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Technical Memorandum

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Technical Memorandum

Subject: Additional Seawater Reverse Osmosis Brine Disposal Options

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Section 1: Seawater Reverse Osmosis Brine Disposal Options

The City of Santa Cruz (City) and Soquel Creek Water District collaborating together through scwd^2 are evaluating a potential seawater desalting project, to produce additional potable water for both utilities. Previous analyses by Brown and Caldwell (BC) explored the potential co-disposal of Seawater Reverse Osmosis (SWRO) brine with secondary effluent through the City's existing effluent ocean outfall and diffuser, located about a mile offshore. In addition to discharging the brine with secondary effluent, scwd^2 could consider other potential disposal or reuse options. These options could include making sea salts, recovering valuable minerals for beneficial uses, discharging through beach wells, and discharging directly through a new outfall. This Technical Memorandum (TM) describes and discusses these options.

1.1 Sea Salt Production

At approximately 50 percent fresh water recovery the SWRO brine salinity would be doubled to about 70,000 milligrams per liter (mg/L) total dissolved solids (TDS). As sea salt is usually made by evaporating seawater in large solar ponds, using the SWRO brine makes the process easier and requires less land area because of the brine's much higher salinity. However, the land area required for solar ponds would still be very large; the City has no significant land area available for this purpose. One alternative would be to concentrate the brine to about 200,000 mg/L TDS and truck the concentrated brine to a salt manufacturing facility for further processing to produce salt. Such concentration could be accomplished using a vapor compression evaporator (e.g. the General Electric RCC brine concentrator/evaporator), a well-established technology for seawater desalination by itself and for Reverse Osmosis (RO) brine concentration for residuals management. The drawback of this technology is that it is both capital-intensive and energy-intensive.

A newer and potentially more attractive technology that could accomplish the brine concentration to 200,000 mg/L TDS is forward osmosis (FO). FO is the opposite of RO in that it uses a draw solution with very high osmotic pressure to draw fresh water from saline water through a semi-permeable membrane, instead of using external hydraulic pressure to create the driving force for water transport through the membrane. The draw solution is typically an ammonium carbonate solution which provides the natural pressure gradient because of it has higher osmotic pressure than that of saline water. Upon heating to approximately 60 degrees Centigrade, ammonium carbonate in the diluted draw solution decomposes back into ammonia and carbon dioxide gases that are recovered for reuse, leaving behind fresh water which is recovered as drinking water with a TDS less than 500 mg/L.

Using FO as a membrane brine concentrator (MBC) is in the process of commercialization. Oasys Water (Boston, Mass.) recently completed a successful pilot testing project, to concentrate produced water from "fracking" for natural gas recovery from Marcellus Shale. The feedwater used in the tests had a 75,000 mg/L TDS for 75 percent of the time, although it ranged from 45,000 to 96,000 mg/L. The MBC product water TDS was less than 500 mg/L and the concentrate TDS was at least 200,000 mg/L, yielding a 62.5 percent volume reduction. Select Energy Services, LLC has ordered a 4,000 barrel per day (bbl/d) (120 gallons per minute [gpm]) MBC system for full-scale implementation. The estimated MBC unit cost of about $2.50/bbl ($60/thousand gallon [kgal]) (capital and operations and maintenance (O&M) costs included) is about 50 percent lower than that of brine concentrator evaporators operating today in the shale markets. For larger SWRO brine concentration projects, Oasys estimated the unit costs to be approximately $10/kgal, or $3,230/acre feet (AF). However, the net cost would be reduced significantly by recovering 67 percent of the water as drinking water. With this water recovery the SWRO capacity and costs would be reduced accordingly. For example, as shown in Figure 1, with 2.5 million gallons per day (mgd) product water capacity, the seawater influent flow is 3.0 mgd and the concentrated brine flow is 0.5 mgd. If the SWRO brine is not concentrated, the influent seawater flow would be 5.0 mgd and the brine flow would be 2.5 mgd. The concentrated brine may have an economic value that would offset the transportation cost of trucking to a salt manufacturing facility for processing to make table salt (e.g. Leslie Salt in Newark, California). However, the impacts of trucks on the roadway in terms of vehicle impacts and emissions would also need to be considered. A flow of 0.5 mgd would require 100, 5,000 gallon tanker trucks for removal, or roughly one truck leaving Santa Cruz every 14 minutes. This option may be evaluated further in the future; however, this technology is in its infancy, not having been tested on brine from seawater desalting nor in flows in excess of about 120 gallons per minute (gpm). In BC's opinion, this alternative presents too much risk to pursue further now.

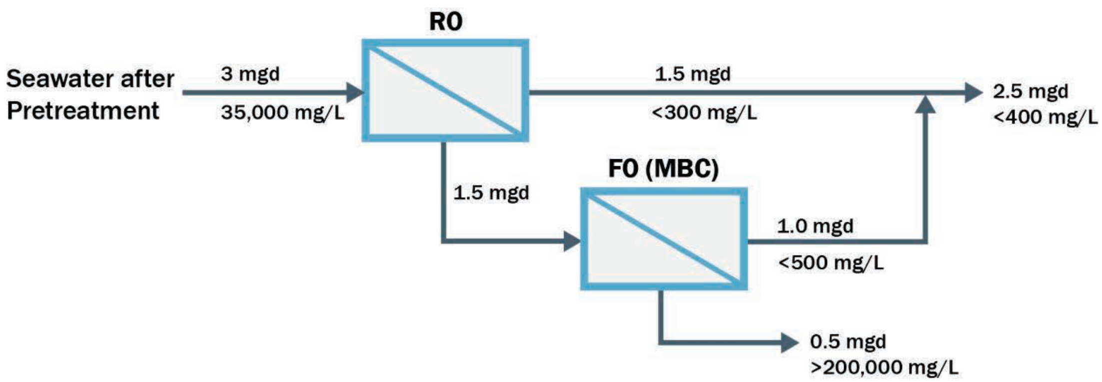

Figure 1. Water Balance Diagram with RO Brine Concentration by Forward Osmosis Membrane Brine Concentrator (MBC)

1.2 Chemicals Recovery for Beneficial Uses

SWRO brine contains large quantities of minerals that may have commercial value when extracted. Besides salt (sodium chloride), magnesium, calcium, sulfate and bromide are valuable minerals. Magnesium compounds have agricultural, nutritional, chemical, construction, and industrial applications. Calcium sulfate (gypsum) is used as construction material for wallboard, plaster, building cement, and road building and repair. Sodium chloride can be used for production of chlorine and caustic soda, highway de-icing, and food products. The existing salt recovery technologies extract salts by fractional crystallization or precipitation. Crystallization of a given salt can be achieved by concentrate evaporation or temperature control. Fractional precipitation is attained by adding a chemical precipitating agent to selectively remove a target mineral from the concentrate solution. Currently commercially available technology exists to extract magnesium and calcium salts from concentrate and for production of structural materials from these salts. While there is the potential for beneficial uses of recovered chemicals in SWRO exist, the economic and market viability is unknown and would require a separate detailed study. Since the scwd² is not in the chemical manufacturing business, BC did not evaluate this option further.

1.3 Discharging via Beach Wells

Discharging the SWRO brine through beach wells could be environmentally friendly if local geological conditions are amenable and other equal or more attractive alternatives are unavailable. Beach wells are used for small- and medium-sized desalination plants with limited success. The cities of Marina and Sand City, California have used shallow coastal wells for RO brine disposal. The facilities inject concentrate with salinity between 30,000 and 43,000 mg/L of TDS into shallow dune sand aquifers via a conventional well for Marina and a horizontal well for Sand City. The injected concentrate blends with groundwater and ultimately diffuses into the turbulent surf zone. At present, the brine from the Marina SWRO plant is no longer discharged through the brine discharge beach well because of severe scaling problems. The 0.6 mgd Sand City desalination plant began operation in 2009 and continues to discharge RO brine through its subsurface discharge. At Sand City the beach formation is large areas of ancient deep, sand dunes. Thus local conditions were suitable for a small scale brine injection discharge. On the other hand, a recent study for the proposed discharge of brackish water RO concentrate from Camp Pendleton's South Advanced Water Treatment Plant via beach wells indicated that the geological formation would not provide adequate permeability for the proposed discharge and this option was abandoned. Further, studies have been conducted along the coast of Santa Cruz that demonstrated infeasible geologic conditions for discharging brine via beach wells and thus this option is not further pursued.

1.4 Discharge via a New Brine-Only Ocean Outfall

If the scwd[2] was to choose a brine-only ocean outfall, with an ultimate desalination capacity of 4.5 mgd (brine disposal of about 7.5 mgd), a new approximately 20-inch-diameter brine-only outfall would be required. Direct ocean discharge through dedicated ocean outfalls is widely used for SWRO projects of all sizes throughout the world. The main purpose of every ocean outfall is to dispose of the brine in an environmentally safe manner, minimizing the discharge zone size in which the salinity is elevated outside of the typical range of tolerance of the marine organisms inhabiting the discharge area. The two options available to accelerate brine mixing from an ocean outfall discharge rely on the naturally occurring mixing capacity of the tidal zone or brine discharge beyond the tidal zone through the outfall's offshore diffuser to improve mixing. The main problem with installing a new ocean outfall is permitting for the construction of the coastal outfall and the direct brine discharge, as opposed to blended discharge. In California both permits are very difficult to obtain due to potential environmental impacts. Hence, a dedicated brine disposal outfall was not pursued further for the scwd[2] project, particularly because of the attractiveness of co-disposal with treated wastewater effluent through the existing effluent outfall.

1.5 Summary and Conclusion

In addition to the co-disposal with treated wastewater effluent through the existing outfall four potential SWRO brine discharge options were identified and evaluated. Due to various reasons these additional discharge options are not further considered. Table 1 presents a description of each option and the reasons for not being evaluated further.

Table 1. Summary of Additional Discharge Options Evaluation

	Option 1	Option 2	Option 3	Option4
Description	Use forward osmosis (FO) to concentrate SWRO brine and truck FO concentrate to a sea salt production facility for use	Recover chemicals from SWRO brine (e.g. magnesium, sulfate, bromide) for beneficial uses	Discharge SWRO brine via beach wells	Discharge SWRO brine via a new outfall
Reasons for not further evaluated	FO technology not mature and truck traffic impacts would be significant	Economic viability is uncertain and the City is not in this business	Infeasible geologic conditions for beach wells along the Santa Cruz coast	Permitting for a new brine-only outfall would be very difficult compared to co-disposal with treated wastewater effluent