technical Memorandum Salinity Management Study, Phase 1, Task 1, Item 1, Literature Search for Impacts of Salinity on Household Appliances, Review of 1999 Salinity Study and Literature Cited, Draft, February 20, 2013.**

This memorandum was completed by Tariq Khalidi, Shubnum for USBR. The purpose of this work was to give an overview of past literature on water-using household appliances and studies related to economic damages related to salinity. The author notes that few studies have paralleled the work of three of the studies discussed above, *Estimating Economic Impacts of Salinity of the Colorado River*, *Salinity Management Study Final Report* and *The Economic Impacts of Central Valley Salinity*. The author also notes that regression relationships from 1972-74 research are still in use for water-using household appliances. The author reviewed a vast amount of literature and discussed the findings of these works by sector, i.e., commercial/institutional, agricultural, etc. The author offers no opinion, conclusions or recommendations.

This work will be helpful in locating additional source data, if required, going forward in the Conservation Potential of Salinity Mitigations Study.

53. **Sister, C., J. Wolch, J. Wilson, A. Linder, M. Seymour, J. Byrne, and J. Swift. 2007. The Green Visions Plan for 21st Century Southern California. 14. Park and Open Space Resources in the Green Visions Plan Area, University of Southern California GIS Research Laboratory and Center for Sustainable Cities, Los Angeles, California.**

54. **Specialists in Business Information SBI. (2005). *The US. Market for Residential Water Treatment Products.* 268. New York: Kalorama Information, LLC.**

Unable to locate. Referenced in Technical Memorandum on Salinity Management Study Phase I, Task 1, Item 1, Literature Search for Impacts of Salinity on Household Appliances, Review of 1999 Salinity Study and Literature Cited, Draft, February 20, 2013 by Tariq Khalidi Shubnum.

55. **Tanji K., Stephen Grattan, Catherine Grieve, Ali Harivandi, Larry Rollins, David Shaw, Bahman Sheikh, and Lin Wu. 2005. Salt Management Guide for landscape Irrigation with Recycled Water.**

This paper summarizes a case study by Shaw (1995) on the composition of drainage from the root zone from plots of turf grass irrigated with potable and recycled waters. Turf grasses included cool season and warm season grasses. Irrigation was scheduled according to the water budget method and with real-time local weather data. The case study demonstrated that recycled water can be beneficially used to irrigate established turf grasses, thus conserving potable water. Shaw noted the reliability of recycled water quality is key - any changes in quality need to be considered in management. Maintaining a salt balance in the root zone is critical for plant performance in semi-arid climates with insufficient rainfall for leaching salts from the root zone. In surface-irrigated soils with unimpeded drainage, salts leach from the upper root zone and accumulate in the lower root zone. Fortunately, most landscape plants are more densely rooted at and near the surface of the soil, where the soil tends to be least saline. Plants extract soil water from the deeper root zone only when the soil water that is available at and near the surface becomes limited. The extent to which salts accumulate in the lower root zone is regulated by the leaching fraction. A leaching fraction of 0.15 to 0.2 is usually adequate to maintain a salt balance for most agricultural crops, and should be applicable to landscape plants with a similar range of salt tolerances.

Using the FAO approach (Ayers and Westcot 1985) of computing the accumulation of salts in quartile root zones, the principles and applications of steady-state LF were addressed by considering the pattern in which roots extract water, as well as the irrigation water's LF and EC. The EC of the drainage water past the root zone may be estimated from the ratio of the EC of the irrigation water to the LF. Computations can be facilitated in an Excel model that is based on the assumption that salts are a conservative parameter (not chemically reactive). This model is an appendix to the paper. Also considered were the impacts of rainfall, mixed water qualities, and reclamation leaching. This model is also an appendix to the paper.

The assessment and management of irrigation are much more established for agricultural irrigation than for landscape irrigation, with the exception of turf. Based on the literature review conducted in this paper, the primary difference between agriculture and landscape irrigation is that agricultural irrigation is aimed at maximizing yield, whereas landscape irrigation is based on maintaining the aesthetic quality and appearance of the landscape. The authors recommended the Water Quality Guidelines of Ayers and Westcot (1985). These Guidelines include a matrix of irrigation-related problems (salinity, infiltration, ion toxicity, etc.) and degrees of restriction on use (ranging from none to severe). These guidelines were applied to four representative compositions of recycled waters. All compositions tended to rank in the "slight to moderate restriction on use" category, with some exceptions related to RSC and boron. The authors conclude that the guidelines tend to be on the conservative side.

The amount of deep percolation in landscape irrigation may vary widely. Intensively irrigated turf and lawns with shallow rooting systems may have an leaching fraction (LF) that ranges from 0.4 to 0.6. Less intensively irrigated landscapes covered by deep-root trees and shrubs may have an LF ranging from 0.1 to 0.4. When recycled water is used instead of potable water to irrigate a landscape, the LFs are expected to be about the same or slightly higher.

This document is a comprehensive review of the scientific literature regarding the factors that affect use of recycled water for irrigating landscapes in California south coastal region. Of the current 533,000 acre-feet (AF) of recycled waters used in California, about 21% is used to irrigate landscapes, mostly turf grasses in golf courses and lawns. Some landscape professionals are reluctant to use recycled water out of concerns that the water may be excessively saline and harmful to landscape plants. Most recycled waters have 140 to 400 mg/L TDS more salt than potable sources.

An irrigation system's major function is to provide water to plants in a manner suitable for fostering their growth and performance. The system should meet the landscape's peak demands, leaching requirements, and other needs, such as control of frost. Sprinkler irrigation is the most common method of irrigating with recycled water (it's less maintenance and is less vulnerable to damage than drip). Operating the irrigation requires determining the water budget and schedule. One popular method, the Water Use

Classification of Landscape Species (WUCOLS) introduces a landscape coefficient adjusted to account for landscape species, plant density, and microclimate. This method is popular, but needs extensive application and testing to become more reliable.

Uniform distribution of applied water is extremely important for root zone salinity management in golf and sports turf. Achieving a uniform application will maintain a uniform wetting front when one is leaching salts through the soil profile and prevents excessively wet or dry areas. Drip irrigation results in a different pattern of salt distribution. The wetted zone of drip-irrigated soils is somewhat ellipsoidal in shape, with salts tending to accumulate in the outer edges of the wetted perimeter. After pro-longed drip irrigation, salts may accumulate between drip emitters to detrimental levels (and need to be leached).

Recommendations for growing ornamental plants with moderately saline water include: water more heavily and less often, keep the soil as moist as possible without retarding growth, use soil with considerable organic matter, select appropriate varieties, apply slow release fertilizers, confirm suspected salt-related injury before beginning to correct it, judge the suitable of water for irrigation by considering salinity, irrigation method, and soil.

56. **State of California, Department of Water Resources, Water Quality in the State Water Project *2004-2005*, April 2009.**

This report presents the assessment of the water quality of the State Project Water for the suitability as a source of drinking water for 2004 and 2005. The water quality parameters assessed included major minerals, minor elements, organic chemicals and nutrients and relative quality comparisons were made to the existing drinking water standards. This is a good resource for understanding the monitoring locations and where salinity is contributed into the State Project water.

57. **Tihansky, D.P., *Economic Damages to Household Items from Water Supply Use in the United States.* Washington D.C.: U.S. Environmental Protection Agency, Economic Analysis Branch, 1970.**

This study translates the physical damages that household appliances and personal items incur when they come in contact with water, into economic losses for a typical household. These losses were estimated at the national and individual State level. For California, it was estimated that the damages are on the order of $230 million. The most significant water quality parameters affecting household expenditures include hardness, total dissolved solids, chlorides, sulfates and acidity. The economic impacts of water supply use on household items were measured in terms of increase in investment and operating costs. Damage functions were developed to estimate the impact of water quality on the service life and operating levels of twenty household items. The household items most vulnerable to deteriorating effects of water quality parameters included piping, water heaters and other appliances, washable fabrics, water utility systems, and soap purchases. This study estimates that the life span of a water softener is approximately 12 years and its original cost and operation and maintenance cost per year is $2.1^{-1}W$ and $1.1^{-4}W^2$ respectively where W is the water quality variable in units of hardness. This study is not directly relevant to the NWRI Salinity Mitigations Study. While it provides the economic impact of higher salinity water on household appliances, it does not provide the water savings that could result from lower salinity water, specifically on large landscape irrigation and commercial, industrial and home water treatment devices.

58. **US Bureau of Reclamation, Effects of Salinity in Central Arizona, 2003 .**

Leaching salts from the root zone and the "wasting" of water used in this process may also be considered

an impact to agriculture in the region. Approximately 10 to 20 percent of agricultural water usage must be allocated to leaching salt out of the root zone. As water becomes more expensive and more difficult to deliver to municipal users, the use of water to flush salts may be perceived as wasteful. These topics are discussed in Chapter 4, Economic Assessment Model, and in Appendix J of this Report (Dickey: not procured or reviewed).

59. **US Bureau of Reclamation, Quality of Water in the Colorado River Basin, Progress Report No. 22, 2005**

This is a biennial report prepared by Reclamation in cooperation with the State water resource agencies and other Federal agencies involved in the Colorado River Basin Salinity Control Program. This estimates that as of 2004, the damage to salinity in the US and Mexico are estimated at approximately $306 million. By the year 2025, 1.8 million tons of salt will need to be removed in order to meet the water quality standards in the Lower Basin below Lees Ferry, AZ. This report shows that approximately 1.1 million tons of salt is being removed and it will be necessary to fund and implement additional programs to remove the additional 7.3 million tons annually by 2025. It is estimated that the damages due to salinity will be approximately $471 million by 2025. These damages are primarily due to reduced agricultural crop yields, corrosion and plugging of pipes and water fixtures. This report provides an in-depth discussion of the Colorado River Simulation System (CRSS) model that was developed to simulate long-term salinity conditions given future develop ent of water, with and without various levels of salinity control.

60. **US Census, 2009-2013 American Community Survey.**

61. **USDA. 1969. Salt Tolerance Criteria.**

The USDA Handbook 60 includes salt tolerance lists, arranged by major crop division. (Dickey: excellent reference, but expanded and updated information exists on salt tolerance)

62. **Wu, Lin and Linda Dodge. Undated. Landscape Plant Salt Tolerance Selection Guide for Recycled Water Irrigation.**

Extensive list of landscape species' levels of sensitivity to salt spray and soil salinity.

63. **Yenny. 1994. Salinity Management.**

Irrigation scheduling should always be managed to minimize runoff. Typically, multiple 30-minute cycles are more effective than a single irrigation cycle of one or two hours. Soil samples should be taken a minimum of twice a year.