

Central Arizona Salinity Study

Phase II – Salinity Control in Waste Water Treatment Plants

September 2006

The Study Partners: City of Glendale, City of Mesa, City of Phoenix, City of Scottsdale, City of Tempe, Arizona-American Water Company, City of Chandler, City of Goodyear, City of Peoria, City of Surprise, City of Tucson, Town of Buckeye, Town of Gilbert, Queen Creek Water Company, Brown and Caldwell and the Bureau of Reclamation

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Appendix A: Cave Creek Water Reclamation Plant Study

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Executive Summary

Increasing salinity concentration in the effluent at wastewater treatment plants (WWTPs) is often not considered an urgent problem in comparison with other WWTP issues, such as sewer capacity and meeting discharge limits. Yet as water resources become more limited and reclaimed water gains acceptance as source water for reuse applications, increasing total dissolved solids (TDS) will have to be addressed due to the implications that high TDS can have with end uses. For example, many golf courses in the Phoenix metropolitan area use treated effluent for irrigation water and TDS in this water can often reach levels of 1,000 milligrams per liter (mg/L). High TDS, especially high sodium, is known to hinder the growth of plants because it limits the plants ability to extract water from the soil. Without the ability to take water from the soil, plants show symptoms of dehydration and require more water to flush the root zones of excessive levels of salinity.

It is anticipated that WWTPs will continue to see increasing salinity concentrations in the future because of high TDS source waters, increased residential and commercial water softener usage, and increased quantities of concentrated blowdown water from cooling towers. Of particular concern is the rising salinity level of the inflow to the WWTPs due to the discharge of brine concentrate from advanced membrane treatment processes. The sewer is currently the most common mechanism for concentrate disposal for inland areas.

The Central Arizona Salinity Study (CASS) has identified several options for controlling salinity at the WWTP, including desalination of effluent for certain reuse applications, point-source control, placing local water quality limits on influent into the sewer system, and/or enforcing best management practices in lieu of influent limits. Little data is available to define the impact of high TDS concentrations on WWTP processes; however, a recent study indicates that the nitrification process in WWTPs may be inhibited when TDS concentrations exceed 2,000 milligrams per liter (mg/L).

Currently, in Arizona there are no water quality regulations governing TDS concentrations for disposal of wastewater into the sewer system. Therefore, there are no legal mechanisms available and/or enforceable to control rising salinity concentrations in the WWTPs.

1.0 Introduction

Wastewater treatment plants (WWTPs) are designed to accept and treat influent from a diverse array of sources, including industrial, commercial, and domestic wastes. The proportions, volume, and quality of each waste source are directly related to the ultimate performance of the treatment plant. Wastewater influent contains total dissolved solids (TDS), the most common ions are sodium and chloride. The potential adverse impacts of elevated TDS on WWTPs are currently the subject of intense study. TDS, also referred to as salinity, can impact the operation of the WWTP, limit reuse options, and/or result in violations of effluent discharge standards. It is, therefore, of utmost importance that the potential impacts of salinity on WWTPs in central Arizona be understood.

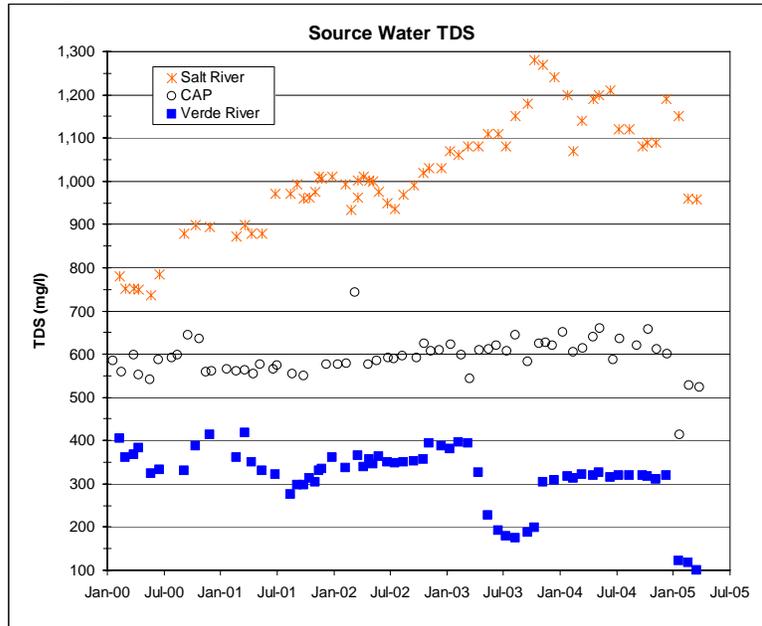
1.1 Background

The purpose of this Central Arizona Salinity Study (CASS) is to identify and recognize the impacts of increasing salinity on WWTP in central Arizona. The study consisted of characterizing the sources of high TDS, evaluating the impacts on WWTP processes and assessing the limitations for reuse of the treated effluent. Improved understanding of the potential impacts will enable planning on both a short- and long-term basis, to revise treatment strategies, make decisions to control (or not) sources of high TDS, and to develop financing strategies to pay for the added cost of TDS management.

1.1.1 Sources of Salinity

The Phoenix area has three primary sources of surface water: the Verde River, the Salt River, and Colorado River conveyed through the Central Arizona Project (CAP) aqueduct system. Each water source has variable TDS concentrations, as shown on Figure 1.1.1.1. The Verde River has the lowest TDS concentrations, averages under 400 milligrams per liter (mg/L). Colorado River water, also referred to as CAP water, 30 year average salinity concentration is 650 mg/L TDS but currently is about 600 mg/L TDS. TDS concentrations in the Salt River range, depending on if it is a wet year or a dry year, around 400 to 1,000 mg/L.

Figure 1.1.1.1 TDS Concentrations in Source Waters



Based on the above data collected by the Salt River Project (SRP), CAP water shows the least variability in TDS concentrations.

Data collected by SRP indicates an increasing trend of TDS from 1991 to the present on the Salt River, as shown in Figure 1.1.1.2 below. The historical data also revealed an inverse relationship between TDS concentration and water levels in the Salt River reservoirs, shown in Figure 1.1.1.3, suggesting that drought conditions exacerbate the TDS problem. Unfortunately, the same drought condition may occur at the same time in the Colorado River reservoirs, resulting in higher TDS concentrations in the waters delivered to the lower Colorado River basin states (Nevada, Arizona, and California).

Tucson currently has three primary sources of water supply: groundwater and CAP water for potable use, and reclaimed effluent for non-potable use. In general, the average TDS concentration of potable water sources used in Tucson is lower than in the Phoenix area due primarily to the Tucson groundwater supply, which has an average TDS concentration of 265 mg/L. However, over time, TDS concentrations in the Tucson groundwater will increase as more CAP water is imported.

Figure 1.1.1.2 TDS Concentrations in the Salt River Over Time

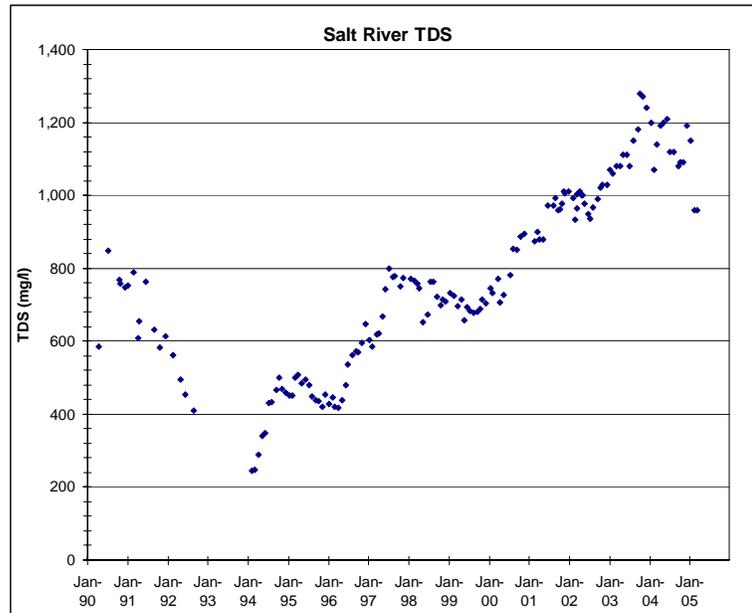
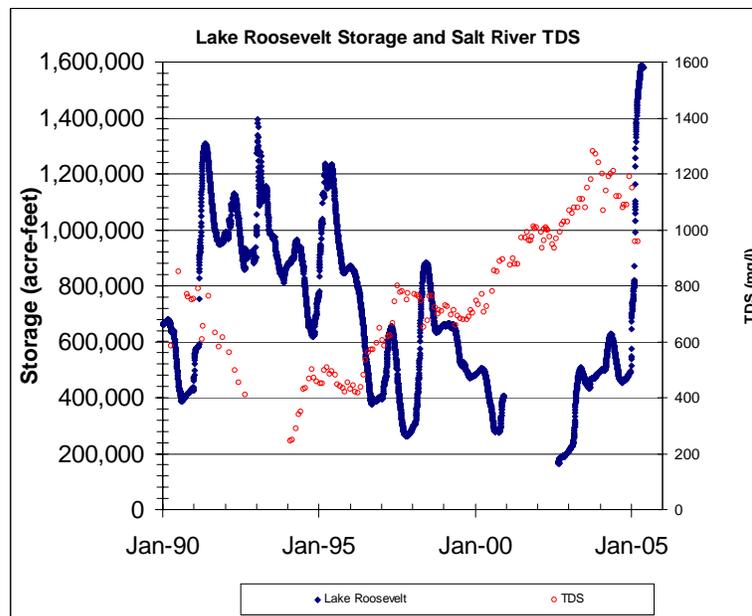


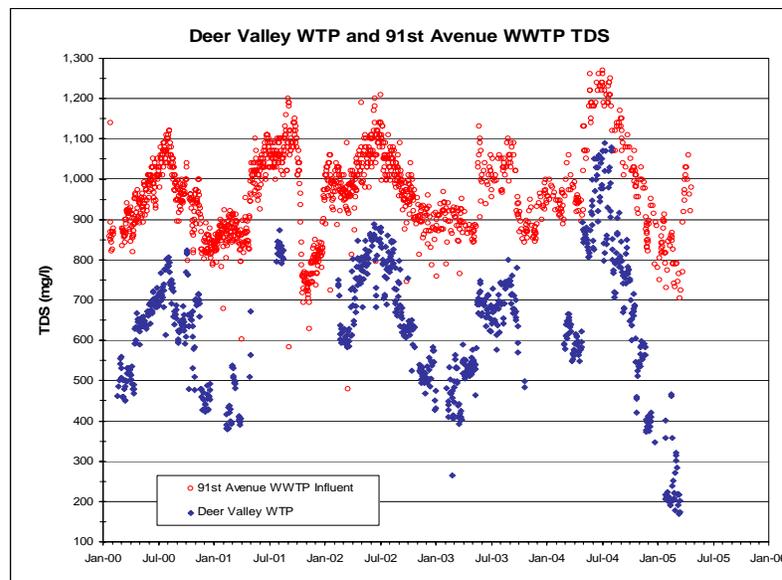
Figure 1.1.1.3 Comparison of TDS Concentrations in Lake Roosevelt Storage and the Salt River



While evaluating TDS concentrations in Phoenix source waters, it became apparent that there was a seasonal variation associated with which water supply was being used in greatest proportion. In the winter, when more Verde River water was being used, TDS concentrations in water entering the water treatment plants averaged between 400 and 500 mg/L, while in the summer, when more Salt River and CAP water was being used, the TDS concentrations increased to over 1,000 mg/L.

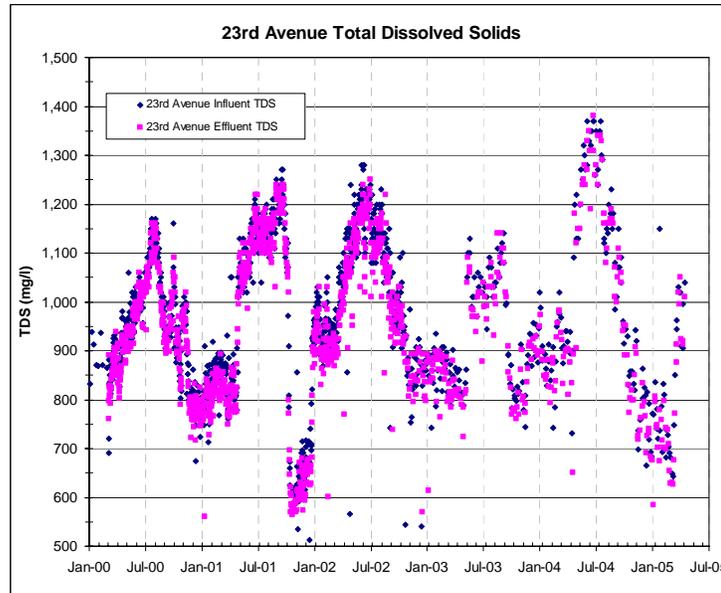
Figure 1.1.1.4 shows the seasonal variability of TDS concentrations and the relationship between TDS in the influent (from Deer Valley Water Treatment Plant) versus the effluent water (from the 91st Avenue WWTP). The difference in TDS concentrations seen between the water treatment plant and WWTP is due to the increased contribution of TDS from commercial, domestic, and industrial sources to the WWTP. The difference in TDS concentrations in the source water as compared to the effluent water varied seasonally also, for example, during the summer, the difference between source water TDS and wastewater TDS averaged 350 mg/L. In the winter, the TDS difference averaged 450 mg/L. This is primarily due to the increased winter discharges from the largest single TDS point source contributor, the Scottsdale Water Campus. In Tucson, a similar increase in average TDS of 250 to 350 mg/L from source water to wastewater is observed.

Figure 1.1.1.4 TDS Concentrations from Deer Valley Water Treatment Plant and 91st Avenue WWTP



Wastewater treatment plants do not treat for TDS. TDS is passed through the plant with essentially no reduction as evidenced by influent/effluent data from the 23rd Avenue WWTP (Figure 1.1.1.5).

Figure 1.1.1.5 TDS Concentration in 23rd Avenue WWTP

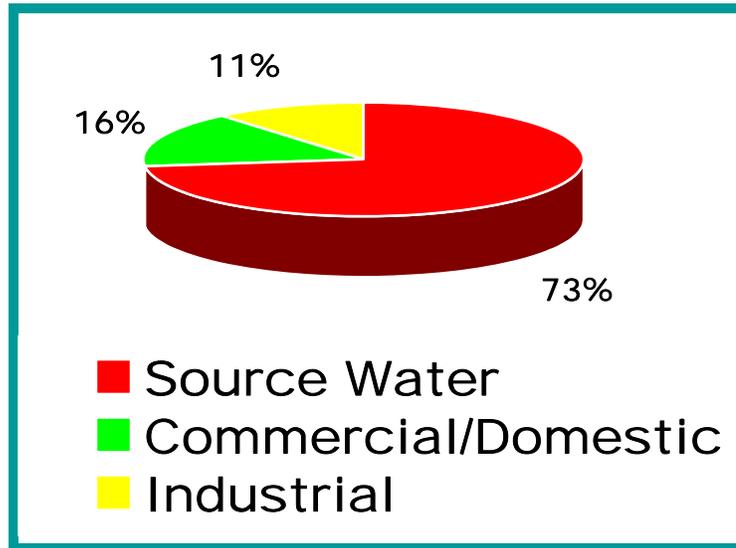


1.1.2 Wastewater Treatment Plants

Phoenix has two major WWTPs: the 23rd Avenue WWTP, with 60 million gallons per day (MGD) capacity, and the 91st Avenue WWTP, with a 179.25 MGD capacity. The City of Phoenix evaluated the TDS concentrations in the influent to the two major plants found that they were receiving (and passing through) approximately 1.83 million pounds of TDS per day. Of this total, approximately 73 percent could be attributed to the source water, 16 percent was from commercial/domestic sources, and 11 percent was from industry (Figure 1.1.2.1).

Tucson has two major WWTP: Roger Road WWTP (41 MGD capacity) and Ina Road Water Pollution Control Facility (25 MGD capacity; expanding to 37.5 MGD). Both plants are owned and operated by Pima County.

Figure 1.1.2.1 Contribution of TDS to Large WWTPs

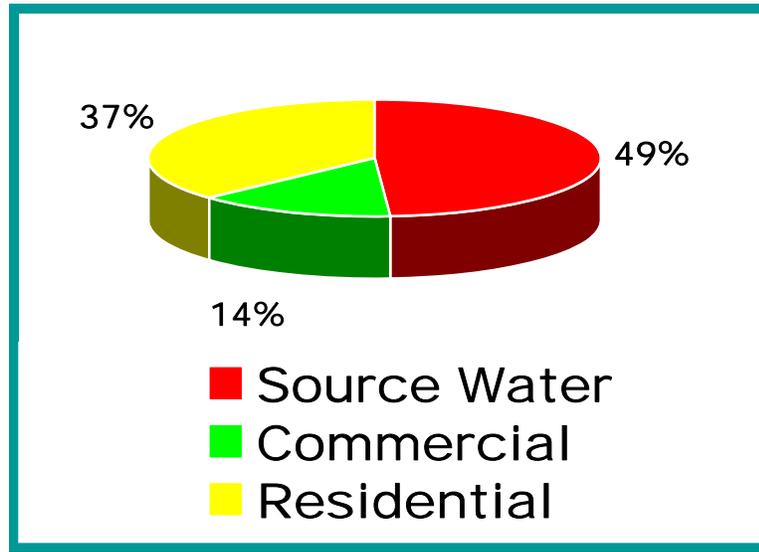


1.1.3 Water Reclamation Plants

Water reclamation plants are smaller WWTPs, typically 5 to 20 MGD capacity, located throughout central Arizona. These plants serve local needs, treating wastewater to produce effluent for reuse purposes such as irrigation, groundwater recharge, or industrial reuse. Most water reclamation plants do not have solids handling facilities, and residuals are returned to the sewer for treatment at larger WWTPs. Water reclamation plants are often located in the outlying, newer parts of town, where the more recently built homes are, and hence, the TDS load from these areas is generally higher because of the increased popularity of water softeners in new homes.

The combination of water reclamation plants having smaller volumes to dilute salinity and having more water softeners contributing to their TDS load, results in less buffering capacity than the larger WWTPs. Therefore, adverse impacts from higher TDS concentrations may become apparent sooner at the water reclamation plants, and may serve as a warning of the impacts of TDS at larger WWTPs. An example is the Cave Creek Water Reclamation Plant (CCWRP). Figure 1.1.3.1 shows the contributions of TDS to the CCWRP effluent. Note there are currently no industrial sources of influent to the CCWRP. The TDS load from residential/commercial sources represents 51 percent of the total; at the larger WWTPs, the residential/commercial load is only 16 percent of the total. That means that there is substantially more potential for impacts at the smaller water reclamation plants from commercial/domestic sources.

Figure 1.1.3.1 TDS Load to CCWRP



The Randolph Park Water Reclamation Facility is located in an older section of central Tucson and operates similarly to other water reclamation plants and WWTPs located in the greater Phoenix area. Effluent from the Randolph Park facility is used in Tucson Water’s Reclaimed Water System. In addition to the facilities discussed in this report, the greater Tucson community is served by eight smaller, satellite WWTPs.

2.0 Industry

Evaluation of data for CASS identified the industrial sector as a significant contributor of TDS to the WWTPs, particularly large water users, such as semi-conductor manufacturers and food processing industries that use highly purified water. These industries typically pre-treat potable water with membrane technologies such as reverse osmosis. While advances in membrane technology have produced more efficient, lower cost treatment systems that can remove a range of contaminants, the result is that they produce a large waste stream. Typically, 15 to 20 percent of the water supplied to the membrane is wasted. This waste stream, called concentrate or brine concentrate, is then discharged into the sewer systems, resulting in higher concentrations of TDS in the inflow to the WWTPs. The U.S. Bureau of Reclamation (Reclamation) estimated that 42 percent of brine produced by RO is discharged into sewers.

The City of Phoenix sampled TDS load from several industries that contributed waste to the major WWTPs. Table 2.1 summarizes the results of the sampling. (The company names have been removed. The sample sites are identified by industry type only.)

Table 2.1 TDS Load Contributed to Wastewater Treatment Plants in 2004

Industry Type	Flow (GPD)	TDS (mg/L)	Loading (lbs/day)
Semiconductors and related devices	1,389,991	1,318	15,279
Semiconductors and related devices	833,710	1,790	12,446
Semiconductors and related devices	567,513	2,240	10,602
Fluid milk	351,430	2,978	8,729
Refuse systems	78,071	7,540	4,909
Linen supply	205,110	2,113	3,615
Bottled and canned soft drinks	174,480	2,298	3,344
Plating and polishing	30,713	10,645	2,727
Industrial launderers	160,617	1,843	2,469
Printed circuit boards	133,377	1,980	2,202
Linen supply	173,740	1,431	2,074
Metal cans	84,341	2,923	2,056
Eating places	136,835	1,521	1,736
Animal and marine fats and oils	66,371	3,130	1,733
Linen supply	86,441	2,272	1,638
Aircraft engines and engine parts	106,824	1,830	1,630
Linen supply	72,247	2,661	1,604
General medical & surgical hospital	141,628	1,305	1,541
Plating and polishing	62,292	2,565	1,333
Linen supply	93,205	1,713	1,332
Copper rolling and drawing	77,338	2,003	1,292
Primary metal products	42,687	3,295	1,173
Industrial launderers	57,025	2,416	1,149
Industrial launderers	55,744	2,470	1,148
General medical & surgical hospital	87,521	1,189	868

2.1 Cooling Towers

Water is the least expensive way to cool air and equipment and the dry desert air provides a perfect vehicle for evaporation of water. A highly economical and efficient cooling system consists of a cooling tower and a heat exchanger, called a chiller and/or a plate and frame. The cooling tower is a low cost piece of equipment used for evaporating and cooling a circulating stream of water. The tower is basically a box that has openings (louvers) on the sides and top. At the top is a large fan that is used to draw air into the tower through the open louvered sides. At the same time, water is distributed over a honeycomb structure which makes up the bulk of the interior. As the water falls slowly over and through the honeycomb in thin layers, the moving air promotes evaporation of the water droplets. Cooling takes place through evaporation. At the bottom of the tower, the cooled water is collected and pumped to a heat exchanger, exchanging heat with a circulating refrigerant or water. This chilled water or refrigerant is used to cool air. The tower water absorbs heat from the circulating refrigerant or water and is returned to the tower, re-cooled and the cycle repeats. As cooling towers evaporate water, the salinity of the remaining water increases until an upper limit is reached. Chemicals are added to the tower to allow higher reuse of the water before it must be discharged. The discharge wastewater is called *blowdown*. Surveys

conducted by the City of Phoenix Water Conservation Department indicate that manufacturers use between 25 and 50 percent of their total water use for cooling. Cooling towers are typically operated between three and four cycles of concentration. Hence, the TDS concentration entering the sewer is two to three times higher than the source water salinity level.

2.2. Process Waters

Process water is used for rinsing, cleaning, chemically treating and, generally, manufacturing a product. Circuit boards, semiconductor chips, aircraft parts, medical devices, golf clubs, LCD displays, machined parts, juices and soda are all made using water. To maintain consistency of product quality, water is often treated by softening, reverse osmosis (RO), and/or deionization. Many manufacturers use softened water to improve rinsing while others soften prior to further treatment with RO and deionization. In addition to increasing the salinity through treatment of water, manufacturing processes, such as cleaning, washing, pickling, metal finishing, plating and etching add salinity from the process chemicals. The wastewater from manufacturing processes must then be treated to adjust pH and remove selected ions in order to meet federal, state, and local discharge regulations. Additional salinity comes from the treatment chemicals. The total increase in salinity discharged to the sewer ranges from 1.25 to two times the source water salinity.

2.2.1 Semi-Conductor Industry

The semi-conductor industry uses water for the rinsing steps required in the production of microcircuitry. For product quality, the removal of most chemicals commonly found in water supply is required. To achieve ultrapure water (UPW), manufacturers often use a combination of methods, including ultrafiltration, RO, and electrodeionization to “create” the water they need. The final product of UPW has all of the salts and organics removed down to part per billion levels. Salinity is concentrated in reject streams from the RO process and disposed of to the sewer system.

In addition to concentrate from the product water, wastewater from the actual manufacturing process is also discharged to the sewer system. This water from the manufacturing process is approximately 1,000 mg/L higher in TDS than the source water and adds ions such as fluorides, sulfates, chlorides, phosphates, ammonium, trace metals, hydroxides, and sodium.

2.2.2 Health Industry

Large hospitals typically have central plants with cooling towers, chillers, and boilers. The cooling towers are generally large and are operated between 3.5 and 5.0 cycles of concentration. The boilers require purified water to control and/or eliminate the build-up of scale on the equipment. The boilers provide steam for autoclaves, sterilizers and laboratories, as well as for heating. Typically, water is softened and then treated with RO prior to being introduced into the boilers. Domestic hot water systems also use softened water for patient rooms, laboratories, surgical units and laundries. The wastewater from hospitals is regulated for chemicals used for disinfection and cleaning. The water discharged to the sewer system includes the softened water, the reverse osmosis reject stream, the boiler

blowdown, the softener backwash, the cooling tower blowdown, and process and domestic wastewater.

2.2.3 Food Processing Industry

Central Arizona has many large industrial food processing facilities, plus hundreds of smaller commercial food processing facilities. In the case of soft drink manufacturers, the high quality of water needed to produce their products is achieved by RO treatment, and the concentrate is then discharged to the sewer system. Other food processing industries (for example, dairies and ice cream plants) also require advanced water treatment systems, including water softeners, and the cleaning process associated with producing food for human consumption, which results in significantly high TDS wastestreams. Simple treatments, such as washing fresh vegetables, may result in pesticide or fertilizer residue, along with other pollutants, in the wastewater discharge

2.2.4 Industrial Laundry Industry

Industrial laundries and commercial laundries represent a large segment of the significant industrial users discharging to the sewer system. These laundries are typically high volume water users and discharge pollutants associated with the industries they serve, along with soaps, surfactants, and other chemicals for cleaning uniforms, shop towels, floor mats, etc. Water softeners are used by many industrial laundries to increase the efficiency of the cleaning process, adding salts to their wastewater.

2.2.5 Metal Finishing Industry

Manufacturers that clean, plate, or otherwise modify metal surfaces for aerospace, electronic or other products, must meet Federal Pretreatment regulations. Such regulated discharges not only contain the salinity from the chemicals used for metal finishing, but also the neutralization and metal removal chemicals used in their pretreatment systems. Industrial pretreatment for cyanide, chrome and other metals add specific salt ions into the wastewater. In addition, certain metal finishing processes require the use of purified water to maintain the quality of the process solution as well as the quality of the finished product. Nearly all such manufacturers use water softeners and RO systems to remove hardness and other ions from their supply water. Water purification concentrate and waste water from the manufacturing process are both discharged into the sewer system, they add between 1,000 and 1,700 mg/L of TDS to the initial TDS concentration in the supply water. The range reflects the variation in wastewater composition from day to day.

2.2.6 Concentrate Disposal to Sewers

Sewer disposal of the concentrate produced from reverse osmosis membranes is currently not limited, either by strength or volume in central Arizona. This is the most common practice in Arizona, and nationally, 42 percent of concentrate is disposed in sewer systems (Mickley, 2001). Concentrate may be indirectly discharged from the WWTP at the discretion of the Arizona Pollutant Discharge Elimination System (AZPDES) permit holder. This can be done assuming there is no interference with the wastewater treatment process and that pass through to the environment would have adverse consequences.

2.3 Commercial

2.3.1 Cooling Towers

In the Phoenix and Tucson metropolitan areas, all high-rise, mid-rise, and some commercial buildings have cooling towers as part of the cooling system. Some low-rise or single-story buildings will have towers depending upon the age and value of the rented space. No mixed-use space has towers but rather have packaged air conditioning units for the office areas and evaporative coolers for the warehouse areas. Nearly all of the cooling towers will be professionally managed and have cycles of concentration between 3.5 and 5.0. The smaller sized buildings and towers have concentration cycles between 2.0 and 3.5. Blowdown from a 1,000-ton tower having 30 to 35 percent year-round utilization is two gallons per hour per ton. This calculates to an average of 5.7 million gallons per year of blowdown water with TDS concentrations ranging from 650 to 2,600 mg/L.

2.3.2 Process Waters

Commercial processes from office buildings, grocery stores, resorts and restaurants will primarily reflect the salinity of food waste and cleaning chemicals. TDS concentrations in the wastewater compared with the TDS in the source water added over background will vary widely with the time of day of operation as well as the size and type of establishment.

2.3.3 Water Softeners

From coffee shops to mega resorts, water softeners are used to keep linens white, plumbing free from corrosion and dishware spot-free. Small operations use systems that are slightly larger than typical residential-sized softeners. Larger restaurants, motels, hotels and resorts use large systems, providing softened water to water features and pools, as well as for cleaning purposes. The range of salt purchased and, hence, discharged to the sewer, varies widely from 1,000 pounds per year for a single small restaurant to nearly 500,000 pounds per year for a mega-resort.

2.4 Residential

Human activities contribute substantial TDS load to sewer systems. Food waste, washing activities (sinks, baths, showers, dishwashers, clothes washers), and sanitary waste (toilets) all contribute TDS to the sewer system. Use of soaps, detergents, cleaners, water based paints, degreasers, and other household chemicals also add to the load. Personal care products (deodorant, perfume, makeup, skin cream) plus pharmaceutical products (prescription and over the counter) add to the emerging contaminants load that will have to be addressed in the future. Emerging contaminants include chemical and microbial constituents that have not historically been considered as contaminants that are present in the environment on a large scale. TDS load from water softeners are addressed below.

2.4.1 RO Treatment

Developed in the 1940s for large-scale desalination plants, RO has become the most popular residential drinking water treatment process, allowing users to further filter their municipal water or well water. A description of how the technology works is located in Section 6.2.1. Residential RO treatment systems consist of a multi-stage system that provides more treatment than carbon filter units. The filtering unit typically fits beneath the kitchen sink

with connections to the cold water line for its supply source and to the drain line for its reject water.

2.4.2 Water Softeners

The U. S. Department of Interior has defined hard water as water having more than 7 grains per gallon (gpg) of calcium and magnesium. In central Arizona, hardness levels can reach 20 gpg or more. This has led many residential and commercial water customers to use water softeners. Softeners employ an ion exchange process that uses a cation resin enriched by brine, consisting of sodium or potassium, to remove calcium and magnesium from water. Water softeners add salinity to the water system in this exchange and this additional salinity flows into the water system and eventually into the sewer system.

There are two basic types of water softeners: automatic water softening systems and portable exchange units. Figure 2.4.1 illustrates the softening process. An automatic water softener system is equipped with a timer that automatically initiates the recharging cycle and every step in the process. Automatic water softeners consist of a pressure vessel, or tank, containing a bed of cation exchange resin, a second vessel that stores the salt (usually sodium chloride [NaCl]) to make up the brine solution, and a control valve to direct the flow of water through the cycle of service and regeneration.

A softener works by flushing the resin bed with highly concentrated brine solution. The hard water enters the resin tank at the valve inlet and flows through the resin bed. The large concentration of sodium or potassium ions in the resin replaces the calcium and magnesium in the water thus softening the water. Calcium and magnesium are removed from the resin and discharged to the drain. The softened water, flows up and out the outlet valve to the sink, washer, etc .

Softener regeneration involves the introduction of a concentrated solution of brine to the resin bed and a reverse exchange process. The water softener system's regeneration valve can be automatically programmed to regenerate at a specific time (for example, midnight) or after a set amount of water has passed through, or a sensing probe can be employed that signals the end of a softening run. Regeneration valves set to regenerate based on water volume, or demand, can reduce salt use by more than 50 percent over timer valves through the elimination of unnecessary regeneration cycles. Ideally, residential softeners should regenerate about once a week, if used correctly. A softener's stated capacity relates to how many grains of hardness minerals can be removed before the resin bed is exhausted. Softener capacity is determined by the volume of resin, the amount of salt used to regenerate it, and by the TDS level of source water. Commercial softeners are also sized according to water usage and can regenerate several times per day.

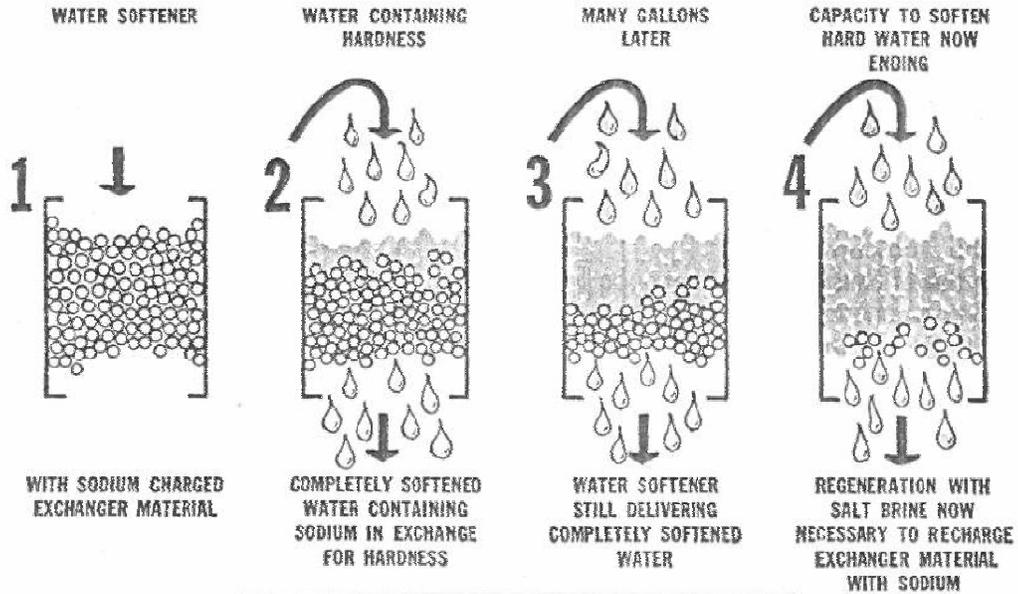
For portable exchange tank softeners, regeneration is performed by a dealer at a central processing (batch) plant. The charged resin tanks are delivered to customers once or twice a month. There are only three such processing plants in the metro Phoenix area, and about 9,000 portable exchange customers. Total discharge from the plants is less than 2,000 gallons per day (gpd) and with the close monitoring of the discharge, it contains very little sodium.

While the majority of water softeners are regenerated with sodium chloride (NaCl), the alternative of using potassium chloride (KCl) is frequently discussed, and is feasible. At most salt settings, NaCl and KCl have similar efficiencies. The reason that KCl is not in greater use is that it is usually about twice as expensive as NaCl, is not as widely available, and is affected by temperature differentials. Typical temperature fluctuations can cause precipitation in the brine tank resulting in severe bridging problems and less potassium available for regeneration.

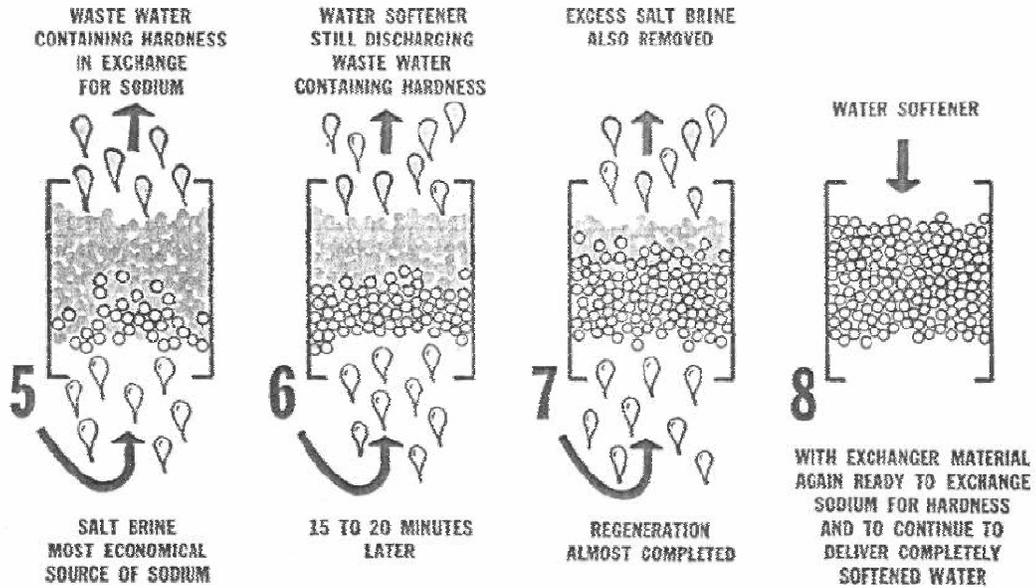
Figure 2.4.1

How Water Softener Exchangers Work

Softening Cycle



Regeneration Cycle



*NOTE: Counter-current brining.

2.4.2.1 Water Softener Survey

CASS has been assessing what the contribution of residential water softeners is to the salinity increase at the WWTPs. To address this issue, Reclamation, on behalf of CASS, contracted with Insights & Solutions, Inc., to conduct a telephone survey in late 2004.

The Phoenix metropolitan area was selected as the study area and was divided into two categories: the established area and the new growth area. (The survey and a map of the study area are provided in Appendix B.) Insights & Solutions contacted and received responses from 2,453 households, with an accuracy of the responses of plus or minus two percent.

Data from the telephone survey indicate that 26 percent of the homes in the Phoenix metropolitan area have water softeners. Thirty nine percent of homes in new growth areas have water softeners as compared with 16 percent of the established area homes. Table 2.4.2.1, below, shows the increase in water softener use from the 1970s to the present. It was in 1985 that the CAP began delivering Colorado River water for use in the Phoenix metro area. (As stated above in Section 1.1.1., Colorado River water has an average TDS of 600 mg/L, higher than native groundwater.)

Table 2.4.2.1 Age of Houses with Water Softeners

Year Home Built	Probability of a Water Softener in House
Prior 1970	17%
1970s	23%
1980s	27%
1990s	47%
2000s	51%

Table 2.4.2.2 shows market penetration of water softeners compared to income. Higher income households are more likely to have a water softener than lower income households.

Table 2.4.2.2 Household Income and Probability of Owning Water Softener

Household Income	Probability of a Water Softener in House
Below \$30k	14%
\$30k to \$60k	26%
\$60k to \$100k	32%
Over \$100k	49%

Nearly every home that had a water softener installed was using it. In 37 percent of the homes surveyed, all the water delivered to the house was softened. In 45 percent of the homes, only the indoor use water was softened. In 9 percent of the homes, only the hot water was softened. Only in 9 percent of the homes surveyed did the respondent not know what water was softened.

Based on the survey results, approximately 40 pounds of salt (one bag) are used per household per month. Further, considering a conservative 26 percent of the homes in the

Phoenix area use a water softener, results in approximately 5,700 tons of salt per month, or approximately 68,000 tons of salt annually, which is sent to the WWTPs, solely due to residential water softeners. That is approximately a quarter of the salinity increase above the source water salinity level that is seen at the WWTPs. At smaller water reclamation plants in the new growth areas, the salinity increase above source water salinity due to residential water softeners is even more acute. At the CCWRP, as discussed in Section 1.1.3 and Appendix A, the residential water softener salt load accounts for 36 percent of the problem.

2.5 Municipal Treatment

Chlorination sites add salinity into the supply water at booster stations and wellheads. For example, the water supply into the CCWRP watershed includes 13 sites that add salinity from either on-site chlorine generators or from the addition of calcium hypochlorite tablets. These 13 sites add 134.8 tons per year of salt into the supply water and contribute 10 percent of the CCWRP sewer shed salt load that returns to the CCWRP.

3.0 Regulatory Issues

The following section discusses the potential regulatory areas of concern that relate to treatment, discharge, and storage of TDS. In this discussion, the TDS discharge may range from highly concentrated (RO concentrate) to moderately concentrated (reclaimed wastewater). In any case, changes to existing rules and laws may have a significant impact on how Arizona manages increasing salinity in water resources, specifically effluent. Regulations associated with discharge or reuse of effluent or with concentrate disposal will, therefore, be site-specific. Disposal alternatives may be dictated by federal, state or local restrictions, depending upon the sensitivity of the water body receiving the discharge.

3.1 Quantity Versus Quality

In Arizona, water is governed by two state agencies; establishment, permitting, and enforcement of water quality standards is the responsibility of the Arizona Department of Environmental Quality (ADEQ), while the Arizona Department of Water Resources (ADWR) regulates water supply (quantity). The two agencies coordinate efforts on such matters as recharge permits, where ADEQ requires an Aquifer Protection Permit (APP) for effluent recharge and ADWR administers quantity aspects of groundwater storage. Arizona encourages recharging water back to the aquifer when it is available for times of drought and even though source waters being recharged differ in quality from water in the aquifer. For this reason, the activity of recharging CAP water is exempt from APP regulations.

ADWR's Underground Water Storage (UWS) Program, also known as the Recharge program, is designed to allow a recharge project to proceed as long as it is hydrologically feasible and will not cause unreasonable harm to other land or water users. Potential unreasonable harm includes both physical impacts (rising water levels) and water quality impacts. The approved and permitted underground storage facility (USF) must be designed, constructed, and operated such that the storage of the maximum amount of water will not impair existing uses of land or the structural integrity or function of existing structures. This demonstration is initially the product of a groundwater flow model or analytical assessment.

The ADWR permit for an USF includes a monitoring network to ensure that as the facility is operated, the protection of other land and water users is maintained.

3.2 Water Treatment Regulations

New water treatment plant regulations, such as the recently revised federal arsenic standard, have the potential to impact the TDS issue. For example, if a well or surface water has elevated arsenic levels, and RO treatment is chosen as the preferred treatment strategy, then the concentrate will contain highly concentrated arsenic, plus other dissolved materials. If discharged to the sewer, that waste stream may cause problems with the National or Arizona Pollutant Discharge Elimination System (NPDES/AZPDES) permits. Other developing water treatment plant limits are becoming harder to meet with conventional coagulation/filtration technology. This is motivating many water providers to consider the use of membrane technologies to meet new, more restrictive drinking water standards. The concentrate from these new plants will be discharged into sewers, unless limits are placed upon such discharges. If local sewer limits are imposed, then water providers may have to pre-treat the waste prior to disposal, requiring capital investment and added operating costs.

At present, the Clean Water Act (CWA) does not specifically address drinking water treatment plant by-products. As a result, they are addressed through a default classification: industrial waste (American Membrane Technology Association [AMTA] 2005). This results in a more stringent set of regulations, potentially higher permitting costs, and public perception problems.

The U.S. Environmental Protection Agency (EPA) has proposed, under the 2004 Effluent Guidelines Plan, a new federal category, under Sections 304(b) and 304(m) of the CWA, that requires review of existing water treatment plant discharges (proposed Drinking Water Facilities category), and may require new federal limits on such discharges, either through Publicly Owned Treatment Works (POTW's) via indirect discharges or to Waters of the U.S. (direct discharges). The schedule for final action on the proposed Drinking Water Facilities category is August 2007.

3.3 Wastewater Treatment Plant Discharges to Waters of the U.S.

In Arizona, the AZPDES program approves, issues, and enforces permits for surface water discharges. Concentrated TDS wastestreams, including RO concentrate, may be indirectly discharged, at the discretion of the AZPDES permit holder, through a POTW, assuming there is no interference with the treatment process, or pass through to the environment that would have adverse consequences. Sewer disposal is the most common practice in Arizona, and nationally, 42 percent of concentrate is disposed in sewers (Mickley 2001). Continuing this practice in the future will not be a regulatory issue but rather a policy issue, developed by each municipality.

WWTPs that discharge to Waters of the U.S. are required to have a whole effluent toxicity monitoring program for the protection of aquatic life. This program requires that sensitive invertebrates, fish, and algae be subjected to varying effluent concentrations, to confirm the presence or absence of toxicity. This is then used as an indicator of potential in-stream

impacts on aquatic life. The CCWRP effluent has demonstrated chronic toxicity and was required to enter into a Toxicity Identification Evaluation (TIE). If a primary toxicant is identified, then the CCWRP will undergo a Toxicity Reduction Evaluation (TRE) for the purpose of identifying effective control measures for effluent toxicity. It is common to spend hundreds of thousands of dollars on such studies, even millions. The City of Phoenix will soon send the sixth quarterly report to ADEQ, identifying activities and strategies developed to identify the cause of this toxicity. To date the results remain inconclusive, but among the possible causes currently under investigation is salinity, specifically sodium concentration.

One possible cause of the observed toxicity may be ion imbalance. The Society of Environmental Toxicology and Chemistry (SETAC 2004) produced a technical issue paper discussing this subject. They concluded that ions commonly found in aquatic ecosystems could be toxic to aquatic organisms when present in concentrations above or below biologically tolerable levels. They observed that changes in the concentration or composition of ions in the external water, particularly over long periods of time, might cause an organism to spend too much energy trying to regulate its internal water balance, resulting in chronic stress. This stress could affect the organism's growth and reproduction. The authors further suggest that sudden changes in ion concentration or composition in the external water could cause death. An interesting conclusion was that TDS levels in freshwater above approximately 1,340 mg/L could adversely affect freshwater organisms. TDS concentrations at the CCWRP regularly exceed this level (see Appendix A). The SETAC paper discusses relative toxicity of specific ions to one freshwater organism, *Ceriodaphnia dubia*, and concluded that potassium was the most toxic ion to the organism, followed by: bicarbonate > magnesium > chloride > sulfate > bromide (least toxic). This may have an impact on the possible substitution of KCl for NaCl in water softeners, as a solution to sodium toxicity in irrigated plants. An interesting conclusion to the article was that in toxicity studies where the only responsible toxicant was identified as ion imbalance, one proposed regulatory solution would be to develop site-specific ion or TDS limits (SETAC 2004).

In another article (Mount et al. 1997), LC50 (lethal dose for 50 percent of test population) values for *Ceriodaphnia dubia* were found at conductivities ranging from 3,500 to 4,000 microsiemens per centimeter (mS/cm). Another study showed major ion toxicity to *Ceriodaphnia dubia* from an industrial process water with a conductivity of 1,800 mS/cm (Jop and Askew, 1994). Conductivity values at the CCWRP regularly exceed all these conductivity levels (refer to Appendix A). In addition, Mount et al. demonstrated that *Ceriodaphnia dubia* is more sensitive to major ion toxicity than *Daphnia magna* or fathead minnows (*Pimphales sp*).

A study conducted by Nikolay Voutchkov (Voutchkov ----year) at the 30 MGD Terminal Island WWTP in Los Angeles, determined that influent salinity above 3,000 mg/l caused nitrification inhibition. Mr. Voutchkov proposed that the bacteria present in the activated sludge were adapted to freshwater/human body salinity, in which optimum TDS concentrations ranged from 2,000 to 3,000 mg/L. If the activated sludge rose to levels above that optimum range, the activated sludge organisms would be subjected to osmosis, where water in the bacterial cells begins to move through the cell membrane toward the surrounding (more salty) wastewater. This osmotic stress can cause cells to rupture or reduce the bio-

assimilation capability of the bacteria, and reduce activated sludge BOD (biological oxygen demand) removal efficiency (Voutchkov, personal communication). Daily average salinity levels at the CCWRP have not reached this level, however, diurnal data indicate that spikes have occurred at higher levels, and these short-term impacts may require further study.

3.4 APPs

APPs are reviewed, issued and administered by ADEQ. These permits require that discharges into aquifers meet Arizona Aquifer Water Quality Standards (AWQS), which were adopted in 1986 and based on the federal primary drinking water standards at that time. The standard practice for ADEQ is that APPs for WWTPs will include alert levels calculated at 80 percent of the AWQS. Alert levels serve as early warning signs for an exceedance of an AWQS. APPs require that the owner/operator of the WWTP demonstrate that the facility is using the Best Available Demonstrated Control Technology (BADCT) for discharge reduction. In addition, APPs require financial and technical capability demonstrations. Because the Arizona AWQSs are based on the federal primary drinking water standards, there are no numeric AWQSs for TDS or salinity. However, the APP Program does have regulatory authority to establish a “narrative” standard for TDS, chloride, nitrate, or any other contaminant if there is a down gradient user that could be impacted by the discharge.

3.5 Biosolids

TDS is not generally considered a biosolids or water treatment plant solids issue because the TDS is separated from the solids using centrifuges, belt presses, filter presses, or other separation technology. The separated centrate, filtrate, or other liquid waste stream does have concentrated TDS and it must be treated appropriately. In cases where a water treatment plant discharges centrate or RO concentrate to a POTW, the POTW may determine that the wastestream be treated as an industrial waste. This determination would be case-specific and would depend upon the potential for the wastestream to interfere with the treatment process or pass through the WWTP.

3.6 Long Range Issues – Emerging Contaminants & Disinfection By-Products

3.6.1 Emerging Contaminants

In recent years, laboratory methods have evolved to the point that certain compounds can be detected in wastewater down to the parts per trillion. Such compounds include pharmaceutical and personal care products (PPCPs) and endocrine disrupting compounds (EDCs), and are often referred to as emerging contaminants or xenobiotics. These products enter the wastewater system from human usage and there is growing concern over their eventual fate in the environment. While most of these compounds are not currently regulated, the long-term impacts of exposure are not yet understood.

There are two principal concerns for the presence of emerging contaminants in effluent: human health effects if effluent is indirectly used for potable water supply, and environmental effects if emerging contaminants are significantly concentrated in a brine waste stream as effluent undergoes membrane treatment.

Public concern over emerging contaminants in potable water supplies has grown in recent years as the ability to detect these compounds has accelerated faster than our understanding of the potential health effects. As effluent begins to be more widely used as a potable water supply, these concerns must be addressed. Further research must be conducted to determine the health effects of these compounds so that municipal water providers can determine the appropriate treatment goals.

The concentration of these materials in brine wastestreams presents another set of challenges. As the use of membrane processes continues to grow, including their use in the treatment of effluent, brine management technologies will continue to evolve. The effects of concentrating emerging contaminants in brine streams must be understood and managed to prevent environmental harms.

There are several treatment technologies that are effective at removing certain emerging contaminants from water. However, none of the current technologies are effective at removing all such compounds. The use of a particular technology or combination of technologies must be tied to the eventual end use of the water. Research on new technologies is active and must be monitored so that future projects take advantage of the best available technology at the time.

3.6.2 Disinfection By-Products

The organic content of a source water can react with conventional disinfection chemicals, such as chlorine, to form disinfection by-products (DBPs). These by-products are subject to evolving regulations due to the potential for human health impacts. Treated wastewater effluent contains measurable amounts of organic matter that will form DBPs.

The formation of DBPs in wastewater is of minor concern when the effluent is discharged to the environment or recycled for non-potable uses. DBPs are subject to a variety of natural attenuation mechanisms in the environment. The limited contact that humans have with non-potable recycled effluent, such as turf irrigation and industrial processes, provides an effective barrier to DBP compounds.

However, as water supplies continue to become more limited, many communities will evaluate the use of recycled effluent to augment potable water supplies. This will require additional study of DBPs as effluent becomes an increasingly important source of potable water supply. In addition to further study of DBP formation and health effects, research of the effectiveness of alternative disinfection processes, such as ultraviolet (UV) disinfection, will be warranted. Such processes could reduce the potential generation of DBPs, but they must also be proved effective at preventing disease while being compatible with other disinfection methods used to disinfect the balance of a community's water supplies.

3.7 Water Reuse Regulations

At this time, the EPA is reviewing the 1992 *Guidelines For Water Reuse* (EPA 1992), but has taken no action to revise or expand the existing regulations. The 1992 EPA guidelines

specify pH, turbidity, strength (BOD, total suspended solids), bacteriological, and chlorine residual requirements that are site-specific and vary with the type of reuse. Arizona's reclaimed water quality standards are established and enforced by ADEQ, and are similar to federal standards, requiring different limits for different classes of reclaimed water. There are no reclaimed water standards for TDS, chloride, or other salinity limits in Arizona's rules. Other states have adopted specific water quality requirements for reclaimed water, including limits on TDS, or antidegradation standards (California, Florida, Texas), that are unique to the water quality conditions and laws of each state.

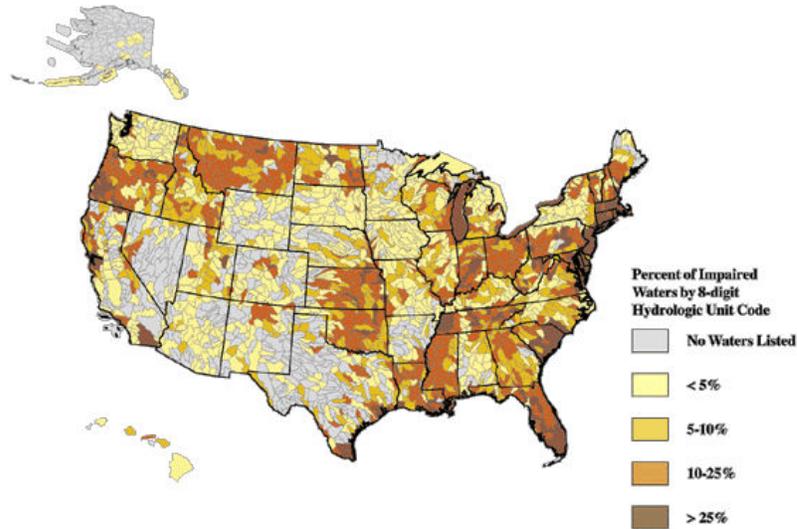
3.8 Narrative AWQs

Arizona's rules provide regulatory authority for ADEQ to establish site-specific narrative AWQs, if necessary, to ensure that all aquifers and surface water bodies be free from pollutants in amounts or combinations that are toxic to humans, animals, plants, or other organisms.

3.9 Total Maximum Daily Load (TMDL)

Section 303 of the CWA requires that each state review, adopt, and modify from time to time, surface water quality standards. EPA must then approve the standards. In addition, each state is required to identify those water bodies or segments that are impaired by one or more pollutants and are not meeting surface water quality standards. Those surface water bodies are then listed on the CWA Section 303(d) list of impaired waters. The CWA requires that each state evaluate the TMDL for each of its impaired water bodies to determine the amount of a specific pollutant a water body can absorb and still meet the surface water quality standard. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and non-point sources, and includes a margin of safety to ensure that the waterbody can be used for the purposes the state has designated. The calculation must also account for seasonal variation in water quality. The attached map identifies all impaired waters in the United States.

Figure 3.9.1 Impaired Waters in the United States



Arizona, like other states has identified impaired waters and reported those to the EPA. The following table lists, for the six Southwestern states, the total water bodies identified as impaired and the total water bodies impaired for by salinity, TDS, and/or chlorides.

Table 3.9.1 Impaired Waters in Specific States

State	Total Impaired Waters	Total Impaired Waters Identified For Salinity/TDS/Chloride
California	1774	70
New Mexico	347	12
Texas	351	33
Utah	364	77
Nevada	217	15
Arizona	100	0

As indicated in Table 3.9.1, Arizona has yet to identify water bodies as impaired for salinity, TDS, or chloride.

3.10 Anti-Degradation Standards

Arizona has adopted, by rule, both numeric and narrative water quality standards and an anti-degradation policy for surface waters. The surface water quality standards are prescribed in Title 18, Chapter 11, Article 1 of the Arizona Administration Code (A.A.C.). Narrative standards are defined in A.A.C. R18-11-108, while the anti-degradation policy is defined in A.A.C. R18-11-107. The current numeric surface water quality standards do not address TDS, chlorides, or salinity, except in certain Unique surface waters, where no increase in TDS is allowed as a result of discharges. However, such standards may be developed in the

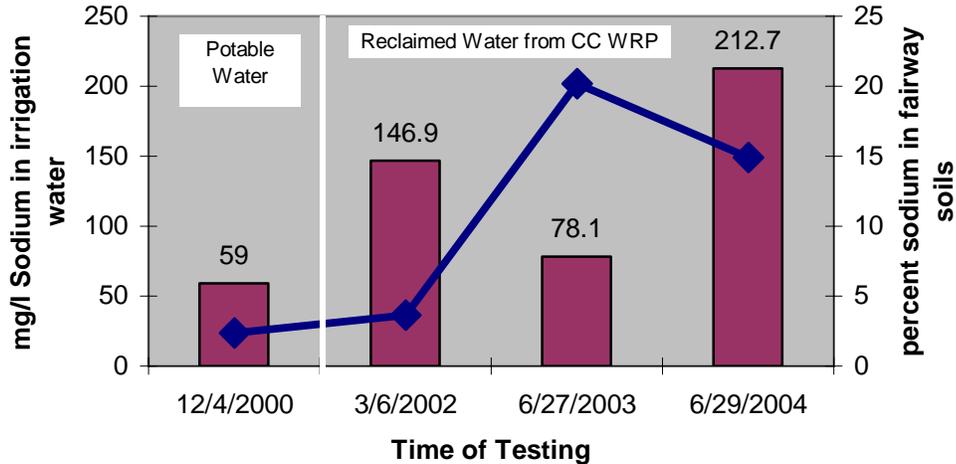
future. It is important to note that Arizona's antidegradation standards require a determination as to whether or not there is degradation of water quality in a surface water on a pollutant-by-pollutant basis. The rule further requires a three-tiered approach that protects existing water uses, does not allow degradation where existing water quality does not meet a standard, and under certain conditions, may allow limited degradation under controlled circumstances. Waters that are classified as Unique under A.A.C. R18-11-112 must not be degraded.

4.0 Case Study of Cave Creek Water Reclamation Plant Sewershed

To assist CASS in clarifying the amount of TDS loading added to the sewer system, a study of the CCWRP was conducted. This plant is a small (2 MGD) water reclamation facility located in a growing area of north Phoenix where effluent is reused for turf irrigation purposes. The CCWRP was selected because it has one source of water for potable supply, a mix of commercial and residential customers, and high salinity is already becoming an issue for reuse customers.

Effluent from the CCWRP is used as the irrigation source water for the Desert Marriot golf course. Conversations with the Desert Marriott's golf course superintendent revealed a pattern of data showing increasing soil sodium levels corresponding to increasing sodium levels in the irrigation water as show in Figure 4.0.

Figure 4.0 Rising Salinity in Turf Fairway



The full study can be found in Appendix A.

4.1 Sewershed Description

Commercial development in the CCWRP sewershed has been focused along the freeway and major north-south roads while large residential development is focused around resorts and greenbelts. Point source contributors of salinity, especially sodium-based softener salt, were investigated to build a reasonable model of a growth-area sewershed. Current data shows that the sewershed adds nearly 500 mg/L TDS over background, a 75 percent increase. The two highest contributing ions to the overall TDS are sodium and chloride. Sodium increases 236 percent and chloride increases 328 percent over background in the CCWRP treated effluent (reuse water).

Two main sewer lines connect to the CCWRP; the northern line is called the Cave Creek interceptor, the southern line is called the Mayo Interceptor. At the time of the study, several large commercial and industrial dischargers were not sending wastewater to the CCWRP due

to a lift station (LS51) that needed repair. This represents approximately 600,000 gpd flow and point source contributions of 85,000 pounds per year of softener salt from three sites.

4.2 Commercial Areas

Commercial areas predominate on the Mayo Interceptor including Desert Ridge Marketplace, a large outdoor shopping mall, and the Desert Marriott Resort. These two sites contribute nearly 650,000 pounds per year of salt from softeners alone. Three additional point sources that currently are diverted to 91st Avenue due to LS51 are: Mayo Hospital, American Express, and the Scottsdale/101 shopping centers. As stated above, these three sites will contribute an additional 85,000 pounds per year of salt when the lift station is repaired. Additional commercial development of the magnitude of Desert Ridge Marketplace is expected in the next 5 years. The frequency and magnitude of softener regeneration can be shown in the spikes of salinity during the monitoring of the Mayo Interceptor. All of the point sources contribute between 500 and 1,100 mg/L TDS over the background supply water, with Desert Marriott and the area east of Mayo Hospital contributing the highest chloride content.

4.3 Residential Areas

The Cave Creek Interceptor is predominately residential. Data collected in this study and in Reclamation's Residential Softener Use Study indicates that the newer homes have a higher percentage of softeners installed and in use than older homes. Three different residential areas were investigated to show the impact of number of homes and ages on the salinity contribution. The first area, Residential A – Desert Ridge, is a mid 1990s development. Over the course of a one-week flow and conductivity testing, the peak conductivity was 10,316 mS/cm with an average flow of 13.6 gpm for a total flow of 3,819 gallons. Residential B- Dove Valley is early 2000s homes with a peak of 6,555 mS/cm conductivity. Residential C- Tatum Ranch/Desert Willow is 865 accounts of early 1990s homes with a peak conductivity of 5,660 mS/cm and an average flow of 170 gpm for a total of 1.7 million gallons over the week's data gathering. The grab samples show another side of the conductivity impact of these three residential areas. Residential A showed a 497 mg/L TDS increase over background. Residential B showed a 1,377 mg/L TDS increase over background, and Residential C showed a 697 mg/L TDS increase over background. Residential B, the newest homes, showed the highest increase of both sodium and chloride over background levels.

4.4 Mitigation Strategies

Commercial and residential salinity contributors have a greater impact on a small water reclamation plant because the salt is not diluted by abundant flow. Potential solutions to improving the quality of the reclaimed water include: diversion of high salt flows to a large wastewater plant; switching from sodium to potassium salt for softener regeneration, evaluation of non-salt regeneration chemistry as used in Europe, developing a water softener portable exchange unit program to reduce salt load to the sewer system, and/or regulation of commercial dischargers with fees used for water treatment at the water reclamation plant.

5.0 Salinity Control Strategies

Increasing salinity represents a threat to the sewer system, and to beneficial use of treated effluent. Decisions must be made to control the salinity from entering the wastewater treatment plants. These controls may be regulatory, financial, or technical, and following is a discussion of possible salinity control strategies.

5.1 Prevention

Preventing salinity from becoming a problem is one of the most difficult issues faced by municipalities in central Arizona. The largest portion of the TDS load comes from source waters, either from the SRP or CAP surface waters, and to a lesser extent from groundwater. CASS has identified source control measures on the watershed scale. While the Colorado River Basin Salinity Control (CRBSC) Forum has prevented a rise in TDS of Colorado River water, no other watershed-level salinity prevention method is currently financially feasible. Therefore, it is likely that in the immediate future TDS in imported source water will continue to be a challenge whether or not there are any human activities to add to the increase in TDS load. Dealing with the salts added by human activities is where preventive measures will be helpful, however, salts imported with the source waters must also be considered when apportioning the costs of treatment to water users.

5.1.1 Local limits

Local limits are designed to prevent introduction of pollutants into the sanitary sewer system that might harm wastewater treatment facilities, to protect the health of treatment plant staff and the public, to allow continued beneficial reuse of treated effluent and biosolids, and to ensure NPDES permit compliance.

In the late 1990's, the Sub-Regional Operating Group (SROG), composed of Phoenix, Mesa, Tempe, Glendale and Scottsdale and co-owners of the 91st Avenue WWTP, was aware of the high TDS problem and recommended that the TDS concentration of effluent flows from WWTP's not exceed 1,200 mg/L. SROG also projected that several advanced water treatment plants would be built by communities in the Phoenix area over the next 20 years to remove excess TDS (greater than 1,200 mg/L) from wastewater flows. SROG further predicted that the advanced water treatment plants would produce concentrate wastestreams with flows of 20 MGD by 2017 (Greeley and Hansen 1997). Current data indicate that the 1997 projection of WWTP discharges exceeding 1,200 mg/L within the next 20 years has already occurred. Discharges from the 91st Avenue WWTP and the City of Phoenix's 23rd Avenue WWTP ranged from 1,300 to 1,400 mg/L in the summer of 2004.

A local limits study was conducted for the 91st Avenue WWTP and the 23rd Avenue WWTP from 2002 through 2004, however, the final recommendations for establishing TDS local limits were inconclusive. The consultant advised that since there were currently no permit limits for TDS, that a local limit could only be established if the WWTP owners, including SROG member cities Glendale, Mesa, Tempe, Phoenix, and Scottsdale, could agree to water quality goals for various uses of treated effluent. For example, there might be different goals for stream discharge, crop irrigation, industrial reuse, groundwater recharge, or golf course irrigation.

A local limits study is currently under way at the CCWRP and data demonstrated that the water being discharged from that plant is even higher, occasionally exceeding 1,500 mg/L. Some of the problems associated with high TDS flows being treated at WWTPs and WRPs are discussed above in Section 3.0 Regulatory Issues.

One method to prevent excessive TDS load is the establishment of numeric local limits. Some cities in other states have imposed local limits on TDS dischargers to POTWs, however, this is an uncommon practice and the limits vary considerably, depending on local conditions (Table 5.1).

Table 5.1 Local Limits for TDS Discharge Into WWTP in Various States

State	City/Utility	TDS Local Limit (mg/L)
Texas	El Paso	6,140
Florida	Boca Raton	2,000
California	Inland Empire Utility Agency	800
Nevada	Clark County Water Reclamation District	Source water TDS plus 400 mg/L

Other non-numeric(narrative) local limits strategies include use of Best Management Practices (BMP's) and prohibitions. An example of a BMP might be encouraging use of water softening methods that do not add salts to the sewer (portable exchange units), while an example of a prohibition might be to not allow the use of self-regenerating water softeners, as was done in Santa Clara, California. Another example of a prohibition might be prohibiting discharge of RO concentrate to the sewer. Local limits, either numeric or narrative, will remain one of the tools available to address salinity problems.

5.1.2 Surcharges

The process of developing surcharges to support sewer services is well established. Municipalities typically develop charges for flow, strength (BOD, TSS), and other parameters, as needed to pay for the cost of wastewater treatment. Some parameters, such as strength are measured accurately at the WWTPs to determine the actual number of pounds being treated. The number of pounds is divided by the actual cost to treat the wastewater, and a cost per pound is developed, typically on an annual basis. Then the strength is measured by sampling at Significant Industrial Users (SIUs), and the SIUs are billed by the pound. In other cases, an analysis is done for a class of users, such as commercial facilities, and those facilities are billed at a uniform rate that ensures cost recovery.

It is currently possible to measure the number of pounds of TDS entering each WWTP, and to develop the actual cost of treating TDS. It will also be possible to develop costs for new

treatment equipment, personnel, and disposal that may be required to manage TDS. It is essential to first understand the sources of TDS entering the system, both water and wastewater, and by accurate measurements, or by developing models, to identify the load generated by various industrial, commercial, and residential user classes. Then it will be possible to fairly apportion the cost of treatment to the contributors, based upon their contributions.

Since the waters imported into central Arizona from the CAP and Salt River Project (SRP) surface waters are the primary TDS sources, all water users would bear some of the burden of treatment, just like they would to treat high turbidity, algae, or any other water contaminant. However, it would be possible to develop a surcharge system that identifies certain contributors that exceed a threshold, and they could be charged appropriately. On the residential side, a strategy might be to identify homes with water softeners, and to add a small monthly fee to treat the added load from that softener.

5.1.3 Point Source Treatment

Point source treatment occurs at many areas throughout the sewershed. Large industrial users use RO or other membrane technology to purify water for their process needs, and then discharge the concentrate to the sewer. Cities treat water, or wastewater, using membranes, and then discharge the concentrate to the sewer. Large centralized cooling systems concentrate TDS, prior to discharge after a number of cycles of concentration. It is possible to identify the actual TDS load generated by these facilities, and to consider whether it may be prudent to require hauling of that concentrate to a centralized disposal facility. One method would be to identify the largest contributors and to consider the economics. If a large contributor had to pay a surcharge, by the pound, to dispose of TDS in the sewer, then it might be possible to develop alternative disposal methods that would be of equal, or even lower in cost. There might be an incentive for cities to assist in developing alternative disposal strategies.

5.1.3.1 Point of Use

5.1.3.1.1 Treatment to Remove Salts as Solid Slurry

One potential control strategy for point-of-use treatment is to use a desalting technique such as DewVaporation™, crystallizers, or RO at larger cooling tower operations to create a solid slurry that could be disposed of as non-hazardous waste. Source water ranges between 500 and 650 mg/L TDS. Larger cooling towers are operated between 3.5 and 5.0 cycles of concentration and concentrate the blowdown to about 1,700 and 3,500 mg/L TDS, which is disposed of in the sewer.

The DewVaporation™ technology has yet to be proven reliable in daily use, but the small compact size would have a distinct advantage over other desalting methods because it requires very little energy relative to other technologies. The City of Phoenix's Sky Harbor Airport evaluated RO on Terminal Two's cooling towers, but did not find favorable economics for water savings.

5.1.3.1.2 Non-Salt Regeneration of Softeners

Non-salt regeneration of water softeners is another potential control strategy for point-of-use treatment. One type of “non-salt” regeneration refers to the use of potassium chloride in lieu of sodium chloride. This is a misnomer, as potassium chloride is also a salt, although it is proclaimed to be a more beneficial salt for health. The EPA has established toxicity limits for potassium and high potassium levels have also been indicated in process inhibitions at WWTPs.

The true “non-salt” regeneration uses an acid to regenerate a weak acid ion exchange resin instead of sodium-chloride brine. This method has been used extensively in Europe and only removes hardness, not alkalinity, from the water. Although water is not completely softened, it may be sufficient in many cases.

Weak acid regeneration works similarly to normal softening in that hard water passes through the ion exchange bed. The difference is that the resin is composed of a weak acid cation that will only remove calcium instead of resin composed of concentrated sodium-chloride brine. The greatest advantage of weak acid regeneration is the reduction of TDS in the treated water, thus reducing the TDS load at the WWTP. The efficiency has been shown to reduce TDS up to 75 percent depending upon the source water composition. Because of the acid used for regeneration, it is better suited to large, point-use systems in hospitals, industrial companies and central exchange bottle operations. The cost difference has not been analyzed and must be demonstrated before this method could be implemented.

5.1.3.1.3 Reuse of Treated Water for On-Site Irrigation

Large industrial firms such as the former Motorola (now Freescale) realized that the investment in water treatment makes water a valued commodity. They also realized that merely discharging this valued resource to the sewer reduced its value for both water conservation and environmental compliance. To offset this, Motorola obtained a ruling from ADEQ to use certain types of treated wastewater for on-site irrigation as well as for cooling tower water makeup. Although Motorola has sold the facility, the irrigation project continues to be used. Reuse of treated water for cooling tower makeup required blending with supply water to reduce corrosion of the metallic components of the cooling water system. Honeywell is investigating the use of treated wastewater for cooling tower makeup to reduce overall water and wastewater treatment costs.

5.1.3.2 Small Regional Treatment

The concept of a small regional “desalting” treatment facility is based upon the successful model of Northwind, a centralized chilled water facility that services several downtown Phoenix buildings. Northwind is an ice storage and chilled water distribution system for cooling tower water in downtown Phoenix that has been in operation for four years. It is a joint venture between Arizona Public Service (APS) and Bank One Ballpark that delivers 34-degree (Fahrenheit) chilled water to 10 downtown facilities. This service reduces construction and operation costs by eliminating the need for chillers and towers at each

customer's site. Power savings are also substantial due to the efficiency of the chiller system. It is expected that the water savings is also significant because smaller and less efficiently run tower systems have been replaced. The infrastructure of chilled water piping in the downtown area proves that a small regional system can be efficient and beneficial.

A small regional treatment desalination facility would be based upon a finite size and customer base, like the Northwind facility, to provide more highly efficient removal of salts and higher quality returned reclaimed water for potential use on site.

6.0 Salinity Treatment Options

Because of the growing need for additional water resources, effluent has become an additional source of water for municipalities, industries and the agriculture. As salinity rises, the ability to use effluent as source water may become increasingly limited and will likely result in either direct treatment for non-potable reuse, or use of highly treated effluent for groundwater augmentation.

If salinity cannot be prevented from entering the WWTP, it may be prudent to use the desalination method for various non-potable uses to continue the ability to use effluent as a source water. This section describes the different uses of effluent, how rising salinity may impact the end uses, and the different desalination technologies available.

6.1 Non-Potable Reuse

Effective reuse of water to maximize potable supply is a resource management issue facing many water providers in central Arizona. Some water providers have developed reclaimed water systems to provide treated wastewater to meet irrigation demands for turf and industrial uses, such as cooling tower water. As the population in central Arizona grows, the need to increase effluent use to provide a supplement for potable uses will occur. As potable water demands increase, competing uses of effluent may drive some creative solutions to issues facing central Arizona communities, including environmental enhancement and restoration projects.

6.1.1 Turf Irrigation

Arizona is a golf paradise, and the tourism industry attracts players to the state from around the world. The largest users of reclaimed water for turf irrigation are golf courses, but other large users include schools, hospitals, parks, industries, and green belts. Use of reclaimed water has resulted in a build-up of salts in soils, required selection of salt tolerant turf, and requires application of up to 25 percent more water than is needed for agronomic purposes, simply to leach the salts through the soil column and into the groundwater. Turf irrigation in well-designed golf courses, with sophisticated underdrain systems will delay the need to address salinity in reclaimed water, although it is wasteful. However, continued turf irrigation in other areas such as public parks, may be threatened more quickly. Information on salinity build-up in golf courses irrigated by the CCWRP may be found in Appendix A.

6.1.2 Irrigation of Agriculture

Irrigated agriculture is and will remain one of the largest users of water in Arizona. Impacts on irrigated agriculture are similar to turf irrigation. Crop selection is dependent upon salinity tolerance. Cotton, for example is much more tolerant than alfalfa. Over-irrigation is required to flush salts out of the root zone, wasting water.

Treated effluent from the 23rd Avenue WWTP is used to irrigate 34,800 acres in the Roosevelt Irrigation District, consuming an average of 25 MGD. Due to seasonal patterns of local water supply, Phoenix typically produces much more saline effluent in the summer than in the winter, the period when water for crop irrigation is most needed.

The U.S. Department of Agriculture has proposed an acceptable TDS range for irrigation water between 450 and 2,000 mg/L. Texas A&M University has proposed permissible limits for classes of irrigation water, shown in Table 6.2.2.1. These permissible limits provide guidance to farmers concerning optimum quality for irrigation, and for lesser quality water that will have negative impacts on plant growth, crop yields, and quantities needed for leaching.

Table 6.1. Permissible Limits for Classes of Irrigation Water

Classes of Water	Concentration, TDS	
	Electrical conductivity (mmhos)	Gravimetric (parts per million [ppm])
Class 1, Excellent	250	175
Class 2, Good	250 – 750	175 – 525
Class 3, Permissible *	750 – 2000	525 – 1400
Class 4, Doubtful **	2000 – 3000	1400 – 2100
Class 5, Unsuitable **	3000	2100

*Leaching needed if used.

** Good drainage needed and sensitive plants will have difficulty obtaining stands.

For irrigation purposes, SRP’s annual water quality report recognizes that salinity has effects on crop yield according to the following scale:

- No problems with crop yield (<500 mg/L TDS)
- Increasing problems with crop yield (500 – 2,000 mg/L TDS)
- Severe problems with crop yield (>2,000 mg/L TDS)

Some states have applied reuse limits for crop irrigation. Utah, for example, limits TDS for crop irrigation to 1,200 mg/L. If those limits were in place in Arizona, effluent from the 91st Avenue and the 23rd Avenue WWTPs could not be used for irrigation during the summer, the period when most water is needed for irrigation.

Other states have applied TDS limits for water used for aquifer recharge that may subsequently be used for agricultural purposes. California has many reuse applications throughout the state, where the limits for recharge are 1,000 mg/L TDS, or less (DRIP 2004). DRIP further noted that meeting this requirement is often difficult because the salinity of water increases by 250 to 500 mg/L every time water is reclaimed. In Arizona, the increase associated with reclamation is 300 to 500 mg/L .

6.1.3 Industrial Reuse

Industrial reuse of municipal treated wastewater has traditionally been to power plants or refineries. In the Phoenix metropolitan area, the largest users of effluent for cooling tower purposes are the Palo Verde Nuclear Generating Station and Red Hawk Power Plant, both owned and operated by APS. High salinity is an issue for power plants because it reduces the number of times it can be used in the cooling tower cycle, but this has been somewhat overcome by tertiary treatment. High TDS also causes a problem because power plants must deal with highly concentrated water that is left over in the blowdown.

Palo Verde Nuclear Power plant has been in operation for 25 years and utilizes 70,000 acre-feet annually for cooling water to condense steam. This water is treated to tertiary standards with filtration, trickling filters for the removal of ammonia, cold lime softening and clarifiers to remove the hard water salts. The site uses evaporation ponds to contain the blowdown water from the cooling towers, so the salinity does not leave the site.

Redhawk receives water from Palo Verde Nuclear Generating Station's tertiary treatment plant and has been operating for almost 5 years. Redhawk utilizes a Zero Liquid Discharge (ZLD) system to treat cooling tower blowdown, which is composed of an evaporator and crystallizer. The plant has experienced some challenges in using municipal effluent for cooling towers because the composition of the municipal effluent contains varying quantities of organics and nitrates, which causes the crystallizer to have impaired operation. Crystallizers by definition are designed to separate a distinct solid compound from a liquid mixture that is highly concentrated in that compound in its dissolved form, but low molecular weight and low boiling organics will transfer over into the distillate from the brine concentrator, causing problems with reuse of that water for boiler makeup. A small surge pond is installed for the purpose of holding cooling tower blowdown water for a sufficient time to repair the ZLD system.

6.1.4 Groundwater Recharge

Artificial groundwater recharge is a water management tool used by water agencies to assist in fully utilizing available renewable water supplies by annually recharging and recovering water for use or storing water underground and recovering it when it is needed at a later date. Recharge in Arizona is typically done via recharge basins or injection wells after vigorous permitting through ADWR, in cooperation with ADEQ.

Many municipalities and sewer companies throughout central Arizona have been recharging effluent, but as TDS in effluent increases, others who pump groundwater in the vicinity may start having concerns that recharge is driving up the TDS in their groundwater.

6.1.4.1. Indirect Potable Reuse

In many places in the United States, unplanned indirect potable reuse routinely occurs when treated wastewater discharged from an upstream community is subsequently withdrawn for potable use by a downstream community. The percentage of wastewater effluent in the raw drinking water supply varies significantly depending upon the specific community. In some cases, up to one half of the raw water can be traced to a wastewater origin.

As the populations of communities in the arid Southwest grow, and other available potable water supplies become fully utilized, the need for planned reuse of effluent as a potable supply source will increase. Communities in California, Texas, and Arizona have already begun to utilize recycled water for indirect potable supply. Some of these projects have been in operation for over 25 years.

In planned indirect potable reuse systems, treated wastewater is intentionally used to augment water supplies. Highly treated wastewater is blended with other raw water supplies through surface reservoirs or by recharging the aquifer prior to final potable treatment and delivery. In order to provide the highest degree of health protection and maintain community support, the concept of multiple barriers to remove contaminants is practiced. These barriers include wastewater treatment, blending with other supplies (including the added benefits of soil aquifer treatment if recharge is employed), effective drinking water treatment, and extensive raw and treated water monitoring.

6.1.5. Surface Water Restoration

With careful planning, water supply and environmental enhancement goals can be mutually achieved. The City of Tucson developed the Sweetwater Wetlands multi-benefit project to treat backwash water from the reclaimed treatment plant filters. Treated effluent is piped to recharge basins in this 18-acre facility, where it and other stored treated water is recovered during the summer months to meet irrigation demands through the City's reclaimed water system. The wetland ponds and surrounding vegetation also provide food and shelter for a variety of birds, small reptiles, and mammals. The Sweetwater Wetlands has become a popular bird-watching site in southeastern Arizona due to the seasonal species it attracts and it also provides additional community educational benefits through school tours and similar activities.

Traditional approaches to restoration projects implemented in partnership with the U.S. Army Corps of Engineers and/or Reclamation may result in a range of design elements with competing water needs. Creative water resource managers look for alternatives that incorporate water supply elements, such as constructed recharge projects, into these restoration projects to result in multi-benefit projects providing water resource, ecosystem, and recreation improvements that meet a range of community needs.

6.2 Desalination of Effluent

There are various treatments of desalination that can be utilized to reduce TDS in effluent for various end uses.

6.2.1 Reverse Osmosis

Osmosis occurs when two liquid solutions of different concentrations are separated by a semi-permeable membrane and water will move through the membrane from the dilute (purer) solution into the more concentrated solution. The flow of water will continue until the concentration on each side of the membrane equilibrates or pressure is applied to the concentrated solution. RO works by applying pressure to the concentrated solution, which then reverses the water flow. Water molecules from the concentrated side are forced through the membrane to the dilute solution. Salt and other dissolved solids are left behind with the concentrated solution. The purified water is referred to as permeate and the concentrated solution of salt and dissolved solids is generally referred to in the water treatment industry as concentrate.

Recovery rates are largely limited by the concentration of some sparingly soluble salts in the feed water and thus in the concentrate or reject stream. If recovery is pushed beyond the saturation limits of one or more of these constituents, precipitation will begin to occur on the membrane surface, causing scale. Sulfuric acid, carbonic acid or hydrochloric acid can be used as pretreatment to RO in order to lower pH and add anti-scalant compounds to prevent precipitation of sparingly soluble salts within the RO system. Careful selection of an appropriate scale inhibitor may allow the RO plant to operate at higher recoveries and thus control the amount of concentrate requiring ultimate disposal.

RO permeate is aggressive and post-treatment is required to condition and stabilize permeate before injection into the distribution system. For stabilization, lime addition is used to add calcium hardness back to the water to generate water that will not degrade the distribution system. Another option for stabilization is bypass blending, where a portion of the feed water is diverted around the RO system and re-blended with permeate. This reduces the amount of RO treatment equipment and additionally imparts hardness to adjust finished water stability.

Nanofiltration (NF) is another membrane treatment, sometimes called “low-pressure RO”. NF works much like RO, but allows more salt to pass through the membrane and does not work as well as RO when TDS levels are over about 1,500 mg/L.

6.2.1.1 Advanced Membrane Treatments for Emerging Contaminants

In addition to treating effluent for salinity, membranes may be used to treat effluent for other contaminants (emerging contaminants). As described in Section 2.4 above, the list of emerging contaminants, which have been detected in secondary effluent, includes pharmaceuticals, personal care products, pesticides, and industrial wastes. The EPA does not currently regulate many emerging contaminants but they may be regulated in the future. Some states, such as California, have developed guidelines or regulations concerning these compounds.

Potential treatment techniques needed to address emerging contaminants include granular activated carbon (GAC) adsorption, RO, and advanced oxidation processes (AOPs). GAC has the ability to remove many different types of pesticides, as well as other man-made organic contaminants. Pharmaceutical compounds and personal care products can be

removed by RO. Certain synthetic organic contaminants, which are not effectively removed by other treatment methods, may be successfully treated using AOPs. The processes employed in AOPs produce hydroxyl radicals during the interaction of two or more oxidants, including ozone/hydrogen peroxide and UV radiation/hydrogen peroxide. The hydroxyl radicals produced have the ability to treat a large number of both man-made and naturally occurring organic contaminants. These techniques may be combined into a system process which effectively removes emerging contaminants from treated secondary effluent.

6.2.3 Thermal Processes

Thermal processes, also called distillation, work by heating a saline solution to boiling and vaporizing pure water while leaving the salts (dissolved solids) in solution. Water collects on a cooler surface and is free from dissolved solids. Distillation is the oldest desalting technology, mostly used for sea water desalination, but requires a lot of energy to heat water. This technology has the highest capital, and operation and maintenance costs of all desalination processes and is most often used in dual power-generating and potable water facilities. Distillation is typically not used in the U.S. because of the cost and power requirements.

6.2.4 Electrodialysis/Electrodialysis Reversal

Electrodialysis (ED) and Electrodialysis Reversal (EDR) are the processes that desalinate brackish water using electrical currents and semi-permeable membranes. ED works by using a direct electrical current to divide negatively-charged ions (anions) and the positively-charged ions (cations) from its salt solution. A semi-permeable membrane then allows either cations or anions to pass, while blocking the passage of the other ion. For example, a cation permeable membrane allows cations to pass, while it prohibits anions from passing through. ED does not remove particles that are not charged or bacteria. The membrane surface often becomes clogged (or scaled) with buildup of salts and organic material.

EDR evolved from ED in the early 1970s and was developed to deal with the scaling issues associated with ED. EDR adds the periodic reversing the polarity of the anode and cathode to the ED technology. This reversal dissipates and prevents buildup of scale on the membrane, which in turn reduces the need for using anti-scalant chemicals and improves the overall life of the membrane.

Although ED/EDR does not have as much sensitivity to constituents (such as silica, silt density and turbidity) as other membrane technologies, it does not address organics, microorganisms, and taste and odor constituents which may be found in effluent.

6.3 Current Desalination Projects at Wastewater Treatment Plants

One way of controlling TDS in effluent of wastewater treatment plants is to treat a portion of that effluent with advanced water treatment methods. The treated effluent could be blended back with non-treated effluent to produce different quality levels of water that could be used for various end uses that require water with lower TDS. Two locations where advanced treatment is being used on effluent is the Water Factory 21 in Orange County, California, and the Water Campus in Scottsdale, Arizona.

6.3.1 Water Factory 21

Water Factory 21 was a long-term testing facility constructed for the purpose of understanding the pros and cons of treating effluent with RO. Water Factory 21 was replaced in the summer of 2004 with a 70 mgd facility that was built to reuse more effluent.

During its operation, Water Factory 21 treated and blended 5 MGD of effluent that had undergone RO, 9 MGD of carbon adsorption-treated secondary effluent, and 8.6 MGD of deep well water to produce 22.6 MGD of water, which met all California Department of Health Services primary and secondary drinking water standards. This water was injected into the ground to act as a seawater intrusion barrier in addition to replenishing the aquifers, from which drinking water is drawn for Orange County.

The Orange County sanitation district supplied reclaimed secondary effluent because it reduced 15,000 acre-feet of ocean discharge, reduced dependency on imported water, and reclaimed water is drought resistant. Water Factory 21's treatment train included chemical clarification, re-carbonation, multi-media filtration, GAC, RO, chlorination and blending. The 5 MGD, which was treated by RO, went through a series of treatments prior to the RO process. All the secondary effluent entering Water Factory 21 went through rapid mixing, flocculation, settling, re-carbonation and multi-media filtration. The multi-media filtration reduced turbidity and consisted of anthracite coal, silica sand, and fine and course garnet for a total depth of 30 inches. The multi-media filtration took the place of micro-filtration membranes prior to the RO membranes. The flow stream was then split with 5 MGD going through RO and 9 MGD going through GAC treatment. Just prior to entering the RO membranes, anti-scalant and sulfuric acid to lower pH were added before the effluent went through cartridge filters.

Operation of the RO units required pressures of 200 to 325 pounds per square inch (psi) produced by two high pressure pumps. The RO unit was designed in two parallel 2.5 MGD systems. The basic elements consist of six spiral-wound cellulose acetate membranes placed end-to-end inside a 23-foot long, 8-inch diameter fiberglass vessel. There were six banks of membranes, each containing 42 vessels, arranged in three-stages to provide 85 percent recovery. The membranes were cleaned in situ, using product water with a detergent additive. Product water had 90 percent of the TDS removed. The concentrate (15 percent of the total input) was returned to the Orange County Sanitation District for disposal via their ocean outfall.

Water Factory 21 is an example of a successful application of RO technology used on effluent. With the knowledge gained from this long-term testing facility, Orange County can build with confidence the new 70 mgd RO facility which will take effluent to a quality where it will meet California state drinking water standards and the 500 mg/L TDS maximum for recharge in California.

6.3.2 City of Scottsdale Water Campus

The Scottsdale Water Campus consists of a 54 MGD conventional water treatment plant for Colorado River water delivered by the CAP aqueduct system, a 12 MGD water reclamation plant, and a 12 MGD advanced water treatment facility, which consists of microfiltration (MF) and RO. Also included with the Water Campus, is a distribution system that provides effluent to 21 golf courses in Scottsdale and a 21 MGD recharge facility that consists of 27 vadose zone recharge wells.

During periods when irrigation demand is low, tertiary effluent is treated by the advanced water treatment facility with MF then RO. This water is then recharged into the vadose zone through shallow recharge wells as future potable water. When the effluent is being used on the golf courses, Colorado River water is treated by MF and then recharged in the vadose zone wells. Although the Colorado River water has a higher TDS than the ambient groundwater, the annual average TDS recharged is close to the TDS of ambient groundwater because the effluent that is treated by RO has a lower TDS than the ambient groundwater.

The MF units consist of 24 USFilter 90M20Cs filters. They are grouped in “sixes”, and each can treat either surface water or tertiary effluent. Pretreatment before the MF units consists of 400 micron screens, and when effluent is being treated, ammonia is fed to ensure that the membranes are not exposed to free chlorine.

The RO units consist of 14 3-stage trains each containing Koch Fluid Systems 8832-HR polyamide membranes. Each train recovers 85 percent of its feed flow. Pretreatment consists of pH adjustment with sulfuric acid and anti-scalant. The concentrate is disposed of in the sewer and transported to a large regional WWTP.

One train of MF is dedicated to effluent treatment year round to supply one or two RO trains with feed water. The RO permeate is used for membrane flushing and cleaning, to blend down CAP water TDS, and to keep the RO trains ready for summertime monsoon events. These rain events reduce demand at the golf courses quickly and require operations to shift RO production from CAP to effluent.

The advanced water treatment portion of the Scottsdale Water Campus is operating successfully. From 1998 to 2003, it has recharged 26,700 acre-feet of water, of which approximately half was effluent processed by RO. The Water Campus creates a new indirect use potable water supply from effluent

6.4 Quantities and Costs

The *Desalination and Water Purification Research and Development Program Report* (Mickely, 2001) indicated that only 15.1 percent of desalination plants in the U.S. used ED/EDR, while almost 74 percent used RO. The remaining 11.3 percent of plants used nanofiltration systems. RO has an advantage over ED/EDR because ED/EDR does not have a barrier to organics and microorganisms nor does it remove taste and odor compounds. Because of the likelihood that RO would be used to treat effluent for the added removal of organics and other microorganisms, only RO was looked at for cost.

Costs for advanced water treatment are very site specific. In 1998, during the Tucson RO study (Reclamation, 2004), cost curves were developed for constructing and operating RO plants of various sizes in the Tucson area. These curves reflected all phases of constructing and operating a RO facility including the costs of MF pretreatment, chemicals, labor, structures, electricity and everything else needed to build and operate a MF/RO facility. Since Tucson and Phoenix are similar (being southwest urban centers with similar labor force and construction material costs), these cost curves were put into a spreadsheet, indexed forward from 1998 to 2004, and used by the Planning Subcommittee for some “high level” planning work. These same curves are now used for this discussion on costs of advanced water treatment of effluent.

It is usually not cost effective or even necessary to treat all the water at a wastewater treatment or reclamation plant. For example, the approximate cost of RO treatment of 150 MGD of effluent at a large WWTP would be about \$150 million in construction and \$13.8 million annual O&M costs. Brine disposal in evaporation ponds would more than double the capital costs. But obviously, not all the effluent at a WWTP requires treatment. Different water qualities are needed for different uses. As an example, irrigation water for commercial crops such as cotton can use fairly high TDS water; there would be no need to treat effluent used to irrigate cotton or other salt tolerant crops. But water used for recharge into a good quality aquifer may need to be treated to 500 mg/L TDS, such as in California, and water for a golf course may need to be treated to below 1,000 mg/L TDS for optimal turf growing.

The following examples illustrate the cost magnitude of decreasing TDS in reclaimed water.

Example 1: A regional wastewater treatment plant with 60,000 acre-feet of effluent that will be recharged for indirect potable reuse has a TDS of 1,200 mg/L. The entity recharging this water desires to decrease the TDS to 500 mg/L. An RO facility utilizing MF pretreatment would have capital costs of about \$64 million and the annual O&M would be about \$5 million. An RO facility of this size would create a brine concentrate stream of 5.33 MGD that would require 1,240 acres of evaporative ponds for disposal. The cost of evaporation ponds would be approximately \$116 million for construction, lining and piping. Capital investment for the RO unit may be feasible, but adding cost of concentrate management makes this example project not cost effective. Solutions for this obstacle involve the creation of a more efficient RO system that produces smaller concentrate streams and developing concentrate disposal alternatives that reduce the volume of concentrate.

Example 2: A new suburban water reclamation plant delivers 500,000 gpd of effluent for golf course irrigation at a current TDS of 1,100 mg/L TDS. The golf course and water reclamation facility would like to decrease TDS to 900 mg/L TDS. An RO facility utilizing MF pretreatment would cost about \$750,000 and the O&M is estimated at about \$70,000 annually. An RO facility of this size would create a concentrate stream of 17,000 gpd that would require four acres of land for disposal at a cost of \$560,000. If the land was already available and a single liner used for the evaporation ponds the costs would be greatly reduced.

Advanced treatment of reclaimed water will be much more likely if an inexpensive concentrate disposal method was available. The desalination of effluent, while expensive, may have to be done to continue using effluent as a renewable water resource for future uses. This is especially critical for indirect potable reuse through recharge.

7.0 Conclusions

Rising salinity at the wastewater treatment plant is often not considered a pressing problem in comparison with other wastewater treatment plant issues such as sewer capacity and meeting discharge limits. Yet as water resources become more limited and reclaimed water gains acceptance as source water for irrigation, manufacturing and eventual indirect potable reuse, increasing TDS will have to be dealt with because of the implications high TDS may have with these end uses.

Currently there are no quantity or quality limits for TDS entering the wastewater treatment plant, although effluent must meet whole effluent toxicity standards as it is discharged. No rules or regulations for TDS levels at the WWTP are expected in the near future. Little data is available to define the impact of TDS load on processes at the large central WWTPs, however, a recent study indicates that the wastewater treatment process may experience nitrification inhibition as influent TDS concentrations reach 2,000 to 3,000 mg/L. It is likely that smaller water reclamation plants will receive more concentrated TDS, and will be impacted sooner than larger WWTPs. This is the case with the CCWRP in northeast Phoenix, which has experienced chronic whole effluent toxicity, possibly associated with TDS or chloride. Adverse impacts at smaller WRP's may be a warning of future concerns at larger WWTP's.

It is anticipated that WWTPs will continue to see increasing salinity concentration in the future because of high TDS source waters, increased residential and commercial water softener usage, and increased quantities of concentrated water from cooling towers. Of particular concern is the rising salinity level of the inflow to the WWTP due to the discharge of brine concentrate from advanced membrane treatment processes. The sewer is currently the most used for concentrate disposal.

There may not be a single solution to resolve the problem of increasing TDS at the WWTP, yet several options for controlling the amounts of salinity entering the treatment plant. These include:

- **Elimination of the largest TDS streams into sewer system to protect WWTPs and WRPs from inhibition or pass through.**

This may require point-source treatment of concentrated TDS streams that is generated at large industrial facilities, membrane treatment, and cooling towers. A strategy may be to encourage the private sector to develop a centralized receiving/treatment facility for TDS.

- **Placing local limits on TDS quantity and quality on known TDS sources discharging into the sewer system.**

Local limits to TDS discharge may be difficult to calculate, because there are currently no regulatory limits on TDS discharges. Studies similar to the CCWRP study will be needed to analyze who and where the largest source contributors are and quantify the chemical composition of the TDS stream so that appropriate treatment processes may be applied to manage the brine concentrate.

A possible alternative to local limits may be to develop a surcharge program. This would require an accurate accounting of TDS sources to support a surcharge, so that the costs can be fairly apportioned. An accurate evaluation of the cost of TDS treatment, including current and new costs for equipment, staff, and residuals handling must be made to allow development of cost per pound of TDS treated. All water users will be impacted by charges for TDS management, however, the largest contributors will pay more.

- **BMPs or prohibitions may be considered in place of actual local limits.**

Examples of BMPs are encouraging use of non-self regenerating water softeners (portable exchange units) and encouraging product substitution, such as using potassium chloride instead of sodium chloride in water softeners. An example of a prohibition might be limiting point source discharges to a certain number of pounds of TDS per day.

- **Allowing high TDS streams to enter the sewer system, but using desalination to treat water for end uses such as turf irrigation, industrial reuse and recharge.**

Allowing high salinity effluent to enter the WWTP would require limits for end uses and may drive up the cost of effluent. Goals should be in a range rather than specific and must be refined upon further study. Potential limits for end uses are:

- Stream discharge: 800 to 1,500 mg/L
- Industrial reuse: industry specific
- Agricultural reuse: 800 to 1,500 mg/L
- Turf irrigation; 500 to 1,200 mg/L
- Groundwater recharge: 500 to 1,000 mg/L or allowing no unreasonable harm

There are still many unknowns on the impacts of salinity on the wastewater treatment plant processes and until these impacts are identified, the mechanisms to control rising salinity entering the plants are not available or enforceable. What is necessary is to further study the effects of salinity on the WWTP and education on the implications of high salinity to water resources, not just effluent.

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