White Pine County Exhibit C

Rebuttal Report on Water-Use Efficiency in the Las Vegas Area

August 25, 2011

Prepared for the Office of the Nevada State Engineer
on behalf of
Great Basin Water Network

Peter H. Gleick

Heather Cooley

Pacific Institute, Oakland, CA 94612

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Introduction

This rebuttal report revisits the points made in my June report, taking into account the materials submitted by the Southern Nevada Water Authority (SNWA) on July 1, 2011, relating to water conservation, water use efficiency and the purported need for the groundwater development project associated with SNWA's water rights applications in Spring, Cave, Dry Lake and Delamar Valleys.

The Las Vegas Valley has been one of the fastest growing regions in the United States, although the recent economic downturn has greatly reduced growth rates. To meet projected long-term water demand, the regional water authority, SNWA, is pursuing a range of options, including the development of additional in-state resources in the form of surface water from the Muddy and Virgin Rivers and groundwater from counties north and east of Las Vegas. One such proposal consists of building a 300-mile pipeline to move groundwater from five valleys, including Snake Valley, which spans the Nevada-Utah border. Acquisition of these resources is already creating social and political tension throughout Nevada and bordering states, particularly Utah. The environmental and economic implications of these projects may also be high.

Conservation and efficiency efforts have reduced Las Vegas per-capita demand in recent years, from 315 gallons per capita per day (gpcd) in 2000 to 223 gpcd in 2010 but despite these efforts the Las Vegas Valley still has much higher than average per-capita water use than most of the western United States, suggesting that significant cost-effective conservation potential still remains. An estimated 60 percent of all water used in SNWA's service area is applied outdoors.

The Pacific Institute is one of the nation's leading independent research centers for assessing water conservation and efficiency potential. In this analysis, the Pacific Institute evaluates water demand projections and conservation and efficiency efforts in SNWA's service area. The analysis reveals the following:

- Long-term planning efforts fail to include substantial conservation improvements that have been successfully and economically implemented widely in other western arid cities, and thus appear to overestimate future demand.

- Given recent economic and demographic trends, the population projections used for the water demand projections now appear too high, thereby further overestimating future demand.

- Las Vegas could significantly expand efforts to reduce inefficient and wasteful water use.

- Cost-effective water conservation and efficiency improvements in Las Vegas can defer or eliminate the need for new water supply facilities and investments.

- Increased indoor and outdoor water-use efficiency improves the reliability of the existing supply and does not result in so-called "demand hardening."

Per Capita Water Use is Declining But More Can Be Done

Recent reductions in per capita demand suggest that while water agencies in Southern Nevada have made significant water-use efficiency improvements over the past thirty years, far more can and should be done.[1] In 1990, per capita demand was 347 gpcd. By 2000, demand had declined to 315 gpcd. By 2010, per capita water use in SNWA's service area had fallen to 223 gpcd,[2] a dramatic reduction from the extremely high rate of 1990. The current goal, which drives future water demand projections, is to reduce water demand to 199 gpcd by 2035, still substantially above average for cities in similar climates. As shown by the trend line in Figure 1, the current goal is very unambitious and suggests a significant retreat from trends over the past 20 years.

SNWA's per capita demand has declined more quickly than that most other agencies within the Colorado River Basin. However, absolute per capita demand remains significantly higher than the median per capita demand (180 gpcd in 2008) for these agencies.[3] Denver, Phoenix, and

[1] Per capita demand trends over time should be viewed with some caution, as changes in the level and type of industry, income, the mix of single-family and multi-family homes may affect per capita demand.
[2] SNWA. 2011. SNWA's Conservation Program. Presentation to the Office of the Nevada State Engineer.
[3] Cohen, MJ. 2011. *Municipal Deliveries of Colorado River Basin Water*. Pacific Institute. Oakland, California.

Tucson, for example, already have much lower per capita demand today than SNWA is projecting for its service area in 2035 – more than two decades from now.

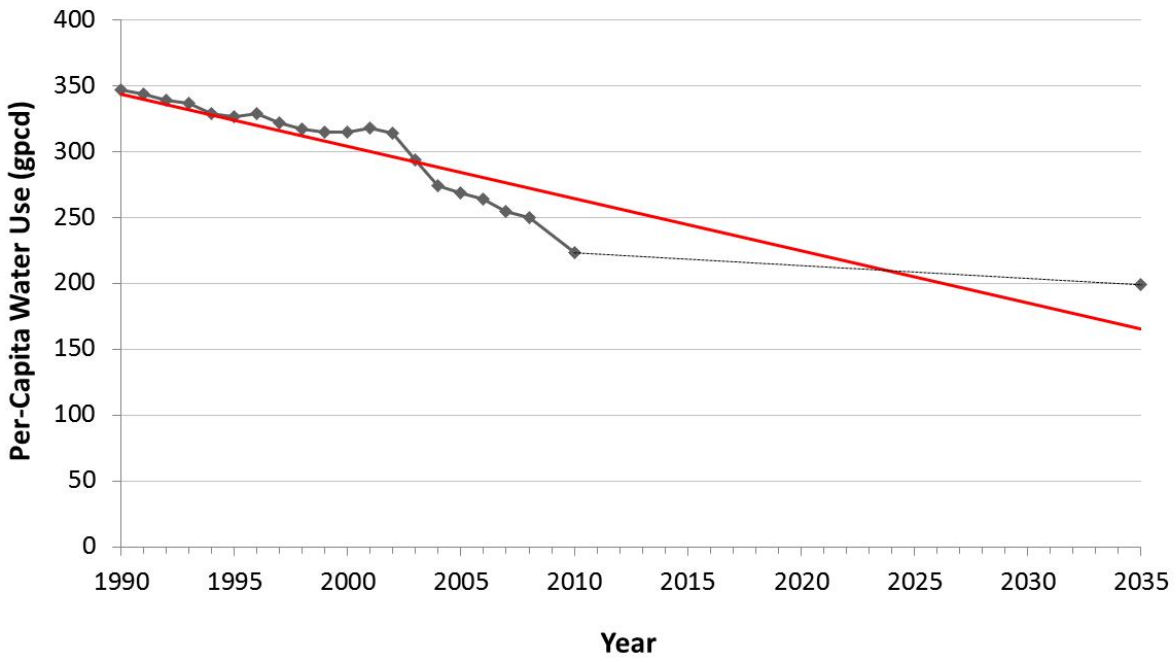

Figure 1. Per Capita Demand in the Southern Nevada Water Authority Service Area, 1990–2035.
Note: 1990 to 2010 reflect actual data. The value for 2035 represents the SNWA projections.
Source: Southern Nevada Water Authority. 2009. Appendix C in Conservation Plan: 2009-2013. Las Vegas, Nevada.

Reliance on Return Flow Credits Inflates Future Demand Projections

SNWA earns return flow credits for treated wastewater that is returned to Lake Mead via the Las Vegas Wash. These return flow credits allow SNWA to withdraw water in excess of Nevada's 300,000 acre-feet basic consumptive use apportionment from the Colorado River. Because SNWA receives credit for return flows, it has long argued that any water-efficiency improvement that reduces indoor, non-consumptive water demand reduces return flow credits and thus does not increase Southern Nevada's water resource portfolio. This argument, however, ignores six points. Increasing indoor water-use efficiency:

- permits more people to be served with the same volume of water, without affecting return flows;

- reduces dependence on water sources vulnerable to drought and political conflict;

- delays or eliminates the need for significant capital investment to expand conveyance and treatment infrastructure;

- reduces energy and chemical costs associated with pumping water from Lake Mead, treating it for use, transporting it, and treating it again as wastewater;

- reduces energy-related greenhouse gas emissions; and

- saves the customer money over the life of those improvements through reductions in energy, water, and wastewater bills.

Furthermore, SNWA projects future water demand based on total deliveries rather than consumptive use. Thus, both excessive use of water for return flow credits and projections based on delivery rather than actual consumption, inflate water demand estimates. These demand estimates are then used to justify the development of new water supplies. Reductions in indoor water demand thus represent a real savings based on SNWA's own demand projections and can help delay or defer the need to develop new, expensive water resources.

Additional Effort is Needed to Expand Indoor Conservation Efforts

According to their Water Conservation Plan, "SNWA has developed and implemented one of the most progressive and comprehensive water conservation programs in the nation."[4] Yet as noted above, water conservation efforts in Las Vegas largely ignore the potential for indoor efficiency improvements, particularly for single-family homes. Those measures targeting indoor water waste have been poorly implemented. While many water agencies in the western United States offer homeowners rebates and other incentives to replace wasteful fixtures and appliances with

[4] Southern Nevada Water Authority. 2009. Conservation Plan: 2009 – 2013. Las Vegas, Nevada.

more efficient models, these incentives are not available to many Las Vegas residents. The Water Efficient Technologies (W.E.T.) Program provides rebates for some efficient appliances to multi-family, commercial, and industrial customers, but only 29 projects are currently enrolled in the program.[5] Expanding indoor efficiency efforts and improving implementation could provide substantial water and energy savings.

Recent conservation assessments indicate that there are a substantial number of cost-effective technologies that can dramatically reduce residential water demand – both indoor and outdoor – to levels far below those projected for SNWA service area. For example, a 1997 study by the American Water Works Association (AWWA) found that conservation could reduce indoor water use from an average of 65 gpcd to 45 gpcd for single-family homes, a savings of over 30 percent.[6] The largest reductions were realized by replacing inefficient toilets and clothes washers with more efficient models and reducing leaks.

Similarly, a 2000 Seattle study found that conservation and efficiency could substantially reduce indoor water use. Installing new, water-efficient fixtures and appliances reduced single-family indoor water use from 64 gpcd to 40 gpcd, a savings of nearly 40 percent. Again, the largest reductions were achieved by installing efficient toilets and clothes washers. Further, homeowners rated the performance, maintenance, and appearance of the efficient appliances higher than the older appliances.[7] It is of note that these studies were completed 6–10 years ago and do not include newer, more efficient appliances, such as dual-flush toilets, that would reduce per capita demand even further.

Furthermore, other conservation assessments have concluded that there is significant water savings in the non-residential sector. A 2004 report by the Pacific Institute finds that existing, cost-effective technologies could reduce California's current (2000) water use for the non-residential sector by 26 percent. Savings vary by industry, but are largest for schools, office buildings, golf courses, retail stores, and restaurants. Recirculating cooling towers, x-ray water recycling units, and restaurant pre-rinse spray valves are among a few of the most promising

[5] Southern Nevada Water Authority. 2010. 2010 Annual Report. Las Vegas, Nevada.
[6] AWWA WaterWiser. 1997. Residential Water Use Summary – Typical Single Family Home.
[7] Mayer, P.W., W.B. DeOreo, and D.M. Lewis. 2000. Seattle Home Water Conservation Study: The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes. Aquacraft, Inc. Water Engineering and Management.

technologies.[8] Similarly, the Santa Clara Valley Water District , a water agency serving communities along the southern edge of the San Francisco Bay, commissioned a survey of 26 commercial, industrial, and institutional facilities and found that water conservation measures could reduce water use by 38 percent.[9]

Outdoor water savings potential is also large. While estimates for efficient outdoor water demand will vary regionally according to local climate, reducing Las Vegas' outdoor water demand to the levels achieved in Tucson or Albuquerque, e.g., 57 and 42 gpcd, respectively, could cut consumptive use substantially. While some progress has been made by SNWA in outdoor residential and commercial water efficiency improvements, far more can be done. Recent ordinances in the Las Vegas area prohibiting turf in front yards and limiting turf in backyards in new developments will help reduce overall outdoor water demand in coming years, and could be expanded to gradually apply to existing homes (upon resale, for example). Furthermore, existing, cost-effective technologies can reduce demand from the non-residential sector by 25 percent to 40 percent.[10,11] In summary, significant indoor and outdoor conservation potential exists for the Las Vegas Valley.

Population Projections Overestimate Future Water Demand

Future water demand and use depend on many factors. One of the most important and influential is the size of the population that will have to be served. Population and water demand in SNWA's service area have grown tremendously since 1990 but future population remains uncertain. The 2009 Water Resource Plan forecasts water demands based on the June 2008 Clark County Population Forecast prepared by the University of Nevada Las Vegas Center for

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[8] Gleick, P.H., D. Haasz, C. Henges-Jeck, V. Srinivasan, G. Wolff, K. Cushing, and A. Mann. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California." Pacific Institute for Studies in Development, Environment, and Security. Oakland, California.

[9] Pollution Prevention International, Inc. 2004. Commercial, Institutional, and Industrial Water Use Survey Program: Final Report. Prepared for the Santa Clara Valley Water District. http://www.cuwcc.org/uploads/tech_docs/CII_H2OUse_Survey_Prgrm_Final_Rpt_04-05-25.pdf

[10] Gleick, P.H., D. Haasz, C. Henges-Jeck, V. Srinivasan, G. Wolff, K. Cushing, and A. Mann. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California." Pacific Institute for Studies in Development, Environment, and Security. Oakland, California.

[11] Pollution Prevention International, Inc. 2004. Commercial, Institutional, and Industrial Water Use Survey Program: Final Report. Prepared for the Santa Clara Valley Water District. http://www.cuwcc.org/uploads/tech_docs/CII_H2OUse_Survey_Prgrm_Final_Rpt_04-05-25.pdf

Business and Economic Research (CBER). In 2007, an estimated 2.0 million people lived in Clark County. According to CBER, the population within Clark County was projected to reach an estimated 3.65 million people by 2035.[12] Based on this forecast, SNWA projects that water demand will increase by nearly 34 percent during this period, from an estimated 553,000 acre-feet per year in 2010 to 739,000 acre-feet per year in 2035.

More recent analyses suggest that the population assumptions in the 2009 Water Resource Plan are significantly higher than are likely to materialize and that this assumption alone has a large influence on future water demand projections. Newer population projections released by CBER in June 2009 and again in June 2010 project that the Clark County population will reach 3.13 million people by 2035, about half a million fewer people than was the basis of the 2009 Water Resource Plan.[13,14] If we assume that per capita demand in 2035 is 199 gallons per person per day and that about 97 percent of the population in Clark County is served by SNWA and its member agencies, then 500,000 fewer people in the region would reduce water demand within SNWA's service area by about 100,000 acre-feet per year. This dramatic result alone strongly suggests the need for a re-evaluation with another, more realistic population projection.

Furthermore, combining reductions in both projected population ***and*** per capita demand may completely eliminate the need for the new supplies. If SNWA reduced per capita demand to about 166 gpcd – higher than Los Angeles's *current* rate, and comparable to the *current* delivery rates of Albuquerque and Phoenix – by the year 2035, and population within Clark County grows to 3.13 million people instead of 3.65 million,[15] total water demand in SNWA's service area would be about the same as it is now.

The recent economic downturn has resulted in a significant reduction in future population, and thus water demand. When and how the region will recover is not known. Rising temperatures

[12] "Clark County Nevada Population Forecast 2008-2035," June 2008, Center for Business and Economic Research (CBER) at the University of Nevada, Las Vegas.
[13] Center for Business and Economic Research (CBER). 2009. Population Forecasts: Long-Term Projections for Clark County, Nevada: 2009 – 2050. University of Nevada, Las Vegas.
[14] Center for Business and Economic Research (CBER). 2010. Population Forecasts: Long-Term Projections for Clark County, Nevada: 2009 – 2050. University of Nevada, Las Vegas.
[15] We assume that SNWA and its member agencies provide water to about 97 percent of the population of Clark County.

and changes in precipitation patterns resulting from climate change will also affect water supplies and demand. Given this uncertainty, it is wise to consider pursuing water supplies or demand management options that can be expanded incrementally. Unlike most other water supply options, water conservation and efficiency can be expanded when water demand pressures are high and relaxed when demand pressures subside.

Significant Conservation Potential Remains in the Las Vegas Valley

While per capita demand comparisons can be extremely valuable in gauging an agency's performance in promoting water conservation and efficiency and evaluating the strengths and weaknesses of a city's water conservation efforts, they also have limitations.[16] Per capita demand, for example, is affected by a variety of factors, including the level and type of industry, income, climate, and mix of single-family and multi-family homes. Thus, a city with a high degree of water-intensive industrial or commercial development would tend to have a higher per capita demand than a largely residential city. Likewise, a city in a hot, dry climate, like Las Vegas, would likely have higher outdoor demand requirements than a city in a cool, wet climate, all other things being equal.

An end-use analysis, which evaluates the potential savings for every water use within a given region, provides a means to evaluate the conservation potential. A 2007 analysis by the Pacific Institute found that water demand in Las Vegas is substantially higher than in many other western communities. While data limitations prevented a full end-use analysis of all water users in the Las Vegas Valley, our review of single-family residential customers, hotels, and casinos indicates that installing water-efficient fixtures and appliances could reduce current *indoor* water demand by 40 percent in single-family homes and nearly 30 percent in hotels and casinos. Installing water-efficient landscapes could further reduce current *outdoor* demand by 40 percent in single-family homes. In total, water conservation and efficiency improvements for just these three sectors could reduce current water diversions by more than 86,000 acre-feet per year. While behavioral changes and efforts in other water-using sectors can produce even greater reductions, these were not included in the 2007 Pacific Institute analysis, but they are often

[16] Cooley, H., T. Hutchins-Cabibi, M. Cohen, P.H. Gleick, and M. Heberger. 2007. Hidden Oasis: Water Conservation and Efficiency in Las Vegas. Pacific Institute and Western Resource Advocates.

included in the conservation portfolios of western municipal water agencies and should be evaluated for SNWA.

Demand Hardening

Both the 2009 Water Resource Plan and the 2009 Conservation Plan raise concerns about demand hardening. Specifically, the report states that

> "While conservation is an important water management tool, the more aggressive and responsive a community is to calls for conservation, the more difficult it becomes to realize additional conservation gains. This phenomenon of diminishing returns is referred to as 'demand hardening.' For communities where a majority of the water supply comes from one source (such as Southern Nevada), the prospect of demand hardening requires development of additional alternative water supplies regardless of conservation levels achieved" (SNWA 2009).

Demand hardening refers to the concern that implementation of short term drought response measures may be ineffective if permanent water-use efficiency measures have previously been employed. Some water planners, including SNWA, argue that extensive conservation removes the slack in the system, hindering their ability to reduce demand in the event of a water shortage.

Demand hardening could be a concern for water providers in certain situations, but its importance has been overstated.[17,18] The demand hardening argument ignores a number of key points:

- Most providers can use a significant portion of water they conserve to serve new customers without harming reliability, provided that the overall demand does not increase during a shortage.

[17] Chesnutt, T., D. Pekelney, and D. Mitchell. (1997). Valuing Conservation. Proceedings of AWWA Annual Conference, 1997, Atlanta, GA. American Water Works Association.
[18] Howe, C.W. and C. Goemans. (2007). The Simple Analytics of Demand Hardening. Journal of the American Water Works Association, October 2007, Volume 99 Number 10.

- Customers who participate in long-term conservation measures and reduce their demand through technological improvements, such as low-flow toilets and efficient clothes washers, can still reduce their water use through behavioral changes during a shortage.[19]

- The technologies and economics of water-use efficiency are constantly changing. New, more efficient technologies are coming on to the market, and the price of those that are already on the market is dropping, thereby continuing to expand the cost-effective conservation savings potential of existing and new customers.

- For many water providers, conservation allows more water to be kept in storage (either in reservoirs or in aquifers underground), thereby reducing the risk and potential impacts of drought.

Furthermore, a recent AWWA article notes the economic pitfalls of relying upon the demand hardening concept: "to ignore long-term conservation benefits and to build excess water supply capacity simply to facilitate cutbacks during drought can be highly uneconomical."[20]

Conclusions

Our analysis concludes that there are a number of flaws with current water planning efforts in the SNWA service area that overestimate future water demand and underestimate the importance of conservation and efficiency, including the failure to incorporate cost-effective conservation improvements, the use of outdated population projections, and the concern about "demand hardening." As a clear example of this, simple forecasts that use more up-to-date population projections and a per capita water demand target of 166 gpcd (lower than the current SNWA estimate but well in line with current practice in most western, arid-climate cities, total water demand in SNWA's service area would be about the same as it is now. This approach would delay or even eliminate the need for new water supplies, with substantially lower economic and

[19] Mayer, P., D. Little, and A. Ward. (2006). System Reliability and Demand Hardening. Colorado Statewide Water Supply initiative, Conservation and Efficiency Technical Roundtable, March 2006.
[20] Howe, C.W. and C. Goemans. (2007). The Simple Analytics of Demand Hardening. Journal of the American Water Works Association, October 2007, Volume 99 Number 10.

political risks. These factors deserve equal consideration in any long-term water planning strategy.

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A Cheaper Way to Clean Water

Oasys Water says it will test complete, large-scale systems using forward osmosis early next year.
By Kevin Bullis

Oasys Water, a company that has been developing a novel, inexpensive desalination technology, showed off a new development facility in Boston this week. The company, which has been demonstrating commercial-scale components of its system in recent months, plans to begin testing a complete system early next year and to start selling the systems by the end of 2011.

Currently, desalination is done mainly in one of two ways: water is either heated until it evaporates (called a thermal process) or forced through a membrane that allows water molecules but not salt ions to pass (known as reverse osmosis). Oasys's method uses a combination of ordinary (or forward) osmosis and heat to turn sea water into drinking water.

On one side of a membrane is sea water; on the other is a solution containing high concentrations of carbon dioxide and ammonia. Water naturally moves toward this more concentrated "draw" solution, and the membrane blocks salt and other impurities as it does so. The resulting mixture is then heated, causing the carbon dioxide and ammonia to evaporate. Fresh water is left behind, and the ammonia and carbon dioxide are captured and reused.

Oasys says the technology could make desalination economically attractive not only in arid regions where there are no alternatives to desalination, but also in places where fresh water must be transported long distances. In California, for example, a massive aqueduct system now transports water from north to south.

"The cost will be low enough to make aqueduct and dam projects look expensive in comparison," says Oasys cofounder and chief technology officer Robert McGinnis, who invented the company's core technology. The process could also require substantially less power than other desalination options. "The fuel consumption and carbon emissions will be lower than those of almost any other water source besides a local lake or aquifer," he says.

The key to making the process work was developing a draw solution with easy-to-remove solutes, something that was done at a lab at Yale University. "Others have tried to develop other solutes for desalination," McGinnis says, "but they haven't been successful so far."

The next-biggest technical challenge has been developing the membrane. The membranes used in reverse osmosis are unsuitable for this process because they work best at high pressures. Forward osmosis doesn't use high pressures, so water moves through these membranes too slowly for the system to be practical. McGinnis and colleagues reëngineered the membranes, reducing the thickness of the supporting material and increasing its porosity without changing a very thin layer that blocks salts. These changes enabled water to pass through 25 times faster, McGinnis says.

The system uses far less energy than thermal desalination because the draw solution has to be heated only to 40 to 50 °C, McGinnis says, whereas thermal systems heat water to 70 to 100 °C. These low temperatures can be achieved using waste heat from power plants. Thermal-desalination plants are often located at power plants now, but it takes extra fuel to generate enough heat for them. The new system, on the other hand, could run on heat that otherwise would have been released into the atmosphere.

The Oasys system requires just one-tenth as much electricity as a reverse-osmosis system, McGinnis says, because water doesn't have to be forced through a membrane at high pressure. That's a crucial source of savings, since electricity can account for nearly half the cost of reverse-osmosis technology. Not working with pressurized water also decreases the cost of building the plant—there is no need for expensive pipes that can withstand high pressures. The combination of lower power consumption and cheaper equipment results in lower overall costs.

The Oasys system will not help everyone. For example, it is unlikely to do much for farmers; although they account for about 80 percent of fresh-water consumption, it wouldn't be cost-effective for them, in part because farms are often located closer to aquifers and other water supplies than are large coastal cities such as L.A. In addition, "there's a minimum amount of energy needed to strip salt ions out of water," says Peter Gleick, president of the Pacific Institute for Studies in Development, Environment, and Security in Oakland, California. "I don't think it will ever be cheap enough for irrigation." In agricultural areas where water is scarce, he says, it's cheaper to switch to better irrigation practices.

As coastal cities grow, however, so will their need for desalination services, says Kenneth Herd, director of the water supply program at the Southwest Florida Water Management District. "It's not a matter of if," he says, "but a matter of when."

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Oasys Water Commercializing Forward Osmosis Membrane

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is well known to be an emerging alternative for lower cost desalination, but thus far two developments have limited its widespread adoption; a recoverable solute and a membrane with both high flow rates and high salt rejection. Last year, the company announced a solution for solute recovery; a patented ammonia carbonate formulation producing high osmotic pressure which is recoverable using low grade heat. Today, the company is announcing that it is commercializing an improved membrane developed by Yale University and its associated FO Membrane which requires fair specifications for the production of these membranes at full scale.

This advancement now paves the way for commercialization of next generation desalination products using the company`s patented Engineered OsmosisTM platform. "We are excited about the performance of this first generation FO membrane using thin film composite polyamide chemistry and we`ve tested modules produced on existing membrane manufacturing lines without modifications. By releasing performance specifications we are further encouraging the development of new FO membranes and accelerating the deployment of lower cost desalination", says Lisa Sorgini, Vice President of Markets and Strategy for Oasys Water.

A publication in this month`s Environmental Science and Technology (ES&T) journal entitled High Performance Thin-Film Composite Forward Osmosis Membrane authored by Professor Menachem Elimelech, Chair of Chemical Engineering at Yale University, details the specifications and performance of the FO membrane. Through an exclusive license and sponsored research agreement, Oasys has rights to patented technology from Yale and is now expanding the collaboration to further promote industry standards for forward osmosis.

"Yale continues to lead in the scientific understanding of forward osmosis and we look forward to incorporating future developments into our products. We believe that open collaboration with academia is critical to educating the public on FO," adds Oasys Chief Technology Officer, Rob McGinnis.

About Oasys Water

Oasys (Osmotic Application Systems) is a Cambridge, MA based company developing a suite of proprietary energy and resource recovery products to address the growing, global water crisis. Engineered OsmosisTM (EOTM) is a platform for reducing cost in the production of clean water, power and energy through more efficient and sustainable utilization of resources. For information, please visit: http://www.oasyswater.com.

Inquiries:
Lisa Sorgini, VP Markets and Strategy
LSorgini@OasysWater.com
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Room N3-2b-42, School of MAE,
50 Nanyang Ave, Singapore 639798.

Collaborator : Han Hee Juan, General Manager, Ultra-Flo Pte Ltd

Summary :

Fresh water shortage in future will be unavoidable. At present, the oil rich Middle East countries and some developed nations, includes Singapore, exchange of oil for water using desalination technologies which are still very costly. The issues of global warming, depletion of oil reserve and the escalation of oil price, the idea of exchanging oil for water will be unsustainable. In search of more efficient desalination processes and attempting to use waste heat would be a long terms trend in desalination research and development.

This proposal aims to explore the forward osmosis (FO) membrane desalination process using a draw fluid with a high solute concentration. The FO process is to create a high osmotic pressure in the draw fluid on one side of the membrane and draw the water from the saline water on the other side of the membrane into the draw fluid. The draw fluid, diluted by water, is subsequently treated to obtain the pure water and the solute is reused in the fresh draw fluid.

Research workers reported different chemicals as solute in draw fluid and different techniques to obtain pure water from the water diluted draw fluid. So far no one had successful applied the research findings in commercial scale desalination plant.

This project will explore different FO draw fluids, different method of removing solute from draw fluid, cast dedicated RO membrane for FO process without the internal polarization and use energy efficient heat pump for transporting heat of solute regeneration.

Objective :

The objective of this research is to explore the FO as low cost desalination processes. The approaches are : (a) find a suitable draw fluid of high osmotic pressure; (b) cast a suitable RO membrane for FO process with less internal polarization; (c) minimized electric energy input and (d) use waste heat or energy efficient device like heat pump.

Motivation :

More than one out of six (1.1 billion) people lack access to safe drinking water. There are 26 countries do not have enough water to sustain agriculture and economic development. A third of Africans live without enough water as does most of the Middle-East. Within the next fifty years, the world population will increase by another 40 to 50 %. This population growth - coupled with industrialization and urbanization - will result in an increasing demand for water.

The oil rich Middle East countries and some developed nations, includes Singapore, overcome their water shortage through the exchange of oil for water using desalination technologies. The issues of global warming and pollution, depletion of world oil reserve and the escalation of oil price, the idea of exchanging oil for water will be unsustainable. In search of more efficient desalination processes and using

the available waste energy for desalination would be a long terms trend in desalination research and development.

Proposed research :

Topic : Forward osmosis membrane desalination process (FO)

The Forward osmosis (FO) process exploits the natural tendency of water to move in the direction of higher osmotic pressure when two aqueous solutions having different salinity separated by a semi-permeable membrane. Water flows across the semi-permeable membrane from a saline feed stream into a highly concentrated "draw solution", thus effectively separating the water from the saline feed water stream.

Water is subsequently extracted from the diluted draw solution by removing the solute. In order to achieve an effective FO desalination, the draw solution must have a high osmotic pressure and contain solutes that are simple and can be easily removed and reused.

In an ammonia–carbon dioxide FO process, the draw solution is composed of ammonium salts formed by the mixture of ammonia and carbon dioxide gases in an aqueous solution. A high concentration of ammonium salts in water offers a solution of high osmotic pressure that is higher than that of the seawater. When a semi-permeable membrane is placed in between the seawater and the draw fluid of higher osmotic pressure, water flows across the membrane from the seawater feed into the draw solution causing the dilution of the draw solution.

Fresh water is subsequently extracted from the diluted draw solution by removing the solute through heating at low pressure. As a similar quantity of heat would be released when the solute is re-channeled back and dissolved into the draw solution, a heat pump system could be applied to harvest the released heat from the concentrated draw fluid as heat source for heating the diluted draw solution at higher temperature.

A system block diagram is shown in figure 1.

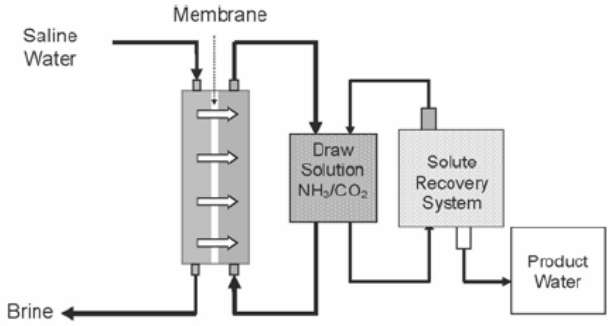


Figure 1 Block diagram showing a forward osmosis desalination system

In this proposal, work will based on ammonia-carbon dioxide water solution as draw fluid to study the FO desalination process. Heat pump would be the new contribution to the work for recovering the solute instead of using waste heat suggested by others. The project would also attempt to explore other solutes for the draw fluid aimed to reduce energy consumption and better quality of the water from the process.

All the commercial RO membranes are designed for SWRO processes. The thick membrane structure including the backing materials might not suit the FO application. It was reported that membrane internal polarization hindered the permeate flux. This work also attempts to cast a new RO membrane that is dedicated to the FO application.

The FO desalination does not require the high mechanical energy like the RO desalination process. Theoretically, the energy for heating up the diluted draw solution to extract the water can be harnessed

from the exothermic dissolution of gaseous solute into the concentrated draw solution. The only energy input is for the heat pump, and its COP could be as high as 15 due to the small temperature difference between the diluted and concentrated draw fluids.

Some statistics from others :

1. Electrical energy – 0.25 kW-hr / cu M
2. Heat for removing gaseous solute – either waste heat or heat pump for heat reuse
3. Permeate flux – 2.1 to 21 gallon/sq ft per day
4. Recovery ratio – up to 75%

The advantage of this method is that it completely avoids the high mechanical energy needed to go against the osmotic pressure in the RO process. The decomposition of the diluted draw solution could be done by low quality waste heat at low temperature whose electric energy equivalent would be negligible. The heat could also from the heat generated when the ammonia and carbon dioxide dissolved in the water though a heat pump. The method could be applied to seawater and brackish water desalination and also equally applicable to the extraction of water from treated sewer discharge.

Project plan :

The project will last for 36 months and the works to be carried out are listed as follows :

1st year : Select, develop and test suitable membranes for this application. Study the basic parameters that affect the process. Study of using heat pump for the transfer of heat.
2nd year : Formulate and test other draw solutions and compared those with the Ammonia-Carbon dioxide.
3rd year : Construct and test a sizeable system using the technology.

Costing :

13 man-years of either PhD student/engineer/scientist	$864,000
Cost of research hardware	$400000
Cost of a sizeable test system	$600000
Misc, travel, conference, patent and contingency	$200000
7% GST	$84,000
20% NTU cost	$429,600
Sub total	$2,577,600

Total research grant applying = $2,577,600 (Two million five hundred and seventy-seven thousand and six hundred dollars)

White Pine County Exhibit G

South Orange Coastal Ocean
Desalination Project

SOUTH ORANGE COASTAL OCEAN DESALINATION (SOCOD) PROJECT STATUS REPORT: July 25, 2011

Status of Key Issues for the Project

1. **Iron and Manganese Issues Research** – The iron and manganese issue is a project cost issue that needs to be understood for several reasons. The major issue is one of cost. Treatment and removal of iron and manganese is not a project fatal flaw, but it needs to be planned for **if these constituents** will be in the water over the long term. Treatment would not be required if the pumped water remains anoxic (without oxygen) which causes the iron and manganese to remain in solution, but would require waste handling for the iron and manganese in the concentrate prior to outfall discharge. Treatment represents a capital cost issue of about $50 million and an overall impact on the project cost of about $200 per AF towards the cost of the project water. If the iron and manganese is only a transitory issue, it may be able to be handled in a different manner for disposal during the start-up period until the pocket of iron and manganese laden water is fully pumped out.

   A secondary issue has to do with gaining a full understanding of the flow of water from the ocean sources into our slant well to be assured that our groundwater model is properly calibrated and to validate the preliminary yield estimates. Schematics at the end of this briefing show conceptually the three sources of the water flowing into our well – (1) brackish groundwater, age dated at about 650 years, (2) older marine groundwater, age dated at about 7500 years, and (3) the "younger" ocean water moving vertically through the system. Testing via age dating and radium isotopes is helping us to understand what percentage mix we are seeing at any particular time in the well water we pump. For some of the tests there is a one month lag in getting the analytical work completed. If, as originally expected, we pull water from the younger ocean sources, there should not be any appreciable amount of iron and manganese in the water (that is a good result). If we continue to draw water that has a high iron and manganese level, we are pulling more water laterally into our well than vertically from the younger ocean sources and the question remains will the high levels continue (if the iron and manganese disappears, that is good). The last issue is whether the water we pump will end up with oxygen in it or if it will remain anoxic (no oxygen) as it has since we started pumping. If the water remains in the anoxic state, our testing indicates the iron and manganese can be easily removed by the membranes. Plugging and fouling of the membranes will occur if the water contains iron and manganese and we get oxygen into the system. If the well begins to pump oxygenated water it will be unlikely that any iron or manganese would be present.

   a. There are two ways to better understand the flow and sources of water from under the ocean. The first is to continue what we are currently doing which

includes pumping and testing the water we pump. The exact time it will take to prove out what is occurring is unknown – it could take an extra 3 months, 6 months or more. We will only know the answer through the monitoring and testing of the water, more specifically, the age dating of the water that tells us where the water that we are pumping originates from. Our current estimate is that it will cost about $410,000 to extend the pumping for 7 months from November 2011 through June 2012. If we have to continue for an additional 5 months, the cost would be another $290,000. Funds are currently not available for these activities. Staff has met with the BUREC and MET and has requested funding assistance for this activity.

b. The second way to tell more specifically what the subsurface formation looks like under the ocean and to sample for iron and manganese concentrations is to conduct offshore geophysics and borings from the ocean into the subsurface formation. This work is expensive. Ultimately, it would probably be smart to complete this work in any event, however, given our budgetary constraints, a deferral of this work at this time is likely. We have estimated the cost of conducting borings and associated testing work at about $1.5 million to conduct three borings or about $3.0 million to conduct 10 borings. A major expense of this work is the barge rental and mobilization.

c. We are planning a Technical Advisory Committee of the Participants later in July or in early August to discuss these two options with our consulting team to develop a recommendation to bring back to the Participants group.

2. **San Juan Basin Groundwater Modeling.** This work is going slower than expected, but part of the reason we are moving slower is to make sure the San Juan Basin Authority agencies, the ocean desal agencies, our consultants and the consultant doing the Groundwater Management Plan for the SJBA are in sync with the modeling work. Our consulting group has had a number of meetings among the modelers over the past month or so to make sure we don't get to the end of the process and then have to back track and make changes for an assumption made early in the process. The effort is quite technical. We have applied a lot of resources and we have a good consultant group with whom we are working and it should ensure that our results will hold up under future scrutiny. As the modeling moves forward, we have a number of continuing meetings planned to bring all of the agencies along in the process. This should ensure that there are no surprises when we get to the end of the process. Our schedule of meetings and tasks is attached at the end of this report.

   On another matter, the SOCOD Participants requested that we approach the San Juan Basin Authority to discuss cost-sharing of the $325,000 being spent on this last phase of the groundwater modeling work. SOCOD staff met to discuss the modeling work with the San Juan Basin Authority staff, Dan Ferons from SMWD, Eva Plajzer from MNWD, Joe Sovella from South Coast and West Curry from San Juan Capistrano. Cost sharing

options were discussed. The San Juan Basin Authority agencies expressed three comments on cost-sharing of the groundwater modeling:

- The first was that they were already cost sharing because of the work Wildermuth Environment has been providing via quality assurance in reviewing and providing input into the Geoscience Modeling work.
- The second cost sharing is completing the Groundwater Management Plan by Wildermuth Environmental at an estimated cost of $400,000 that will show how the ocean desalination project will be included in the regional water resources within the groundwater basin to be collectively managed. The desal group has not been requested to contribute towards this effort, other than the groundwater modeling work.
- The third comment was that typically when a change is being requested that affects an entity such as the San Juan Basin Authority members, the proposing entity is responsible for detailing the issue and bringing it forward. In this sense, the ocean desalination group would be responsible for funding the effort.
- They requested that this position be reviewed at the next meeting of the SOCOD Participants.

3. **Cost of Water from the Project**. The project cost is estimated at $215 M at the midpoint of construction in 2017 dollars and has an estimated all in cost, including pre-treatment for iron and manganese of $1580 per AF after deducting for the MET subsidy. The weak areas of the cost estimate are the energy costs from SDG&E and the need for pre-treatment for iron and manganese. The cost estimate includes a $50 million allowance for iron and manganese removal facilities.

    a. To compare the project cost to the future cost of MET water, MWDOC has under preparation a spreadsheet model showing the SOCOD project costs compared to the cost of MET water under various assumptions. The model will allow any user to make the assumptions they feel are most appropriate to understand the impacts on the graphic plot shown below as Attachment A. The comparison of the project costs to the cost of MET water was one of the items from the workshops on which to be followed up. Because of the time required to manage the various project requirements at this time, staff has not yet finished following up on these cost issues.

    b. The current plot of project costs compared to the cost of MET water is provided below as Attachment A.

    c. The cost and other issues identified in the April 25 Workshop meeting are included below in Attachment B. These are the comments from the Participants at the Workshop.

4. Regulatory Issues – Staff continues to track and participate in the major issues that could impact our project. Most recently, Richard Bell coordinated with CALDESAL and the South Orange County Wastewater Authority to provide comments and input to the State Water Resources Control Board staff as they proceed on the Ocean Plan Amendments to study the issues of:

    a. Brine Toxicity

    b. Brine Disposal

    c. Impingement and Entrainment

    Studies on all three topics are being scoped out by the State Board and they are putting together a list of questions and issues to address and will be convening experts who will assist in the process. The State Board will use this process to establish standards which must be met in the permitting process. It is important that we continue to participate in these processes. Richard provided input at a July 5 meeting in Sacramento. His input is attached as Attachment C.

5. **Reliability Issues**. The South Orange Coastal Ocean Desalination Project provides an improvement in two types of reliability to the region and to the five local Participants. The first type of reliability is SYSTEM Reliability to allow the local agencies to continue meeting demands for water in the event the imported system or Diemer Filtration Plant is knocked out of operation. The length of time of an interruption in service is based on professional opinions and certain events could make the outage and recovery time longer than now used in planning. This uncertainty remains. SYSTEM reliability has been improved in South Orange County by the Upper Chiquita Reservoir, the Irvine Interconnection Project and the Baker Treatment Plant. The Ocean Desalination Project as well as other local supplies developed by the Participants help to improve both SYSTEM and SUPPLY Reliability. SUPPLY Reliability has to do with having the wet stuff to put in the system. The spreadsheet analysis being worked on by MWDOC will accumulate the costs of the ocean desalination project over and above the cost of MET water so the costs and benefits of the project can be better understood in terms of SYSTEM and SUPPLY Reliability investments. MWDOC has been working with several of the agencies in trying to understand the opportunities and risks of the existing import system compared to the opportunities and risks of developing an ocean desalination project or other local supply. We will continue with these efforts.

6. Other issues include the following:

    - The Phase 3 test facility began operation on June 3, 2010 and has operated consistently since that time, with the only exceptions being limited shutdowns due to power outages and the one week shutdown for the cleaning of the discharge pipeline. However, on Saturday, July 9, the pumping was shut down due to safety considerations with beach goers based on the high water level in the lagoon. The berm closure to the ocean can result in high water levels in the lagoon, which are

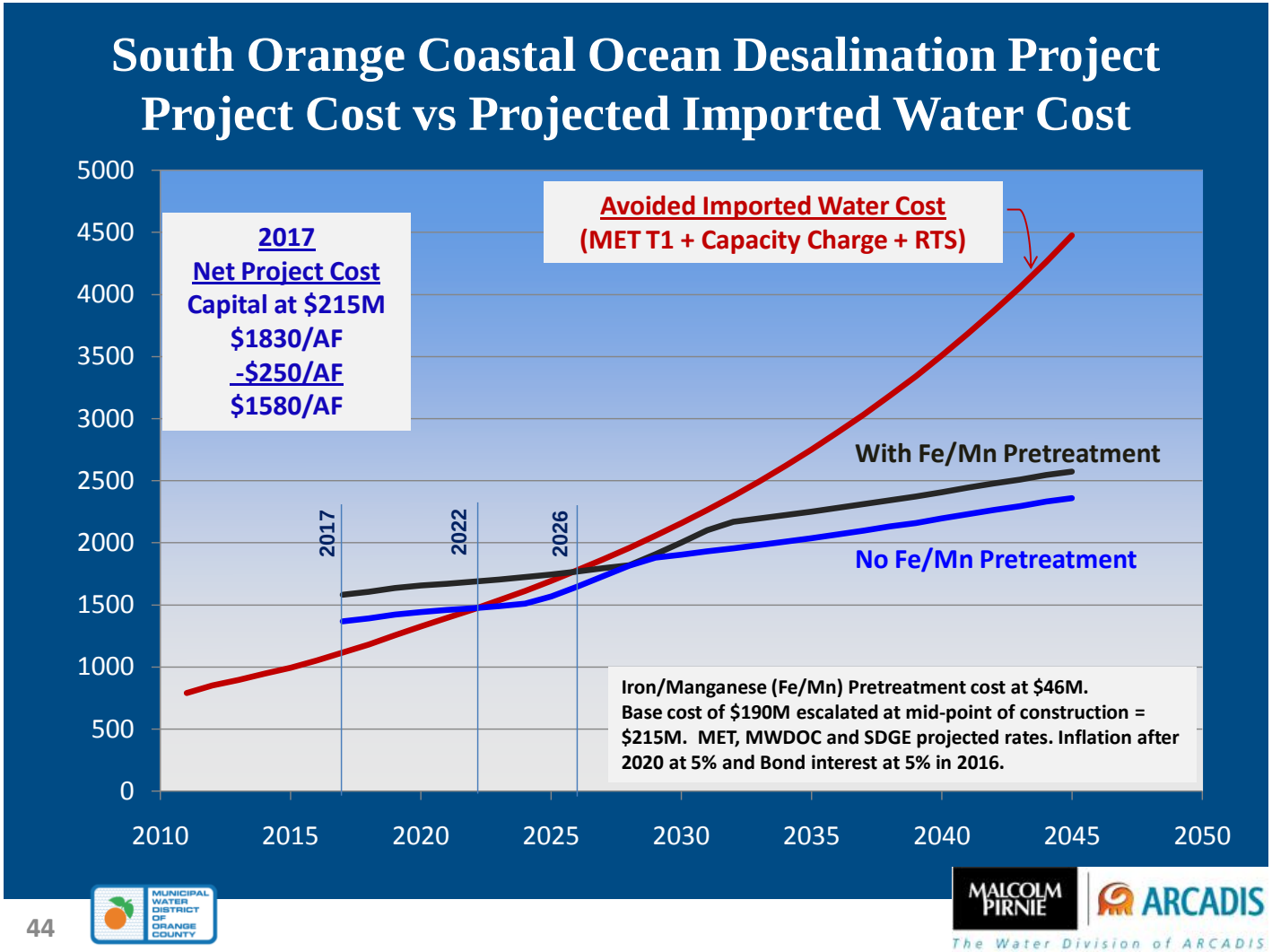
made higher by our discharge into the lagoon. State Parks was concerned about a breach in the berm creating unsafe beach conditions.

What we have found over the last year is that the lagoon and berm area are very dynamic. We had the flooding and massive sedimentation from the late December storm that changed the entire configuration of the lagoon and the location of the berm. The berm moves with the tides and wave action and flows in the creek. Our discharge was designed to flow into the ocean, but the berm moved so far out that our discharge now occurs in the lagoon. Our pumping will remain shut down until such time as the berm recedes to its normal position allowing discharge to resume to the surf zone. One option we are considering at this time is to construct an extension of our discharge pipeline further out along the groin to ensure it flows into the ocean. Staff has researched this issue and estimated the cost of extending the discharge further along the groin at a cost of about $70,000. We will be discussing this issue with the Technical Advisory Committee and developing a recommendation for the Participants. Another option is to wait for the berm to move on its own. The timing for that is uncertain. We need to complete the iron and manganese pilot plant testing which requires running the system for another four months. The longer we have to wait before start up, the longer it will take to get back to where we were when we shut down. The TDS at shutdown on July 9 was 16,200 mg/l.

- A meeting was held with the San Diego Regional Water Quality Control Board staff to brief the new head of the core regulatory group on our project, to discuss issues relative to the discharge from our Pilot Plant, and to assess any issues with extension of the pumping test.
- We have to scope out the Brine Disposal Compliance Study work with SOCWA that will need to be completed and submitted into the current SWRCB Ocean Plan Amendment process this fall. This will work will also need to be authorized at our next meeting.
- Next Participants' Meeting – We are currently assessing the need and timing for the next Participants Meeting. We will need to meet in August or September to make decisions and authorize funding for the extension of the pumping test and to relocate the Pilot Plant discharge further out along the groin so the water flows into the ocean.

South Orange Coastal Ocean
Desalination Project

Attachment A



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MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

MALCOLM PIRNIE | ARCADIS
The Water Division of ARCADIS

Attachment B

Questions or comments from the April 25 Workshop on costs:

- What was the basis of the energy cost projections? A schedule developed several years ago by an energy consultant. The annual escalation in energy is about 1.8% per year and compares favorably with a more recent California Energy Commission report. Impacts from AB-32 are **NOT** factored in.
- How were the MET costs arrived at? Used MET projections for the next 10 years and then escalated at 5% over time. The MET rates are being driven up by the Delta Fix, labor costs, the costs of securing new supplies and declining sales. Folks want to understand the major MET rate drivers.
- Need an explanation of the land costs? The number of $50 per AF was based on conceptual discussions with an appraiser familiar with the terms of the boat storage deal that was structured by South Coast Water District.
- The staffing costs for the facility look low? A staffing plan for the facility is needed, including the assumptions of how many hours it needs to be staffed and what level of maintenance is done in-house vs contracted out. The costs can vary considerably.
- No costs for staffing of the JPA were included in the cost estimate. Staff will work on this.
- What are the costs of proceeding with a conventional intake system? This is not our focus right now, but conceptual information is available from a number of years ago.
- What size land area is needed? About five acres.
- Were the costs for SDG&E electrical facilities included? Only about $1.3 million was included. SDG&E pays for most of the electrical infrastructure and recovers their costs over time via the energy rates.
- What assumption on the outfall from SOCWA? $4.6 million in improvements to the outfall was included in the estimate.
- Was the State Parks Fee included? Yes, a rough allowance was included in the amount of $2.5 million.
- What was included for San Juan Basin? The only cost included was a placeholder of $1.0 million for mitigation.
- What is the sensitivity of the project to energy costs? Very – staff will do additional work in this area.
- What bidding climate was assumed? Somewhere between medium to aggressive.
- The capital and energy are the major drivers – we need to better understand those.
- We also need to fully understand the MET water costs and why they are shown to be increasing so rapidly.

- We need full disclosure of all assumptions – they need to be documented.

Ed Means did a wrap up at the end and requested input from all Participants. The comments were captured as follows:

1. The cost of the project is important to us. We need to fully understand what is and is not included in the estimates provided, such as the land and the energy costs. Completion of the technical issues will lead us to resolve the issues on the pre-treatment with the iron and manganese. We need to fully digest the O&M costs and the costs of setting up the JPA. A technical review group made up of staff from the agencies would be good for vetting the information more fully.
2. Need to fully understand what is and is not included in the MET costs and why they are shown to increase at a faster rate. Need to have the assumptions fully detailed and we need to know the sensitivities of the various assumptions. We also need to add in the costs imposed by the San Juan Basin issues – those have not been included. We need to know what the costs from the State Parks will be and include that.
3. It is important for us to understand the primary drivers in the decision-making process and when we will be faced with those decisions. A Gantt Chart or critical path chart or schedule is needed to help us understand the decision-making process. The discussion on DBB vs DBO is not needed for several years and complicates things now and should just be taken off the table.
4. We need to know when the next increment of funding will be needed to be supplied by the Participants. We need to understand what we will be getting from the Phase 3 work, what off ramps exist and what the next steps and cost of the next steps will be. It would also be important to assess the position of all of the Participants to determine their general sense – maybe a straw vote.
5. Population is doubling every 15 years and the growing population and growing number of immigrants is driving the demand for water up while competition, the environment, laws and judicial rulings are driving the availability of water down. Projects like this will help us to balance that situation.
6. The cost of **NOT** doing the project needs to be understood. What costs would be incurred from being unreliable in droughts and earthquakes and from lack of water over the long run or the cost of just depending on MET to meet our future water needs. This project has a benefit/cost improvement to the region and we need to understand this.
7. Alternative intake structures should be investigated. Not everyone agreed on this as a primary objective at this time.
8. We need to educate the constituents on the availability of water and the risks to our future water supply from the Delta and the Colorado River.

9. We also face the political reality of having a turnover of our elected officials every two years and so we face the loss of institutional knowledge. This issue is critical and must be dealt with. A technical committee of the staff will help with this issue.
10. We need to make sure to take into account the water use efficiency savings so that we properly plan for our future needs.

The summary of requests can be boiled down to:

- Asking the Participants to describe their utilities' need for water from their perspective
- Explanation of MET cost increases and reliability issues in the Delta/Colorado River
- Chart on decision process for implementation of the project
- Clarification of funding needs for intermediate steps
- Completion of the technical work and SJBA modeling

Attachment C

Statement of
Richard B. Bell, PE
Principal Engineer/Project Manager
Municipal Water District of Orange County
Representing the South Orange Coastal Ocean Desalination Project (SOCOD Project)
and
Brennon Flahive
Environmental Compliance Administrator
South Orange County Wastewater Authority (SOCWA)
San Juan Creek Ocean Outfall Owner and Operator
before the
SWRCB
Ocean Plan Amendment Process
Brine Disposal Panel Stakeholders Meeting
July 5, 2011

SOCOD Project and SOCWA Background

- **SOCOD Project Participants: South Coast Water District, Laguna Beach County Water District, Moulton Niguel Water District, City of San Clemente, City of San Juan Capistrano and Municipal Water District of Orange County. Project Participants investigation funding is being supported by grants from the California Department of Water Resources, U.S. Bureau of Reclamation and U.S. Environmental Protection Agency.**
- **Metropolitan Water District of Southern California is providing general desalination support and will provide up to $250 per Acre Foot to the project under its Seawater Desalination Program.**
- **We are currently in Phase 3 Extended Pumping and Pilot Plant Test**
- **Modeling indicates feedwater supply at 30 mgd from 7 slant wells (95% from the ocean/marine groundwater and 5% from upstream brackish groundwater)**
- **Project yield at 15 mgd would produce 15 mgd of concentrate (brine)**
- **Outfall capacity is 85 mgd. Ownership by 5 agencies (4 in SOCOD Project)**
- **Outfall dry weather flow varies seasonally from 17 mgd to 22 mgd**
- **The California Coastal Commission supports co-disposal of ocean desalination brines as a cost-effective means to reduce environmental and water quality impacts and to make better use of existing facilities at reduced public costs**
- **The planned SOCOD Project co-disposal of 15 mgd of brine with 17 mgd of wastewater will result in a blended, buoyant wastewater stream close in salinity to ocean water.**

Brine Disposal – Suggested Questions for the Experts Panel

- **What are the critical data needs and what is the process to prepare, submit and review the SCWRRP Experts Panel draft report? Schedule?**

- **The panel should understand the methods and technology of brine disposal.**
- **The panel should insure that co-disposal of ocean desalination brine and wastewaters is a best disposal technology considering the environmental benefits that receiving waters can derive (reduction of salinity shock, reduced concentrations of conventional and trace pollutants, reduced buoyancy, etc)**
- **The panel should focus on how the Zone of Initial Dilution (ZID) can be allowed in co-disposal operations, which will need a horizontal mixing zone. The panel should evaluate how a horizontal component for dispersion can be established, evaluated and monitored.**
- **The panel should evaluate how outfall diffuser port technology can be enhanced to improve initial dilution.**
- **Data gaps appear in the area of salt toxicity and effects on relative species abundance and that a balance in the process needs to be struck to ensure that a narrowly focused toxicity regime does not, in affect, prevent ocean desalination in California. The panel should be charged to insure that its recommendations can allow disposal of ocean desalination brines.**

Experts Panel

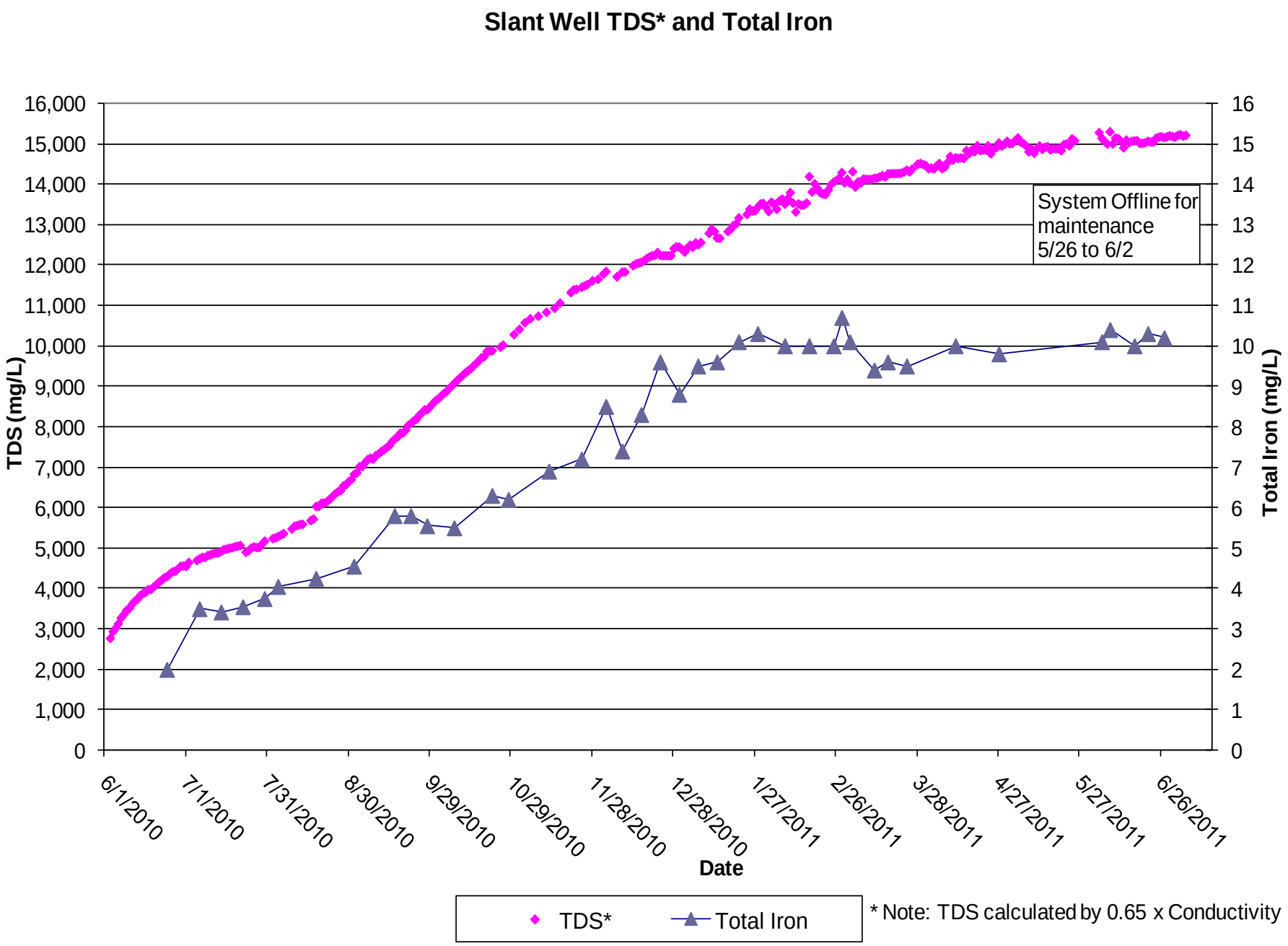
- **We suggest that the SCWRRP Experts Panel include at least 4 members with specialization in coastal marine biology, physical and chemical oceanography, diffuser and plume dispersion numerical modeling, brine disposal technology, marine biochemistry and marine toxicology. The Experts Panel preferably should have sufficient experience and capabilities in their respective disciplines as well as a working knowledge of California coastal water conditions across areas of planned ocean desalination. Some familiarity with the SWRCB/RWQCB's regulatory process for brine disposal would be welcomed. Geographic diversity amongst the members would likely be helpful.**

Stakeholders Input

- **We have $50,000 in Project EPA grant funding available for a co-disposal study. After the SCCWRP Experts Panel identifies the issues/data gaps, we can perform the study with submittal into the process to assist in their charge. How can we do this and help the process? This could be submitted about 4 months after the issues/data gaps and scope/budget is finalized.**

Recognize the Importance of Ocean Desalination as Part of the Future Water Supply Mix

- **The Experts Panel and State Board should recognize that the combined effects of population growth, impacts of extended drought, future climate change, and the increasing demands on traditional sources of water make Ocean Desalination an important and sustainable part of the future drinking water supply mix for California.**
- **The Experts Panel and Board should not overlook that ocean desalination is successfully practiced in water scarce regions around the world.**



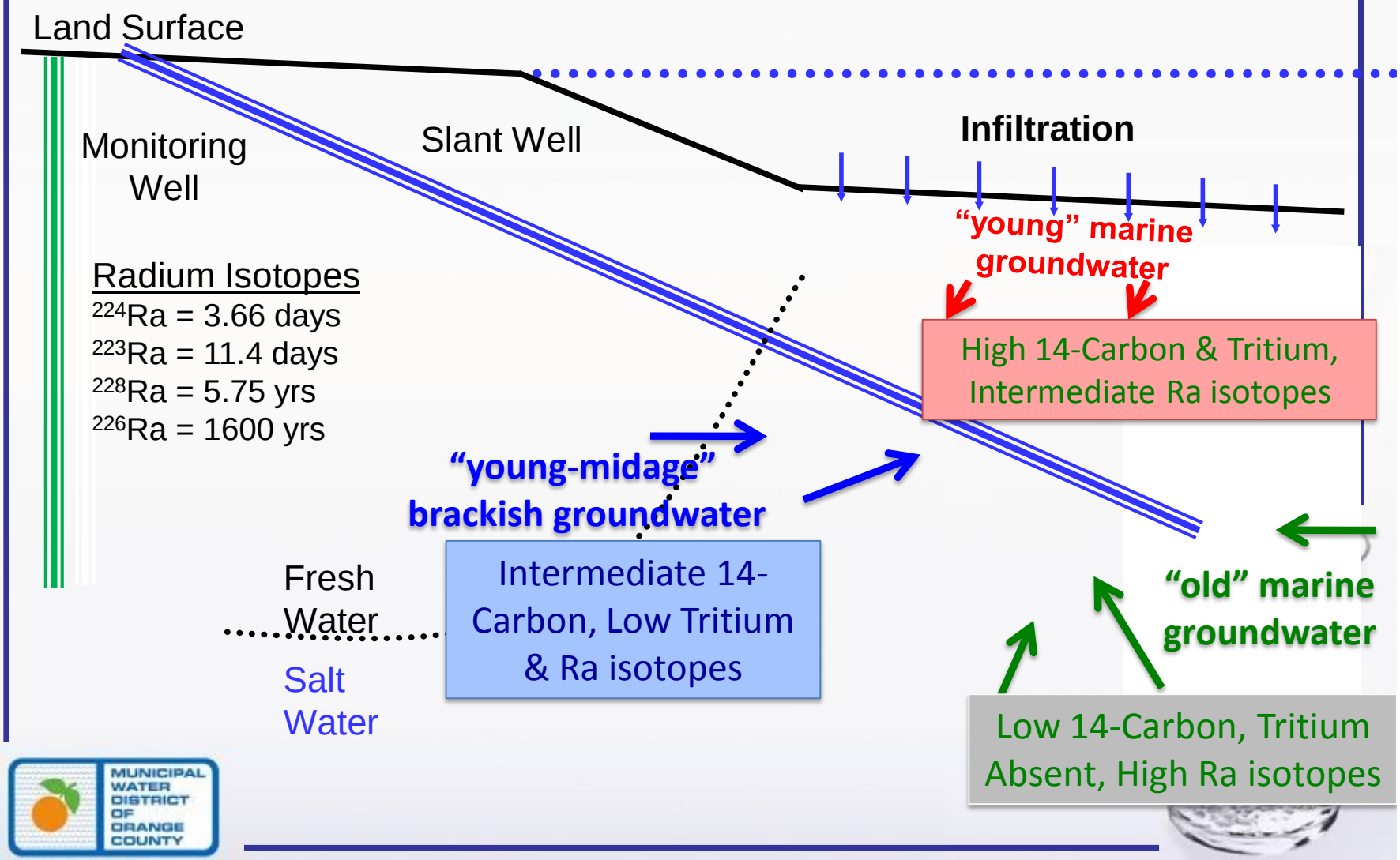
* Note: TDS calculated by 0.65 x Conductivity

Geochemistry Studies

- Led by Dr. Matt Charette at Woods Hole Oceanographic Institute
- Lagoon Tracer Study
  - SF_6 used as a tracer in San Juan Creek Lagoon to quantify hydraulic connection and travel time between lagoon and slant well
  - Very low levels of SF_6 have been detected in the slant well, within error range, indicating no significant connectivity
- Radium Isotopes
  - Used to identify recharge source for the slant well
  - Results to date indicate slant well water is old marine groundwater, with little influence from overlying ocean at this time
- Groundwater Age Tracers
  - Carbon-14, Helium-Tritium, and Helium-4 tests are also being conducted
  - Older groundwater indicates offshore horizontal flow of marine groundwater, where younger water indicates vertical recharge

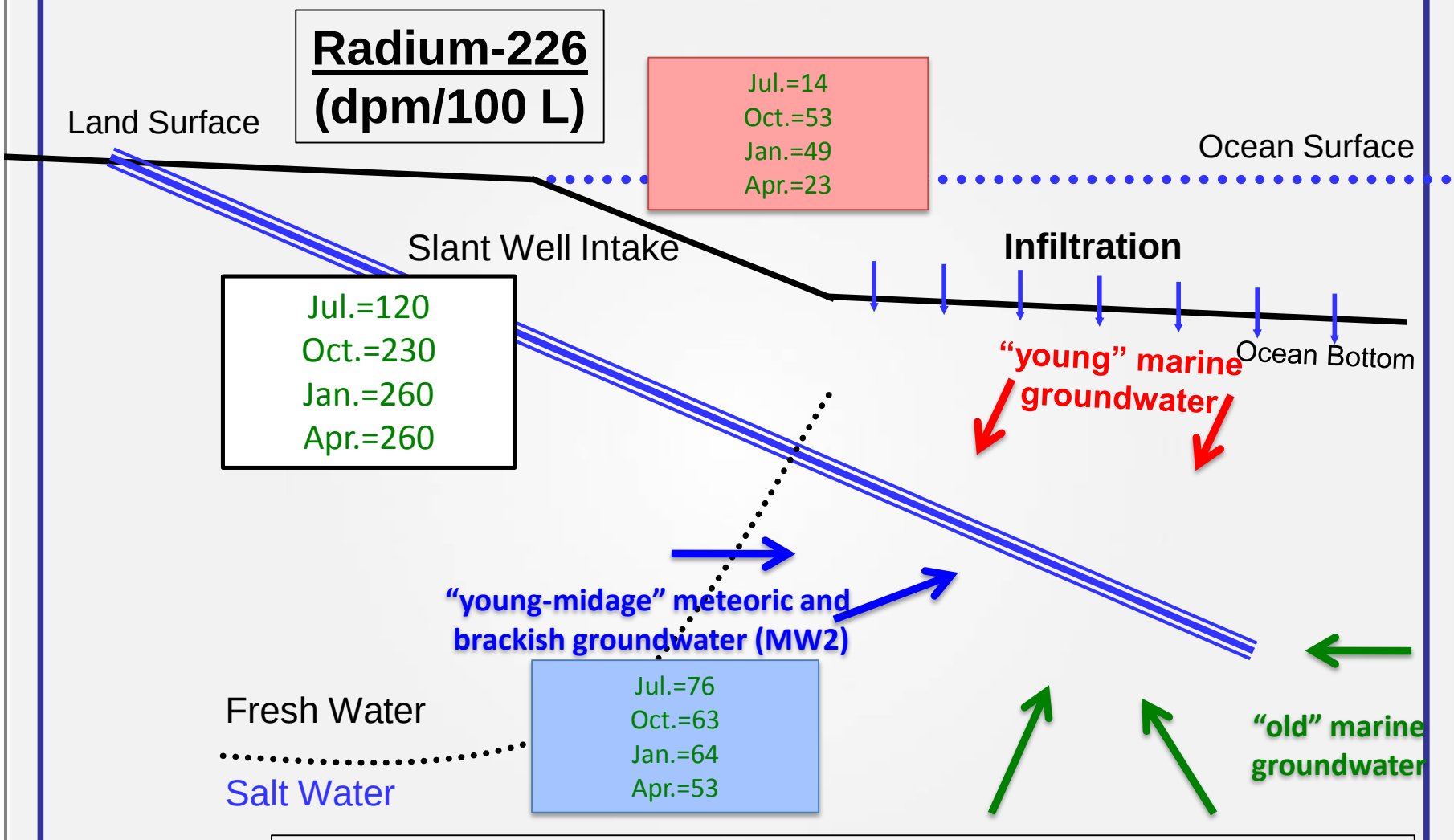
MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Groundwater Fingerprinting and Age Dating



MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

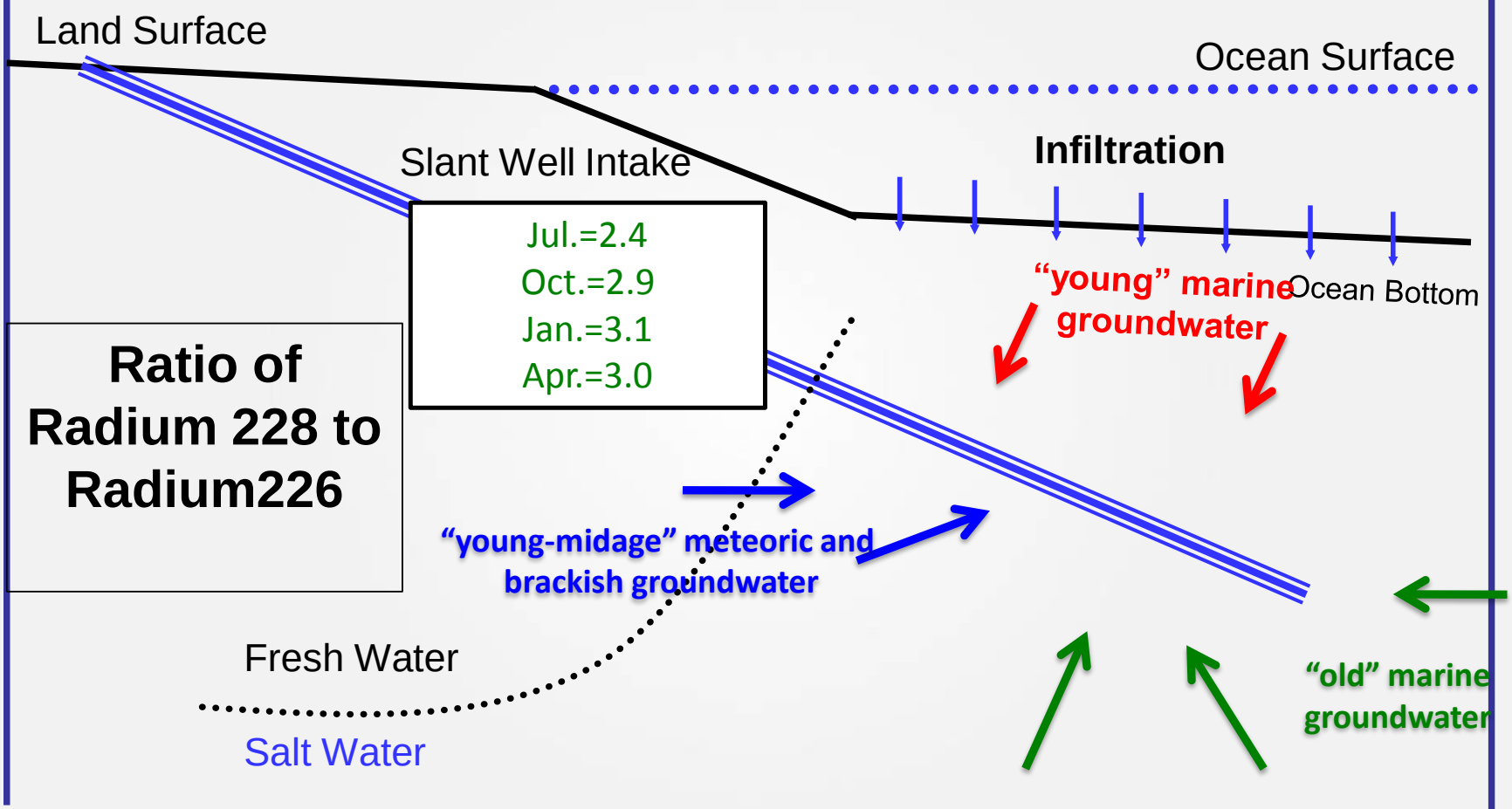
Groundwater Fingerprinting and Age Dating Using Radium Isotopes



Increasing radium levels at the slant well intake relative to ocean water and meteoric groundwater suggest that pumping has not yet entrained a significant portion of young marine groundwater, however, the rate of increase slowed and reached a plateau between January and April. This could be interpreted as evidence for entrainment of a small fraction of young marine groundwater.

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

Groundwater Fingerprinting and Age Dating Theory: Radium Isotopes



Increasing ratio of radium 228 to 226 indicates that the slant well intake is entraining marine groundwater from a more rapidly flushed portion of the aquifer (higher ratios are driven by (1) radium removal during exchange with the overlying ocean water followed by (2) faster regeneration of the shorter lived 228Ra relative to 226Ra)

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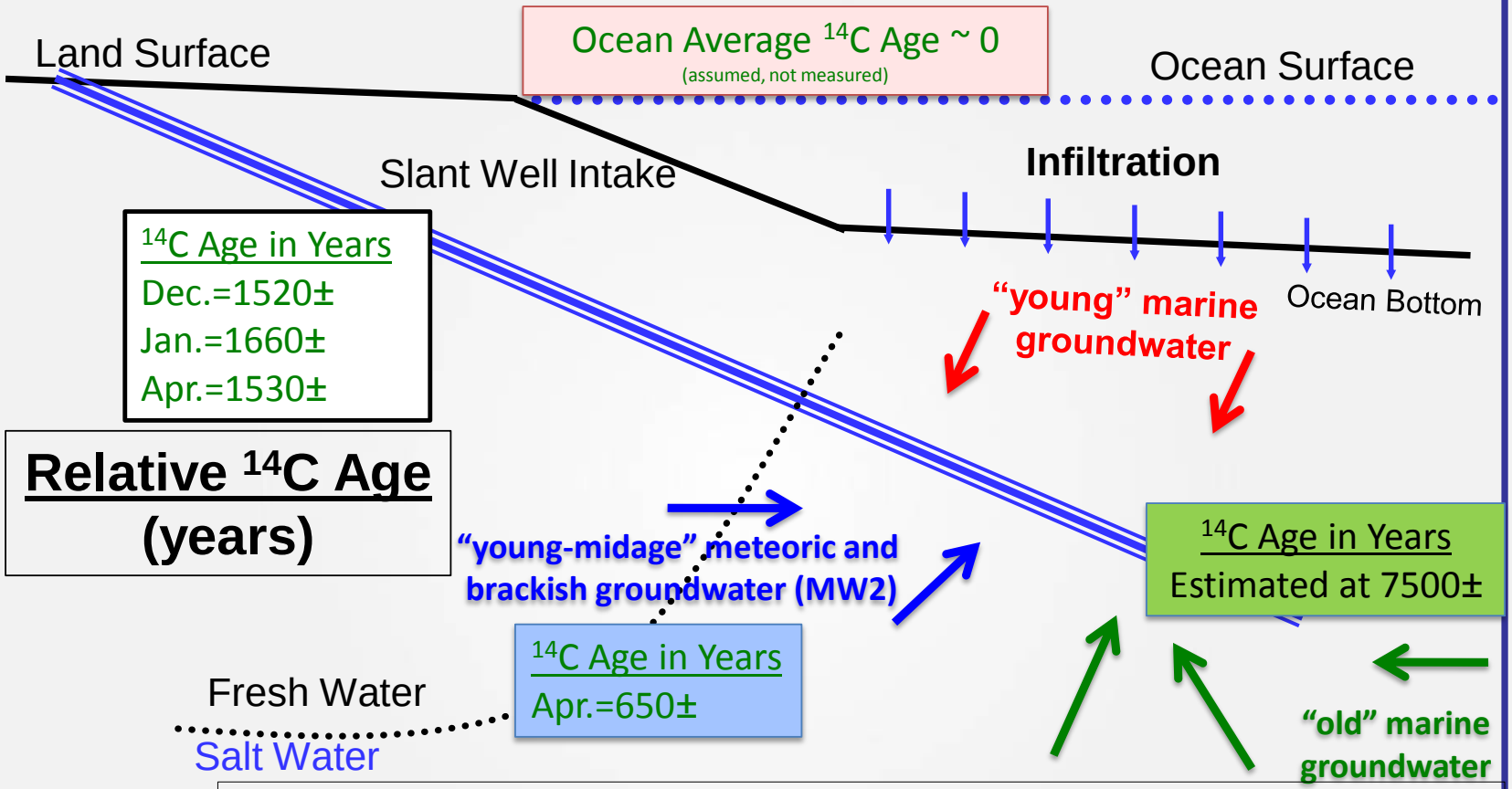
Groundwater Fingerprinting and Age Dating Theory: Radiocarbon (^{14}C)



Measured in dissolved inorganic carbon (DIC), carbon-14 can be used to age date groundwater up to ~50,000 years old. So far, the age of the slant well intake water has ranged from ~1500-1700 years, roughly 2.5 times higher than onshore brackish groundwater. Given a seawater radiocarbon age of ~0, this confirms that the slant well intake is capturing mostly older marine groundwater. From Dec. 2010 to Jan. 2011, slant well groundwater age increased ~140 years implying continued entrainment of "old" marine groundwater. However, we observed a decrease in age by Apr. 2011 with an increase in salinity, a possible sign of younger marine groundwater capture. However, the relatively small change in age makes this conclusion tenuous at this stage. The planned additional sample collection (through the end of 2011) should help solidify these trends.

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DRAFT

Project Schedule - Refinement of the San Juan Basin Groundwater Model

Task	Description	Jun-11				Jul-11				Aug-11					Sep-11				Oct-11					Nov-11				Dec-11			
		6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	5	12	19	26
1	Update the SJB Groundwater Model with Updated Hydrogeologic Data	Completed																													
2	Refine Model Layers and Aquifer Parameters Based on Results from a Lithologic Model			WEI 2					WEI 4																						
3	Refine Model Recharge Terms with Results from a Watershed Model Developed by PACE		WEI 1					WEI 3		MAC 1																					
4	Augment the SJB Groundwater Model with a Solute Transport Model Capability (using SEAWAT Version 4, a 3-dimensional, variable density, groundwater flow and solute transport model)																														
5	Develop a Focused Model in the Vicinity of Ocean Desalination Wellfield and San Juan Creek Coastal Lagoon (with finer cell size and vertical discretization, approximately 10 layers with a cell size of 10 ft by 10ft)																														
6	Perform Model Calibration and Predictive Runs (All model runs include groundwater flow and solute transport model simulations using both the SJB Groundwater Model (i.e., "regional model") as well as the focused model in the Project area (i.e., "local model"))																														
6.1	Case 1 - Calibration/Historical Simulation											WEI 5			WEI 6			MAC 2													
6.2	Case 2 - Maximum Local Yield (No Ocean Desalination Project)(Iterative model runs required)																			WEI 7			MAC 3								
6.3	Case 3 - Ocean Desalination Project with Adjusted Basin Operations																								WEI 8						
6.4	Case 4 - Physical Mitigation Measures Runs (Assumes Three Mitigation Measures including Radial Collector Wells, Addition of Recharge Basins and Injection Barriers)(Iterative model runs required for each mitigation measure)																										MAC 4				
7	Preparation of Reports																														
7.1	Prepare Draft Model Report																														
7.2	Address One Round of Comments and Preparation of Final Model Report																														3 weeks after comments have been received

WEI 1: Meeting with WEI on 17-Jun-11 to review San Juan Basin Surface Water Model
WEI 2: Meeting with WEI on 24-Jun-11 to review San Juan Basin Lithologic Model
WEI 3: Meeting with WEI to review refined San Juan Basin Surface Water Model
WEI 4: Meeting with WEI to review refined San Juan Basin Lithologic Model
WEI 5: Meeting with WEI to review calibration of San Juan Basin Groundwater Model
WEI 6: Meeting with WEI to review refined calibration of San Juan Basin Groundwater Model
WEI 7: Meeting with WEI to review San Juan Basin Groundwater Model results for No Project Conditions
WEI 8: Meeting with WEI to review San Juan Basin Groundwater Model results for Project Conditions

MAC 1: Meeting with MAC to review San Juan Basin Surface Water Model
MAC 2: Meeting with MAC to review calibration of San Juan Basin Groundwater Model
MAC 3: Meeting with MAC to review San Juan Basin Groundwater Model results for No Project Conditions
MAC 4: Meeting with MAC to review San Juan Basin Groundwater Model results for Project Conditions