CENTRAL ARIZONA SALINITY STUDY ---- Phase I

Technical Appendix O

Municipal TDS Research

Introduction

Water availability and quality are among the world's most important environmental issues. Demand for water is increasing at an alarming rate and so are people's water quality expectations. High quality, readily available, and safe water, is essential to our quality of life. One aspect of water quality is salinity. Arizona municipalities are actively participating in studies and research to evaluate salinity in the water and wastewater. This paper will discuss the projects related to salinity or total dissolved solids (TDS) that are currently being examined by the City of Phoenix and others.

Total Dissolved Solids

TDS is considered an emerging contaminant. Although salinity has been a problem in agriculture for years, within the past 5-10 years municipalities have begun the address this issue. Municipalities across the country, particularly in the southwest, are actively researching salinity issues. Salinity or TDS is defined as the sum of dissolved solids in the water. The main constituents that make up dissolved solids include: calcium, sodium, sulfate, magnesium, chloride, and potassium.

Source Water

The City of Phoenix source water supply consists of water from the Salt River, Colorado River, Verde River, and groundwater wells. Each of these sources has a different water quality, including TDS concentrations. Colorado River water is diverted to central Arizona through a 336-mile long system of aqueducts, tunnels, pumping plants and pipelines known as the Central Arizona Project (CAP). **Figure 1** shows the TDS concentrations in the Salt River, CAP, and Verde River from January 2000 to January 2003. The TDS concentration in the water supply varies with the weather. During drought years, the levels of lakes and rivers decline due to evaporation. As the water is evaporated away, salts and impurities are left behind. This results in a direct relationship between low flow years and high salinity. **Figure 2** is a graph of the Lake Roosevelt water storage in acre-feet from 1990 through 2003. The Salt River TDS concentration is plotted along the right side of the graph. As the water storage in the reservoir decreases, the TDS in the Salt River increases. There is also a direct relationship between TDS levels in source water and drinking water because there is no reduction of TDS in a conventional water treatment plant using coagulation, sedimentation, and filtration processes. Therefore, the TDS in the source water is approximately equal to the TDS in the water distribution system.

Wastewater

Source water, irrigation runoff, residential and commercial sources, and industrial discharges all contribute to the TDS concentration entering the wastewater treatment plants. The concentration of TDS entering the wastewater treatment plant is somewhat proportional to the concentration of TDS in the water treatment plant. **Figure 3** shows the breakdown of the 1.83 Million pounds of TDS per day that are entering the 91st Avenue Wastewater Treatment Plant (WWTP). The source water is the largest contributor of TDS to the wastewater plants. Approximately 73 percent of the TDS entering the wastewater plant is a result of source water. The correlation can be seen on the graph in **Figure 4** where the Arizona Canal Water Treatment Plants (WTPs) are plotted against the 91st Avenue WWTP. The increase in TDS between the two lines is due to the salt load added from industrial, residential, commercial, and irrigation sources. The addition is also due to water conservation and concentration of salts in the system.

Residential/Commercial

Residential and commercial sources include water softeners, sanitary waste, food waste, and cooling towers. Water softeners in homes use an ion exchange system to reduce the hardness of water. Hard water, like the water supply in the southwest, contains a high concentration of calcium and magnesium. Water softening systems replace the calcium and magnesium ions with sodium ions. Water softening units require salt addition for the ion exchange to take place. The salts from the ion exchange process are normally discharged to the sewer system, thus increasing the concentration of TDS in the wastewater. Food waste also increases the TDS load in the system. Garbage disposals and discarding of liquid waste down the drain elevate concentrations. Many commercial facilities use cooling towers as an effective method to cool air in the hot months in Phoenix. A study performed by the Phoenix water conservation department concluded that 15 percent of all water produced goes to cooling towers. These units use water cycled through the system to cool the air through the process of evaporation. The water is discharged to the sewer system when the salt concentration gets too high and starts impacting the cooling process. Standard practice calls for concentrating brine 3 to 5 times before discharging to the sewer. Currently there are no regulations on brine discharge from cooling towers into the sewer system.

Industrial

Industries also have an impact on the concentration of TDS in the wastewater. Many industries require highly purified water, and must provide expensive pretreatment to remove dissolved solids before they can use the water. The concentrated brine that results from this pretreatment is frequently discharged back into the sanitary sewer system. This increases the salt load to the wastewater treatment or water reclamation plants. Membrane usage for industry needs is expected to increase as technology improves and the cost of the membrane technology decreases. This increase in membrane usage is going to result in an additional TDS load to the sanitary sewer system.

Membrane Technology

As communities are searching for additional water sources, many coastal cities are turning to the ocean to supplement their water supply. Membrane technologies have made it possible to transform ocean water into drinking water. The concern is "What to do with the brine?" In 1992 there were 133 desalting plants in the United States. This number has increased to 203 in 1999 and many more plants are in the development stages. Brine disposal is one of the critical issues that must be solved before a desalting plant can be put into operation. The US Bureau of Reclamation conducted a survey of brine disposal practices and reported that 45 percent of brine waste is discharged to surface water or the ocean. Because many cities are landlocked, like Phoenix, discharge to sewer accounts for 42 percent of all disposal methods. Deep well injection, evaporation ponds, and spray irrigation are 9 percent, 2 percent, and 2 percent, respectively.

Impacts

There are many impacts to society associated with the increase of TDS in the water system. The EPA has established "secondary maximum contaminant levels" or "SMCLs" as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. The SMCL for TDS is 500 mg/l. Dissolved solids are not considered a risk to human health at the SMCL. The EPA believes that the presence of these contaminants above the SMCL may cause the water to appear cloudy or colored, or to taste or smell bad. This may cause people to stop using water from their public water system even though the water is actually safe to drink. Drinking water high in TDS has a salty and unpleasant taste. The EPA has identified a concentration of 250 mg/l, above which sodium can be expected to impart a "salt" taste to drinking water. In addition to the objectionable taste, there are also possible adverse health effects associated with high TDS drinking water. Individuals on restricted or low sodium diets or pregnant women suffering from toxemia may be affected by high sodium concentrations in the drinking water system.

The impact of elevated salinity on irrigated agriculture land is profound. In the U.S., 14 million acres of land (25% of the total) have been adversely impacted by the build up of salinity in soils and underlying groundwater. Worldwide, 190 million acres have been either taken out of production or have reduced crop yields associated with excess salinity. There is an annual worldwide increase in impacted irrigated land of 2.5 to 5 million acres.

Some plants and crops are very sensitive to high concentrations of salt. Research conducted on fruit crops, such as grapefruit, orange, and lemon reveals that these crops show signs of lower yields when irrigated with water that has TDS values above 1,000 mg/l. Strawberries are among the most sensitive crop with salinity tolerance levels of 650 mg/l. Source water supplies above these concentrations will impact agricultural crops. Additionally, reclaimed water is often used to irrigate crops. Reclaimed water typically has a higher TDS than source water, many times as much as 300 to 400 mg/l greater than source water. This high TDS water could negatively impact the growth and yield of certain crops.

Groundwater is also impacted by high salinity in surface water and reuse water. Farming practices such as fertilizing and irrigation impact the groundwater. Irrigation runoff consists mainly of fertilizers and pesticides. Most fertilizers are forms of salts. Therefore, crops fertilized and irrigated produce a runoff that is high in TDS. This is due in part to the fertilizer used and partly due to the evaporation of the water. Transpiration from plants and evaporation from soils return essentially distilled water to the atmosphere, leaving the salts behind in the root zone. Over time, these salts accumulate in the root zone and could cause the plant to become yellow and stunted or even die. To keep this from happening, additional water is applied to flush the salts out of the root zone. Typically, an additional 5 to 20 percent above the requirement for plant growth is applied. Once this water has percolated through the root zone, it goes on to the underlying groundwater. This deep percolation water also carries all the salts that were in the root zone, the salt in the irrigation water, and the residues of fertilizers and pesticides. This practice of "over watering" to remove salts from the root zone is common among farmers, but not so common with groundskeepers, homeowners, parks departments, etc. Areas with heavy agriculture have higher concentrations due to the practice of deep percolation or flushing salts through the root zone into the groundwater. Since some of the drinking water source water comes from groundwater, the concentrating cycle of salts continues.

Industrial facilities are also impacted by high TDS water. If the potable water they receive is high in TDS, they must spend additional money and resources to "condition" the water prior to use. Many times this conditioning requires membranes such as reverse osmosis units. In the future, wastewater regulations for industries may be in place. These regulations could limit the amount of TDS they can dispose to the sewer. The industry will have to pay for pretreatment devices to treat the water prior to discharge. In addition, surcharges could be imposed for those industries that exceed the limits.

Economics

The economic impacts of increased salinity include corrosion of infrastructure and fixtures, increased treatment costs, on-site pretreatment for industrial use, reduction of reuse alternatives, and an increase by a concerned public in point-of-use devices such as home water treatment systems. In Southern California urban areas, the USBR/MWD salinity management study estimated $100 million dollars per year in damages, and concluded than an additional $100 million in damages per year will occur with each 100 mg/l increase in TDS. In the Colorado River Basin estimated damages per year exceed $330 million dollars.

Research

Research is currently taking place to address regional salinity issues. Watershed studies and source water management plans are underway to monitor TDS in the system. Source control efforts to use water supplies that are low in TDS may be one way to lower the TDS in both the drinking water and wastewater systems. The removal of TDS at water treatment or wastewater treatment plants using reverse osmosis (RO) or membrane filtration technology is another option. Research to increase concentration of brine from RO or membrane facilities will result in higher water recovery. However, this will also produce higher concentrated reject brine that must be disposed. Brine disposal options such as solar ponds, brine pipelines to the ocean, and evaporation ponds are currently being evaluated.

The City of Phoenix has many projects underway to study salinity and brine disposal. In 2002 a study was initiated with Arizona State University to study the Palo Verde Nuclear

Generating Station (NGS) evaporation ponds. For the past 20 years, the Palo Verde generating station has purchased effluent from the 91st Avenue WWTP to use for cooling water. Approximately 64,000 acre/ft a year is delivered to the Palo Verde NGS via a 35-mile pipeline. The wastewater is treated further on-site for use in the cooling towers adjacent to the nuclear generators. Continuous blowout and replacement of solution is required to properly maintain total TDS concentration at approximately 30 times the initial concentration. The blowout from the cooling towers is discharged into two, 250-acre storage ponds located on-site where evaporation is the main mechanism for disposal. Unless the structural integrity of the lining underlying the ponds has been compromised, the entire mass of solutes should remain within the confines of the ponds. The ponds have been in continuous use for over 15 years. The study will characterize the water in the ponds. The concentration of brine in the ponds will be evaluated. If there is a high concentration of brine in the pond, it is possible that natural density stratification has occurred. This would create a solar pond condition in which energy could be recovered from the lower level of the pond. The residuals in the bottom of the pond will be studied. As the residuals become more concentrated due to evaporation of the water from the pond, there could be a potential for a concentration of contaminants. The use of solar ponds as a viable method for brine disposal will be evaluated.

The City of Phoenix is taking part in an AWWARF multi-city study. Five cities were selected to participate in case studies to evaluate TDS contributions from urban residential sources. Phoenix, El Paso, Irvine Ranch, Monterey, and Santa Clara will use water flow meters and in line devices to evaluate common household products and practices, and their impact on the sewer system.

The 23rd Avenue WWTP was selected as a test site for an enhanced water recovery membrane pilot project. The project will evaluate a reverse osmosis (RO) treatment facility as a method to improve the quality of treated effluent for reuse. The membrane effluent will be blended with effluent from the plant. Quantities and concentrations will be studied to determine the most cost effective mix for reuse. Another potential goal of the study will be to evaluate enhanced water recovery systems. RO systems recover approximately 80 to 85 percent of the effluent resulting in a brine reject of 15 to 20 percent. The dewvaporation system was developed at Arizona State University as a low cost method of further concentrating brine. The dewvaporation system will further concentrate the 15 to 20 percent of brine reject from the RO system by utilizing a continuous contact tower that uses evaporation and dew formation to separate water from brine. The dewvaporation system will be operated in series with the membrane system to increase water recovery. Of the liquids entering the dewvaporation system, 99 percent will result in effluent and 1 percent will be brine reject. The potential for industrial and/or commercial applications for the dewvaporation system will be evaluated.

In February 2003, the City of Phoenix initiated a contract with a consulting company to inventory cooling towers in the valley. Cooling towers concentrate salinity in the feed water and discharge it when the salinity reaches a specified level. It is estimated that industries use upward of 30% of their water for cooling. The purpose of the study is to take an inventory of cooling towers and assess the volume and salt content of discharges sent to the City of Phoenix wastewater treatment plants. The study will focus on all cooling towers greater than 250 tons and then use this data to estimate the impact from the smaller tonnage towers. The quantity and concentration of TDS discharged from cooling towers is unknown. This project will quantify both the number of cooling towers as well as the amount of TDS discharged to the sewer from this source.

Salinity build-up and assured water supplies are readily becoming an issue of concern. Consumers, industries, and the environment are adversely impacted by higher salinity concentrations. Treatment alternatives to reduce salinity focus on source waters, industries, and domestic inputs, such as softeners and treatment systems. Although progress has been made to identify the problem, the solution is still unknown. There are many research opportunities available in the areas of source water management, membrane filtration technologies, and brine disposal options. Overall, salinity will continue to be a growing issue that impacts sustainable water supply sources. There are many organizations that have been formed to research and evaluate the impacts of salinity on our water resources. The Central Arizona Salinity Study (CASS) is a project funded by municipalities in Arizona to evaluate the impacts of salinity on the watershed. The multi-state salinity coalition consists of 4 states that have joined together to evaluate desalinization and membrane options for the removal and disposal of TDS from water supplies. The USBR and Sandia Laboratories have teamed up to develop a salinity research roadmap. This research and resulting advancements will minimize the impact of TDS on water supplies in the future.

Figure 1

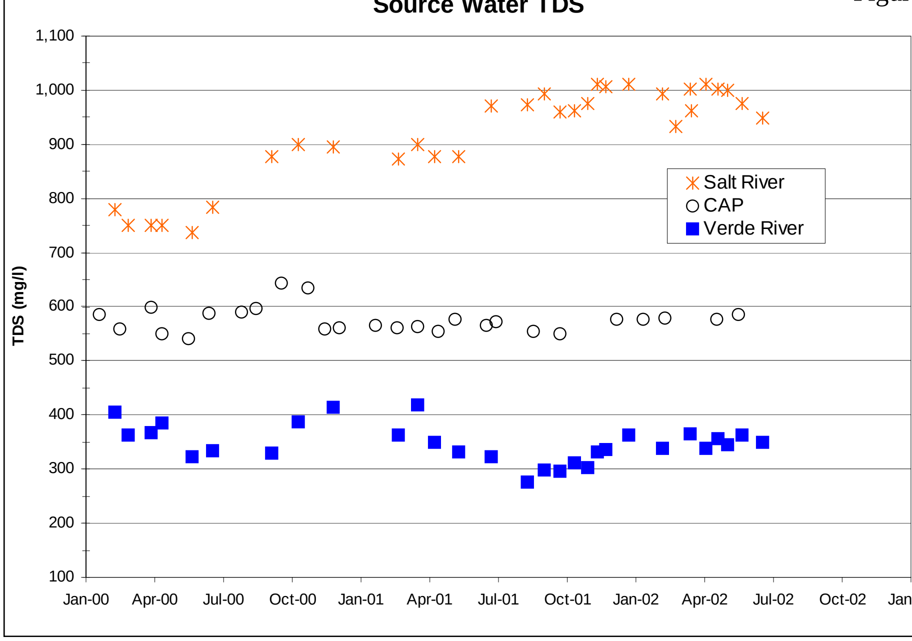

Figure 2

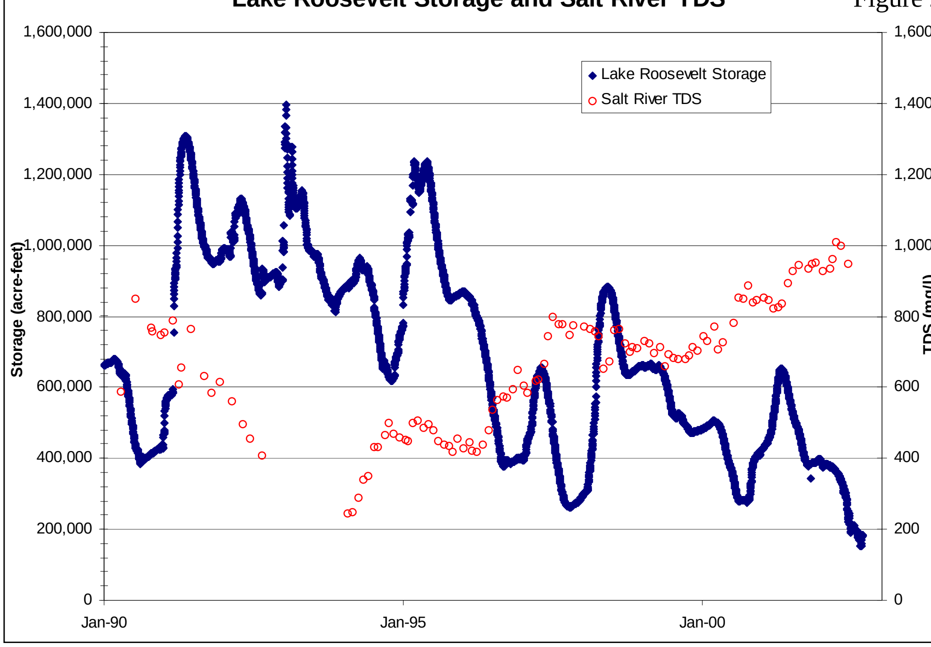

Figure 3

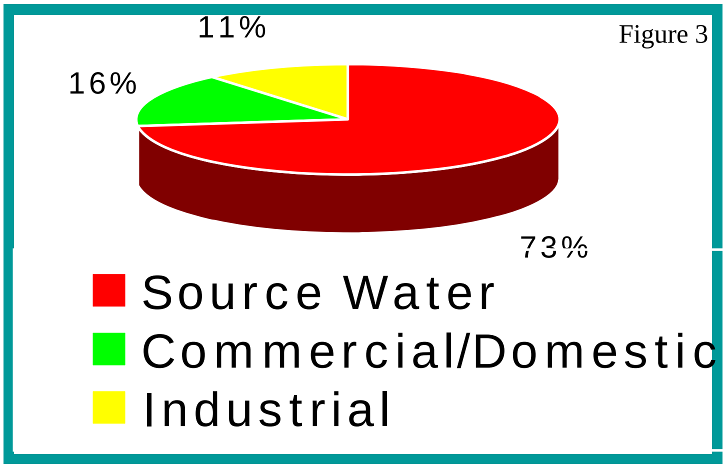

Figure 4