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City of Oxnard

Public Works Integrated Master Plan

WATER

PROJECT MEMORANDUM 2.5
SUPPLY AND TREATMENT ALTERNATIVES

FINAL DRAFT
December 2015

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City of Oxnard

Public Works Integrated Master Plan

WATER

PROJECT MEMORANDUM 2.5
SUPPLY AND TREATMENT ALTERNATIVES

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SUPPLY AND TREATMENT ALTERNATIVES

1.0 INTRODUCTION

The City of Oxnard (City) has long been in the process of identifying and building up a sustainable water supply for their community. The alternatives evaluation presented within this Project Memorandum (PM) builds on previous discussions and studies that have already been conducted on the two systems. Because the water and recycled water systems are so intricately linked, the two systems were analyzed as distinct but synergistic systems and are discussed together within this PM.

The purpose of this alternative analysis was to consider various ways and facilities needed to provide a sustainable water supply for the City over the planning horizon, 2015 to 2040. The outcome of this analysis is used to develop the list of water and recycled water projects to be included in the CIP of the Public Works Integrated Master Plan (PWIMP) with associated project cost, timing, and drivers. The CIP is an estimate of the City's capital expenses over the next 25 years to address limitations, rehabilitation needs, and recommended improvements to the water and recycled water systems. The CIP is intended to assist the City in planning future budgets and making financial decisions.

1.1 PMs Used for Reference

The recommendations outlined in this PM are made in concert with recommendations and analyses from other related PMs:

- PM 1.1 – Overall – Master Planning Process Overview.
- PM 1.5 – Overall – Basis of Costs.
- PM 2.1 – Water System – Background Summary.
- PM 2.2 – Water System – Flow Projections.
- PM 2.3 – Water System – Infrastructure Modeling and Alternatives.
- PM 4.1 – Recycled Water System – Background Summary.
- PM 4.2 – Recycled Water System – Infrastructure Modeling and Alternatives.
- PM 5.5 – Stormwater – Alternatives Analysis.

1.2 Other Reports Used for Reference

In developing the alternatives in this PWIMP, recommendations from other reports were incorporated to ensure a well-rounded and holistic look at the water and recycled water systems. The following reports are used in this PWIMP analysis:

- City of Oxnard 2010 Urban Water Management Plan, May 2012 (Kennedy/Jenks Consultants, 2012).
- Preliminary Draft, Public Health Goals Report, June 2013 (Milner-Villa Consulting, 2013).
- City of Oxnard 2010 Draft Water Conservation Plan (A&N Technical Services, Inc., 2010).
- Preliminary Hydrogeological Review, City of Oxnard Groundwater Replenishment Reuse Project, Potential Wellfield Location Study, Jan 2015 (Hopkins, 2015a).
- Preliminary Hydrogeological Study, City of Oxnard Great Program Campus Park Groundwater Replenishment and Reuse Project, June 2015 (Hopkins, 2015b).
- *Direct Potable Reuse Case Study: Evaluation of Risk Reduction Principles for Direct Potable Reuse* (WRRF-11-10), Draft, July 2013. (WRRF, 2013).
- Seawater Desalination Project Overview, City of Oxnard Recycled Water Retrofit Program, Draft, April 2012 (Carollo, 2012).
- City of Oxnard Water System Optimization: Preliminary Benchmarking Report, March 2015 (Lincus, 2015).

2.0 WATER SUPPLY GOALS

Master planning the City’s water and recycled water systems considered the overall planning objectives for the PWIMP, as outlined in PM 1.1, *Master Planning Process Overview*. In addition, specific water supply goals were identified that provide an overarching framework for alternatives development and comparison. These water supply goals include:

- Provide reliable/resilient supply to meet future conditions (i.e., changes to demand, regulations, water quality).
- Meet City’s water quality objectives.
- Protect existing water rights by maximizing use of groundwater allocation.
- Minimize future reliance on imports by maximizing use of AWPF Facility.
- Attract industry and jobs.
- Keep rates affordable.

One major constraint that is placed upon the City's system and must be worked within is the safe yield of the Oxnard Plain Groundwater Basin, from where Oxnard draws its groundwater. The Fox Canyon Groundwater Management Agency (FCGMA) is responsible for protecting the quantity and quality of the local groundwater by overseeing and managing all contractual withdrawals within the Oxnard Plain Groundwater basin. The 2010 UWMP provides a more detailed discussion of the contractual arrangements related to the City's groundwater rights (Kennedy/Jenks, 2012).

3.0 EXISTING AND FUTURE WATER SUPPLY

To understand the City's water supply needs both now and in the future, a summary of the water supply available to the City was compared with the projected demand between now (2015) and 2040, the planning horizon. For this comparison, several assumptions were made, as follows:

- Imported surface water from CMWD remains equal to the historical allocation.
- Two groundwater pumping restriction possibilities were considered at 75 percent and 50 percent of historical allocation. These assumptions were made in part as a result of conversations with United Water and their relationship with the FCGMA. FCGMA regulates the groundwater pumping restriction on any given year based on their assessment of safe yield of the groundwater basin. Currently, pumping within the Oxnard Plain Groundwater Basin is restricted per Emergency Ordinance E. Emergency Ordinance E, effective July 1, 2014, calls for up to 20 percent reduction in pumping over the City's Temporary Extraction Allocation (TEA). The TEA is defined as any extractions that occurred during 2003 to 2012. Appendix A contains the full details of Emergency Ordinance E. Given the temporary nature of this ordinance, reductions to historical groundwater pumping allocations were instead used to estimate supply for the planning horizon.
- The future of additional groundwater credits (as discussed in PM 2.1, *Water System - Background Summary*) are unknown and not reliable; therefore, these were not included in the available supply analysis.
- Pump-back allocation for any recycled water supplied to agricultural users will be at a 1:1 ratio; though the future of this assumption is also unpredictable.

Tables 1 and 2 summarize the existing and projected available water supply for the two groundwater pumping restriction assumptions, Low (75 percent) and High (50 percent), respectively. Table 3 compares the projected available supply with the projected demand, as determined in PM 2.2, *Water System - Flow Projections*. From Table 3, there is an estimated supply gap, based on quantity only, of between 3,800 and 10,700 AFY, based on the Low (75 percent) and High (50 percent) groundwater pumping restrictions. Figure 1 graphically illustrates the comparison of projected available supply versus demand over the planning horizon.

Table 1 Summary of Projected Supply (assuming Low Groundwater Pumping Restriction[1])
Public Works Integrated Master Plan
City of Oxnard

Supply	Historical Allocation	Projected Supply/Demand					
		2015	2020	2025	2030	2035	2040
Local Groundwater[2]	12,456	7,348[11]	9,581	9,581	9,581	9,581	9,581
Baseline	*954*	--	*954*	*954*	*954*	*954*	*954*
Historical Use	*11,502*	--	*8,627*	*8,627*	*8,627*	*8,627*	*8,627*
UWCD[3]	9,070	7,161[11]	6,803	6,803	6,803	6,803	6,803
CMWD[4]	12,500	13,826	13,826	13,826	13,826	13,826	13,826
Ag Development Re-Allocation[5]		0	149	376	603	830	1,057
Subtotal Supply		**28,335**	**30,359**	**30,586**	**30,813**	**31,040**	**31,267**
Recycled Water Offset[6]		--	1,475	1,475	1,475	1,475	1,475
Loss (Brine)[7]		(800)	(1,890)	(1,890)	(1,890)	(1,890)	(1,890)
Total Firm Supply		**27,535**	**29,944**	**30,171**	**30,398**	**30,625**	**30,852**
Other Potential Supplies							
PHWA Exchange[8]		700	700	700	700	700	
RW Pump Back Allocation[9]		--	3,620	3,620	3,620	3,620	3,620
Good Deeds Trust[10]		1,000					
Total Potential Supply		**29,235**	**34,264**	**34,491**	**34,718**	**34,945**	**34,472**

Notes:
(1) A restriction in the groundwater pumping of 75% of historical allocation (regulated by the FCGMA) is assumed on all groundwater sources, unless otherwise noted.
(2) The City's groundwater allocation is made up of a baseline and historical use allocation. The assumed FCGMA restriction on groundwater pumping is applied to the historical allocation only.
(3) The assumed FCGMA restriction is applied to the historical UWCD allocation.
(4) CMWD projection Tier 1 allocation as of Jan 1, 2015. It does not include 4,700 AFY allocated to PWHA.
(5) Estimate for ag re-allocation is based upon planned ag conversion acreage through 2040 and using a re-allocation factor of 1 AFY per acre converted.
(6) Based on contracts as of 2015; does not account for future urban or ag uses at this time. For details, see PM 4.2.
(7) Based on existing (as of 2015) desalting capacity of 7.5 mgd (8,400 AFY).
(8) Annual transfer of FCGMA credits from PWHA, per 2002 Three Party Water Supply Agreement.
(9) Based on a 1:1 pump-back allocation ratio of RW supplied to ag users (Southland, Houweling, Reiter, and River Ridge Golf Course).
(10) Only through 2019. UWCD has not transferred the allocation since 2013 and the City has requested a refund for payments made.
(11) Based on Emergency Ordinance E, Temporary Allocations.

Table 2 Summary of Projected Supply (assuming High Groundwater Pumping Restriction(1)
Public Works Integrated Master Plan
City of Oxnard

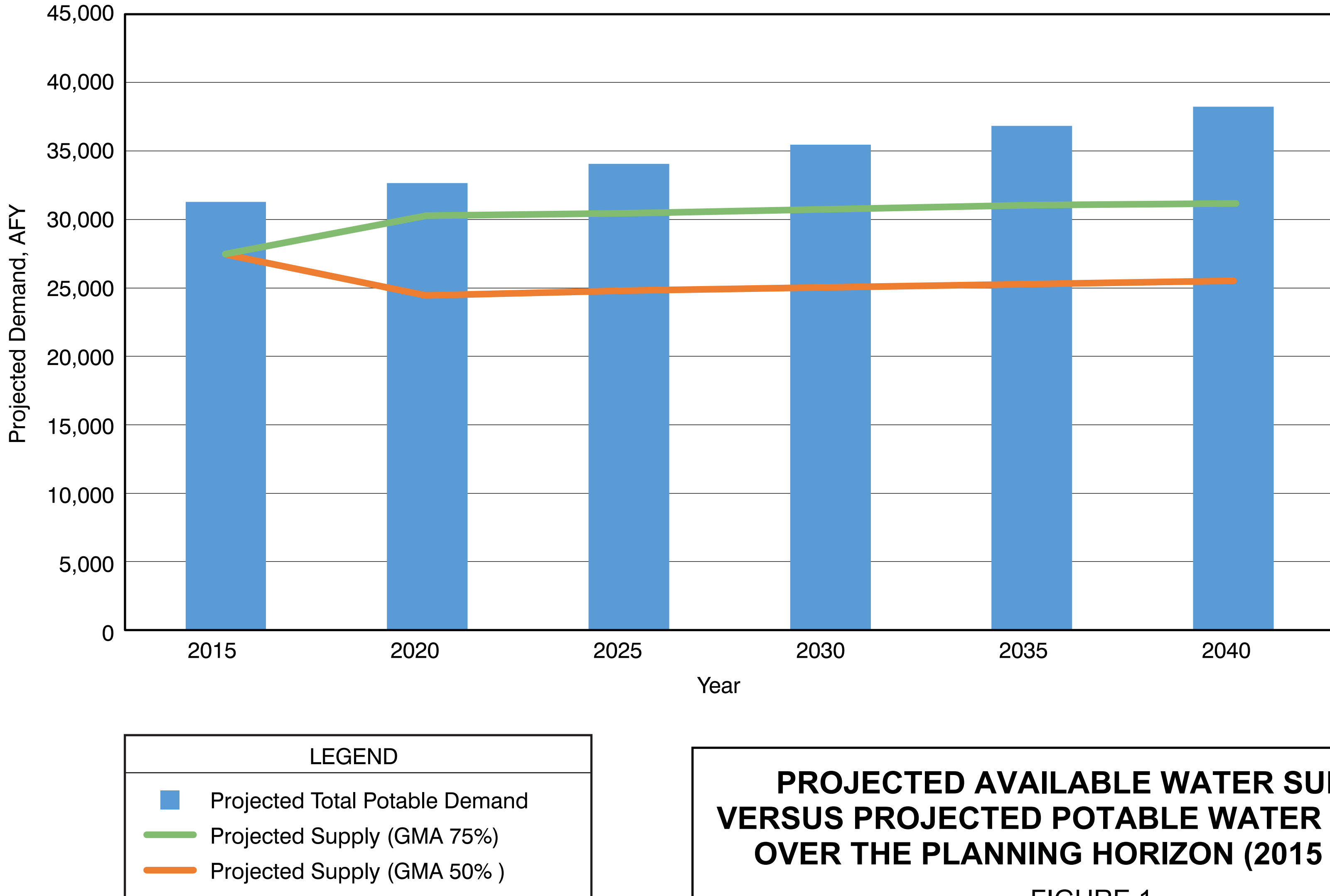
Supply	Historical Allocation	Projected Supply/Demand					
		2015	2020	2025	2030	2035	2040
Local Groundwater(2)	12,456	7,348(11)	6,705	6,705	6,705	6,705	6,705
Baseline	*954*	--	*954*	*954*	*954*	*954*	*954*
Historical Use	*11,502*	--	*5,751*	*5,751*	*5,751*	*5,751*	*5,751*
UWCD(3)	9,070	7,161(11)	4,535	4,535	4,535	4,535	4,535
CMWD(4)	12,500	13,826	13,826	13,826	13,826	13,826	13,826
Ag Development Re-Allocation(5)		0	149	376	603	830	1,057
Subtotal Supply		**28,335**	**25,215**	**25,442**	**25,669**	**25,896**	**26,123**
Recycled Water Offset(6)		--	1,475	1,475	1,475	1,475	1,475
Loss (Brine)(7)		(800)	(1,890)	(1,890)	(1,890)	(1,890)	(1,890)
Total Firm Supply		**27,535**	**24,800**	**25,027**	**25,254**	**25,481**	**25,708**
Other Potential Supplies							
PHWA Exchange(8)		700	700	700	700	700	
RW Pump Back Allocation(9)		--	1,810	1,810	1,810	1,810	1,810
Good Deeds Trust(10)		1,000					
Total Potential Supply		**29,235**	**27,310**	**27,537**	**27,764**	**27,991**	**27,518**

Notes:
(1) A restriction in the groundwater pumping of 50% of historical allocation (regulated by the FCGMA) is assumed on all groundwater sources, unless otherwise noted.
(2) The City's groundwater allocation is made up of a baseline and historical use allocation. The assumed FCGMA restriction on groundwater pumping is applied to the historical allocation only.
(3) The assumed FCGMA restriction is applied to the historical UWCD allocation.
(4) CMWD projection is based on Tier 1 allocation as of Jan 1, 2015. It does not include 4,700 AFY allocated to PWHA.
(5) Estimate for ag re-allocation is based upon planned ag conversion acreage through 2040 and using a re-allocation factor of 1 AFY per acre converted.
(6) Based on contracts as of 2015; does not account for future urban or ag uses at this time. For details, see PM 4.2.
(7) Based on existing (as of 2015) desalting capacity of 7.5 mgd (8,400 AFY).
(8) Annual transfer of FCGMA credits from PWHA, per 2002 Three Party Water Supply Agreement.
(9) Only through 2019. UWCD has not transferred the allocation since 2013 and the City has requested a refund for payments made.
(10) Based on a 0.5:1 pump-back allocation ratio of RW supplied to ag users (Southland, Houweling, Reiter, and River Ridge Golf Course).
(11) Based on Emergency Ordinance E, Temporary Allocations.

Table 3 Projected Supply vs. Demand
Public Works Integrated Master Plan
City of Oxnard

Supply	**Projected Supply/Demand**					
	2015	**2020**	**2025**	**2030**	**2035**	**2040**
Total Projected Demand (from PM 2.2)[1]	31,274	32,664	34,054	35,445	36,835	38,225
Low GMA Pumping Restriction[2]						
Total Potential Supply	29,235	34,264	34,491	34,718	34,945	34,472
Net Supply	**-2,039**	**1,600**	**437**	**-727**	**-1,890**	**-3,753**
High GMA Pumping Restriction[3]						
Total Potential Supply	29,235	27,310	27,537	27,764	27,991	27,518
Net Supply	**2,039**	**-5,354**	**-6,517**	**-7,681**	**-8,844**	**-10,707**

Notes:
(1) Based on 2030 General Plan Low Population Demand projection (using 132 gpcd use factor) from PM 2.2.
(2) The Low FCGMA Pumping Restriction assumed to be 75%.
(3) The High FCGMA Pumping Restriction assumed to be 50%.



PROJECTED AVAILABLE WATER SUPPLY VERSUS PROJECTED POTABLE WATER DEMAND OVER THE PLANNING HORIZON (2015 - 2040)

FIGURE 1

CITY OF OXNARD

PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES

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The project supply numbers are under review currently as the 2015 UWMP is being developed. It is expected that the supply projections will fall within the range being depicted in Tables 1, 2 and 3 herein.

4.0 WATER SUPPLY ALTERNATIVES CONSIDERED

More than a decade ago, the City sought to create a sustainable water supply for the future by implementing its Groundwater Recovery Enhancement and Treatment (GREAT) program. The major components of the GREAT program include:

- **Recycled Water System**: Treatment of wastewater to the most stringent levels with an Advanced Water Purification Facility (AWPF) and distribution.
- **Water Supply**: Treatment of groundwater for total dissolved solids and nitrate reduction (referred to as a desalter).
- **Groundwater Injection**: Wells that allow for injection of recycled water into and extraction out of the local groundwater aquifer.
- **Elements related to both**: Concentrate Collection and Treatment – Collect and treat concentrate (brine) from both AWPF and desalters.

When considering sources of potential supply to bridge the supply gap noted in Table 3 above, the same key sources (recycled water and groundwater treatment) of the GREAT program were the first primary sources considered within this PWIMP. In addition, some secondary sources/offsets were also considered that would reduce the gap in supply, but could not be relied upon to be a primary source.

4.1 Primary Sources

Primary sources are those that could solely, or in combination with other primary or secondary sources, provide the City with the additional potable water needed to meet the gap in supply. A main purpose of this alternatives analysis is to determine the improvements needed to make that additional supply a reality. The primary sources include:

- **Groundwater –** Additional local groundwater as well as UWCD water may be available for pumping. However, due to the high TDS and hardness of these sources, untreated groundwater quality becomes a limiting factor. Therefore, any discussion of increased groundwater pumping must be coupled with additional treatment to improve water quality.
- **Indirect Potable Reuse (IPR)/Aquifer Storage and Recovery (ASR) –** The City has already constructed an AWPF, at 6.25 million gallons per day (mgd) capacity, to supply high quality recycled water for urban and ag irrigation. As well, permitting and construction of an IPR/ASR demonstration well injecting/extracting recycled water from the AWPF into the local groundwater aquifer is underway, set to be completed in 2016. IPR/ASR offers a high quality water source for the City. This plan considers the possibility of expanding IPR/ASR under a variety of alternatives.

- **Direct Potable Reuse (DPR) –** Rather than injecting water from the AWPF into the groundwater basin, DPR is an alternative that could be considered. Again, DPR would be a high quality water source for the City. DPR requires above ground storage of the treated water prior to injection into the potable water distribution system.
- **Brackish Water Desalter –** The City has also had initial talks with Port Hueneme about taking over operation of their 3 mgd desalter which would bring water rights and Port Hueneme within the City's service area.

4.2 Desalination

Desalination of seawater could be an alternative to future AWPF expansions. Desalination was reviewed in the Title XVI study for the GREAT program and found to be not cost effective. The City requested that Carollo estimate desalination costs only as a comparison to the other chosen alternatives but recognizes that it is not cost effective at this time.

4.3 Secondary Supplies/Offsets

The following secondary supplies could provide offset or an additional source of potable water. The supplies listed herein would not be able to provide enough offset to make up for the projected supply gap through the planning period and therefore, can only be considered in addition to the primary sources already noted:

- **Conservation –** Based on the City's historical water use as presented in PM 2.2, *Water System – Flow Projections*, there may be very little room for additional conservation. The per capita potable water use is trending well below the SBX7-7 target of 132 gpcd. In the 2010 Draft Water Conservation Plan, the recommended programs and measures would only result in a savings of approximately 5 percent over 2012 demands but would require a significant investment of time and dollars. A summary of the recommended conservation measures is included in Appendix B. In addition to SBX7-7, in April 2015, the State passed mandatory cutbacks in potable water use, which for the City means an additional 25 percent reduction in use. These are expected to be temporary; however, the exact length of implementation is drought-dependent.
- **Recycled Water for Irrigation –** The City currently has contracts to provide 1,475 AFY for urban irrigation (New Indy Paper, River Ridge Golf Course, River Park Development) reuse and 4,020 AFY for ag irrigation reuse (Southland, Houweling, Reiter, River Ridge Golf Course). The City has considered additional recycled water use within the City as well as to the nearby ag users, as outlined in the 2009 Recycled Water Master Plan. For purposes of this PWIMP, only the current recycled water contracts are considered.

- **Ventura Intertie –** An intertie with the City of Ventura could serve as an emergency or temporary backup supply. Preliminary discussions have been held between Oxnard and Ventura to discuss the benefits of an intertie and the logistics of implementation. No firm plans have been developed yet.
- **Stormwater –** Options for adding stormwater as potential secondary supply are addressed in PM 5.4, *Stormwater – Treatment Alternatives* and will not be discussed further here.

4.4 Process Optimization

Another way to increase supply would be to decrease the quantity of water lost in the system, especially in the desalter operation. Currently, the reverse osmosis (RO) desalter is a two-stage system with each phase recovering 80 percent of the water as potable. An analysis was conducted to determine whether a third stage could be added for higher recovery, resulting in more potable water output for the same raw water input. However, due to the ambient levels of silica and calcium carbonate in the raw water supply, the scaling potential for the membranes and downstream piping would be too significant to be functional. A more detailed analysis is included in Appendix C.

5.0 WATER QUALITY CONSIDERATIONS

The water quality of the various potential sources varies and warrants a discussion. As part of the PWIMP process, water quality objectives (WQO) were developed that were used to evaluate the type of source and the projected use of that source. The water quality goals included:

- TDS < 500 milligrams per liter (mg/L).
- Hardness < 100 mg/L.
- All Public Health Goals (PHG).

Table 4 summarizes the water quality for the potential primary sources of water named above. Note that the local and UWCD groundwater sources are significantly higher in TDS and hardness than the water quality goals set by the City for their system. The City currently uses RO to remove the TDS and hardness to target levels; this method of treatment is also referred to as desalting. It is anticipated that desalting will be needed on any future groundwater supplies to meet the TDS and hardness goals listed.

On the other hand, the AWPF effluent's TDS and hardness levels are substantially lower than the water quality goals set. Because AWPF effluent will be the source of water for IPR (via ASR injection/extraction), this could pose an issue when extracting the water via ASR well and injecting it directly into the distribution system. It is expected that the extracted ASR water quality would remain relatively similar to AWPF effluent values while being stored in the below ground aquifer, with only a 15-20 percent degradation in quality near the edges of the plume over time. Given that, it is expected that water withdrawn from an ASR well for use in the potable water system will need to be blended with untreated groundwater prior to use so that the water is not too aggressive as to cause damage to existing and new infrastructure.

**Table 4 Water Quality for Potential Sources of Water
Public Works Integrated Master Plan
City of Oxnard**

Source	TDS, mg/L	Hardness, mg/L	Nitrate, mg/L
CMWD(1)	350	120	10-60
UWCD(2)	1,000	530	22-50
Local Wells(3)	1,200	700	31
AWPF Effluent(4)	50(4)	80(5)	
Current Blended Distribution System(6)	700	350	<45
Water Quality Goals	**500**	**100**	**45**

Notes:
(1) Based on CMWD's 2013 Annual Water Quality Report.
(2) Based on UWCD historical water quality data from 2009 – 2014.
(3) Based on local well water quality data from 2013 – 2104 and City of Oxnard's 2013 Annual Water Quality Report.
(4) Based on AWPF 2015 monitoring data.
(5) Based on AWPF pilot performance.
(6) Based on City of Oxnard's Annual Report Data.

The Preliminary Draft Pubic Health Goals Report (Milner-Villa Consulting, 2013) is summarized in PM 2.1, *Water System - Background* for the existing distributed water, given the current source water blend and treatment. Based on the resulting constituents of concern from the PHG and the proposed approach to meeting the TDS and hardness goals noted above, it is believed that any scenario or alternative that meets the hardness goal of 100 mg/L will also meet the PHGs.

6.0 FATAL FLAW ANALYSIS FOR WATER SUPPLY IMPROVEMENTS

Developing the improvement alternatives for the water and recycled water systems was a two-step process. First, a fatal flaw analysis was conducted by considering viable locations throughout the City for either groundwater treatment (desalting) or for IPR via ASR.

A site was considered viable for groundwater treatment if there was adequate space to add treatment facilities (i.e., RO treatment and appurtenant equipment) and if there was existing infrastructure, such as the O-H pipeline (which supplies UWCD groundwater) or City's wells that could provide groundwater for treatment.

The suitability of a site for IPR via ASR wells was dependent upon the underlying hydrogeologic characteristics of the site. Hopkins Groundwater Consultants provided an assessment (Hopkins, 2015) of several potential sites throughout the City; the results of that analysis are summarized in Table 5. The full report is included in Appendix D.

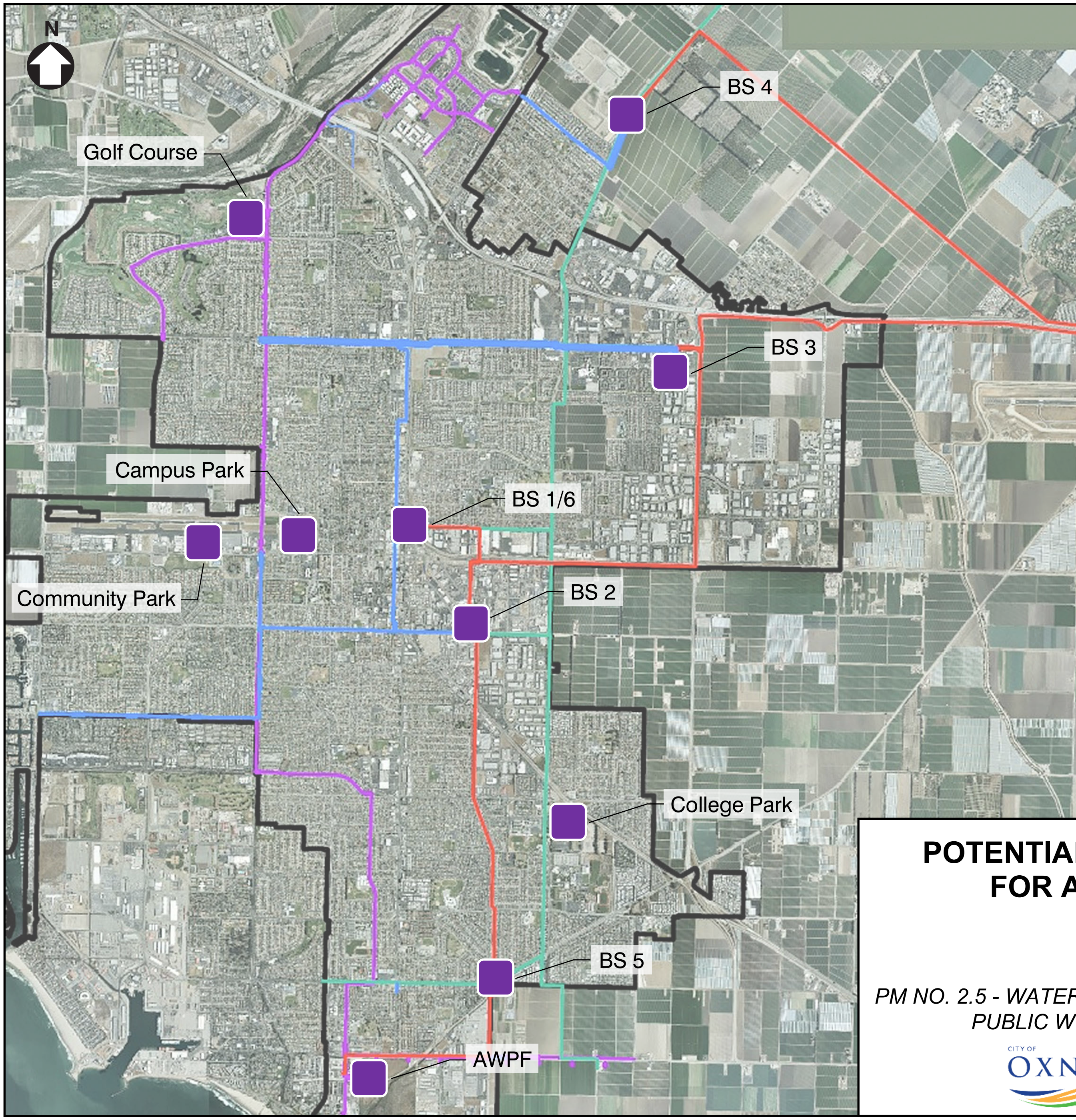
Based upon the hydrogeologic review as well as knowledge of existing potable water distribution facilities (as summarized in PM 2.1), each site was assessed for its potential to either house a potable water desalter or an ASR wellfield. Figure 2 illustrates the potential locations considered for future facilities.

Table 5 Preliminary Production Capacity of Potential ASR Well Sites
Public Works Integrated Master Plan
City of Oxnard

Location	Single Well Replenishment Capacity (gpm)	Estimated Number of Wells	Discrete Zones Available GRRP Operations	ASR Wellfield Injections Capacity (gpm)	Potential Annual Wellfield Capacity (AFY)
BS 1/6	1,500 – 2,500	6 to 9	3 or more	4,000 – 7,500	7,000 (+)
BS 3	1,500 – 2,500	6 to 9	3 or more	4,000 – 7,500	7,000 (+)
River Ridge GC	1,500 – 2,500	6 to 9	3 or more	4,000 – 7,500	7,000 (+)
Community Park	1,500 – 2,500	6 to 9	3 or more	4,000 – 7,500	7,000 (+)
College Park	1,500 – 2,000	6 to 9	3 or more	4,000 – 6,000	7,000
Campus Park(2)	1,500 – 2,500	6 to 9	3 or more	4,000 – 7,500	7,000 (+)
AWPF	1,000 – 2,000	2 to 3	1 to 2	3,000 – 6,000	3,000

Notes:
(1) Derived from Preliminary Hydrogeological Review (Hopkins, 2015).
(2) This site was not included in the Jan 2015 review; however, it was confirmed with Hopkins that this site would be similar in capacity to the Community Park and BS 1/6 sites given its proximity.

River Ridge Golf Course was long planned to be the location of the City's first IPR/ASR well. This well was planned to be installed as a test well at first and then put into full operation once fully approved by regulatory agencies for operation. However, during the planning and design of this well, it was discovered that the River Ridge site had a fatal flaw – the location chosen was near to a closed landfill and construction on that site would have required re-opening of the landfill closure plan. Therefore, the planned location for the initial IPR/ASR well was moved to the Campus Park area where the City had available land for infrastructure use.



LEGEND

Existing Transmission Lines:

- CMWD Pipeline
- O-H Pipeline
- RW Distribution
- Potable Distribution

NOTE:

1. This figure is schematic in nature. The recycled water distribution and potable distribution are independent systems.

POTENTIAL LOCATIONS CONSIDERED FOR ADDITIONAL FACILITIES

FIGURE 2

CITY OF OXNARD

PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES

PUBLIC WORKS INTEGRATED MASTER PLAN

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All of the potential other sites from Table 5 were also considered for fatal flaws and Table 6 summarizes the outcome of that analysis as well as highlights the reasons why some sites were suitable for both, one or neither source options. DPR was also considered within this analysis; the only viable location for DPR is near the AWPF due to space and existing infrastructure considerations. Desalination would also really only make sense near the AWPF, again, due to space and infrastructure considerations.

Table 6 Summary of Fatal Flaw Analysis on Water and Recycled Water Potential Improvement Options and Locations
Public Works Integrated Master Plan
City of Oxnard

Potential Location	Suitable for IPR/ASR?	Suitable for Potable Desalter?	Fatal Flaw?
BS 1/6	Yes	Yes	No
BS 2	No	No	Yes – Site too small to fit additional facilities
BS 3	Yes	Yes	No
BS 4	No	Yes	Yes for ASR – Located above Oxnard Forebay(1)
BS 5	No	No	Yes – Site too small to fit additional facilities
River Ridge GC	No	No	Yes for desalter – no blending station needed or planned there Yes for ASR – potential location would require re-opening of landfill closure plan
Community Park	Yes	No	Yes for desalter – no blending station needed or planned there
College Park	Yes	No	Yes for desalter – no blending station needed or planned there
Campus Park	Yes	No	Yes for desalter – no blending station needed or planned there
AWPF	No	No	Low ASR capacity

Note:
(1) The Oxnard Forebay is an unconfined aquifer and thus, non-ideal for an ASR operation.

Based on the above fatal flaw analysis, the following locations were considered further with priority of location as noted:

- **Water Campus (BS 1/6) – Both ASR and potable desalting (Priority 1).** Because so much existing infrastructure is already in operation at this blend station (local wells, proximity to O-H pipeline, potable desalter), this is an obvious location for additional facilities. The site is somewhat limited in space; however, there is also potential to purchase property next to the BS, which would expand the site by approximately 5 acres.

- **Campus Park – ASR Only (Priority 2).** Because the initial IPR/ASR well will be located within the Campus Park area and due to its proximity to BS 1/6, this is the next obvious choice for additional ASR wells.

- **BS 3 – Both ASR and potable desalting (Priority 3).** Again, due to the presence of existing infrastructure (i.e., wells, O-H pipeline) and its suitability for ASR, this is the second priority for additional facilities. Additionally, there is nearby property that might be attained for further expansion, as space for future facilities will be needed.

- **College Park/Community Park – ASR Only (Priority 4).** Both locations are suitable for ASR:
  – **College Park** is relatively close to the AWPF, which could mean less overall distribution piping needed.
  – **Community Park** is near to the recently installed Recycled Water Backbone System (RWBS) Pipeline that takes recycled water from the AWPF to the River Ridge Golf Course; thus, minimal additional piping would be needed. However, Community Park is currently developed into sports fields which might make construction of facilities difficult without significantly disrupting the community.

- **DPR at AWPF (Alternative).** DPR could be an alternative to an IPR/ASR wellfield installation and this would only be located near the AWPF.

- **Desalination near AWPF (Alternative).** Again, desalination is presented here only for comparative purposes. The most likely location for a desal plant would be near the AWPF.

7.0 DEVELOPMENT OF WATER SUPPLY IMPROVEMENTS IMPLEMENTATION ALTERNATIVES

Using the supply, demand and water quality goals summarized thus far, three alternatives were developed that would provide a sustainable water supply to the City of Oxnard over the planning period (through 2040).

7.1 Alternative Development Assumptions

Due to the complexity of the City's system and various water supplies, several assumptions needed to be made in developing the alternatives. These assumptions are in line with the water supply objectives put forth in Section 2.0. The following high-level assumptions were made:

- **Assumption #1:** Supply Use Priority (maximizes use of groundwater pumping allocation to the extent possible):
  - Local Wells – either pumping native local groundwater or local groundwater available through ASR operation.
  - UWCD.
  - CMWD.
- **Assumption #2**: GMA Allocation at 75 percent of historical use.
- **Assumption #3**: GW Pump Back Allocation of 1:1.
- **Assumption #4**: Water Quality Goals: TDS = 500 mg/L and Hardness of 100 mg/L.

7.1.1 Secondary Effluent Storage

All of the alternatives developed involve expanding the AWPF to varying capacities. This required an assessment of whether there is enough OWTP effluent to feed into the AWPF as the capacity is increased. The OWTP serves as the 'supply' for the AWPF. In general, the capacity of the AWPF cannot be expanded beyond what the OWTP can supply. Table 7 summarizes how much OWTP effluent is needed for the planned capacity expansions at the AWPF.

Not only is it important to assess the average daily flow leaving the OWTP but also the diurnal variation of that flow. The AWPF is operated best at a constant (or relatively constant) flow but the effluent flow from the OWTP varies throughout the day. Therefore, an analysis was done to see if and how much secondary effluent storage might be required to store water such that the AWPF could draw a consistent supply. Table 7 summarizes the results of that analysis. Storage graphs for this analysis are also included in Appendix E.

The OWTP currently has 5 MG of secondary effluent storage, which they use for peak shaving off their effluent pumping. However, based on the required storage noted in Table 7, it is believed that the existing secondary effluent storage will be sufficient to serve as both AWPF storage as well as peak shaving for effluent pumping. Further discussion of how the storage is used for the OWTP is included in PM 3.4, *Wastewater – Treatment Plant Performance and Capacity*.

7.1.2 ASR Demonstration Well

For all of the alternatives identified, each include an ASR Demonstration well that will be constructed in 2016. The construction of this well is grant funded and will serve as a test well for the City to understand how ASR/IPR will work moving forward. The ASR Demonstration well will be used initially as an ASR well for the recycled water system. Recycled water from the AWPF will be injected into the ground and then extracted and put back into the City's RW system for irrigation use. Ultimately, once all of the required start-up

Table 7 Secondary Effluent Storage Needs Public Works Integrated Master Plan City of Oxnard			
AWPF Phase	**AWPF Capacity, mgd**	**Secondary Effluent Needed (Avg Day), mgd(1)**	**Secondary Effluent Storage Required, MG**
1	6.25	8.2	--
2	12.5	16.3	0.7
3	18.75	24.5	2.3
4	25	32.7	(2)

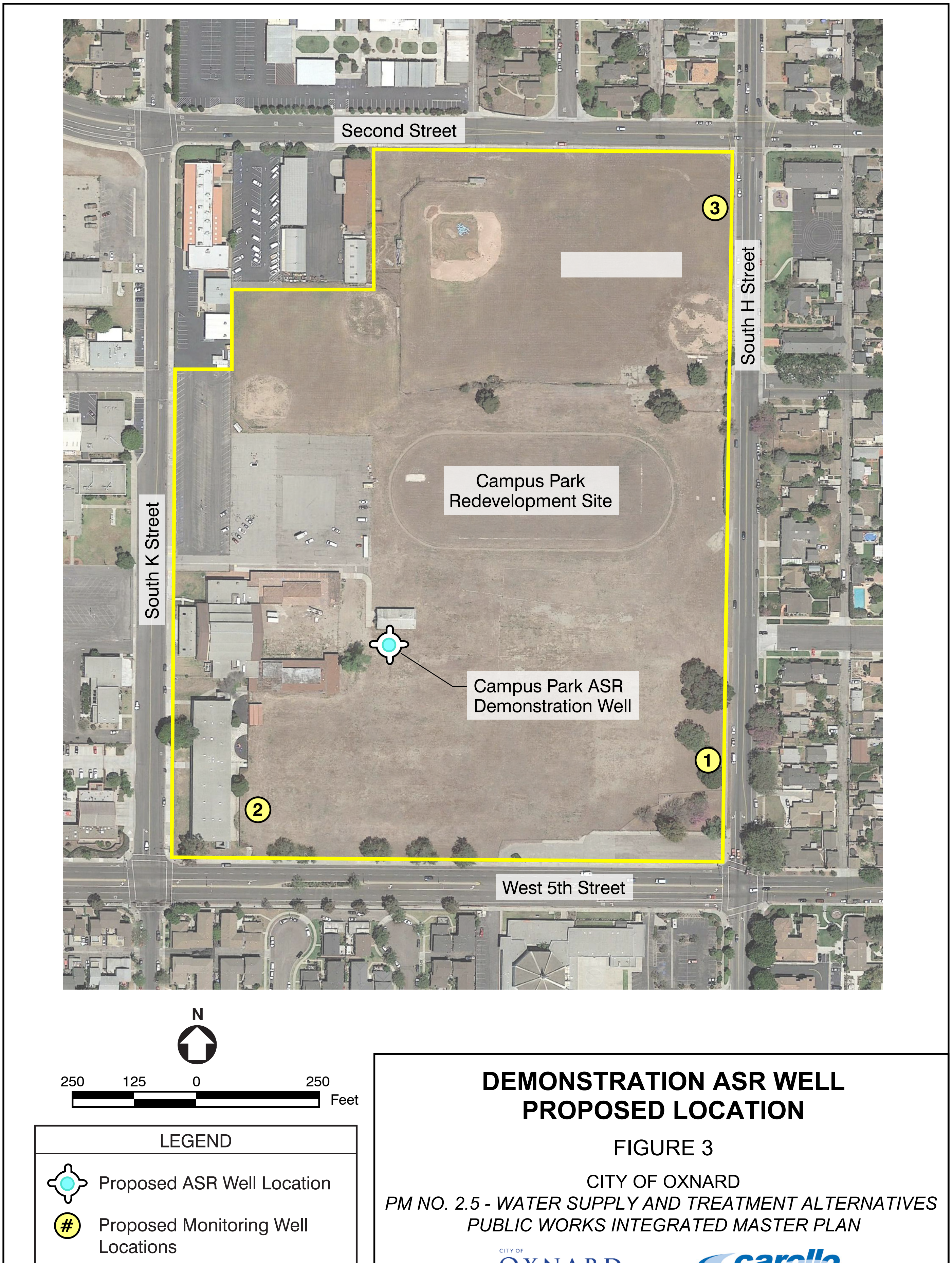
Notes:
(1) Estimated based on a MF recovery of 90% and RO recovery of 85%.
(2) Based upon wastewater flow projections for the PWIMP, it is unlikely there will be enough secondary effluent flow to support an expansion of the AWPF up to 25 mgd.

testing and monitoring is complete, the well will switch to IPR operation with the extracted water being conveyed to the BS 1/6 nearby for disinfection and injection into the potable system. Therefore, each of the alternatives developed contains the following for construction of this IPR/ASR well:

- Construction of 1 IPR/ASR well at the Campus Park site.
- Construction of 3 monitoring wells (2 shallow and 1 deep aquifer) for the 1 IPR/ASR well.
- 2,000 lf of RW piping connecting the IPR/ASR well to the Recycled Water Backbone piping located in Ventura Road.
- 4,000 lf of piping to convey IPR water from Campus Park to BS 1/6 for blending into the potable system (this will eventually be converted to a potable line when the IPR/ASR operation is fully approved).

A preliminary hydrogeological study (included in Appendix F) has been conducted (Hopkins, 2015b) to assess the proposed location and capacity for this well at Campus Park. The injection and extraction capacity of the well is recommended at approximately 2,000 gpm. The well will be operated on a 3-month rotation of recharge, retention and recovery. Figure 3 illustrates the location of the proposed ASR well at Campus Park.

The overall goal of this demonstration is to find an alternative that provides reliability and resiliency for future impacts.



DEMONSTRATION ASR WELL
PROPOSED LOCATION

FIGURE 3

CITY OF OXNARD
PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES
PUBLIC WORKS INTEGRATED MASTER PLAN

CITY OF OXNARD CALIFORNIA

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7.2 Alternative 1: Groundwater Treatment Focused

The premise of this alternative is to maximize groundwater pumping by distributing AWPF effluent to agricultural uses and then, through pump back allocation, to pump an equivalent amount of local groundwater to meet potable demand. To convey the AWPF water to the ag users in this alternative, the City has long planned to install a recycled water pipeline, referred to as Hueneme Phase 2. In addition, more potable wells would be needed to increase overall local groundwater pumping capacity to meet potable demand.

Due to the groundwater quality (high TDS and hardness), this alternative would require additional desalting capacity to improve the overall blended water quality to meet water quality objectives. Increasing capacity at BS 1/6 and adding additional capacity at BS 3 would be necessary. The City already has plans to build a concentrate collection line to provide discharge of the brine from BS 1/6; but for this alternative, that collection line would need to be extended to BS 3 as well.

Table 8 summarizes all of the water and recycled water facilities needed to implement Alternative 1. Figure 4 illustrates the location of all of the proposed facilities.

7.3 Alternative 2: Combination of Groundwater and IPR/ASR

Alternative 2 seeks to add flexibility and resiliency to the groundwater only alternative by combining the use of some additional groundwater pumping and treatment with use of recycled water through expansion of IPR/ASR. This alternative contains facilities needed to distribute recycled water to meet potable demands (in addition to groundwater pumping) to IPR/ASR wellfield, but then sends excess AWPF effluent to agricultural uses for irrigation through the planned Hueneme Phase 2 pipeline. In addition, this alternative includes construction of a RW Loop that would connect the existing Recycled Water Backbone System (RWBS) pipeline running north and south along Ventura Road to BS 1/6 via 5th St. and then south along Rose Avenue back to the AWPF. A RW loop would offer better overall water quality and access to other potential ASR sites, such as College Park and BS 1/6, in the future.

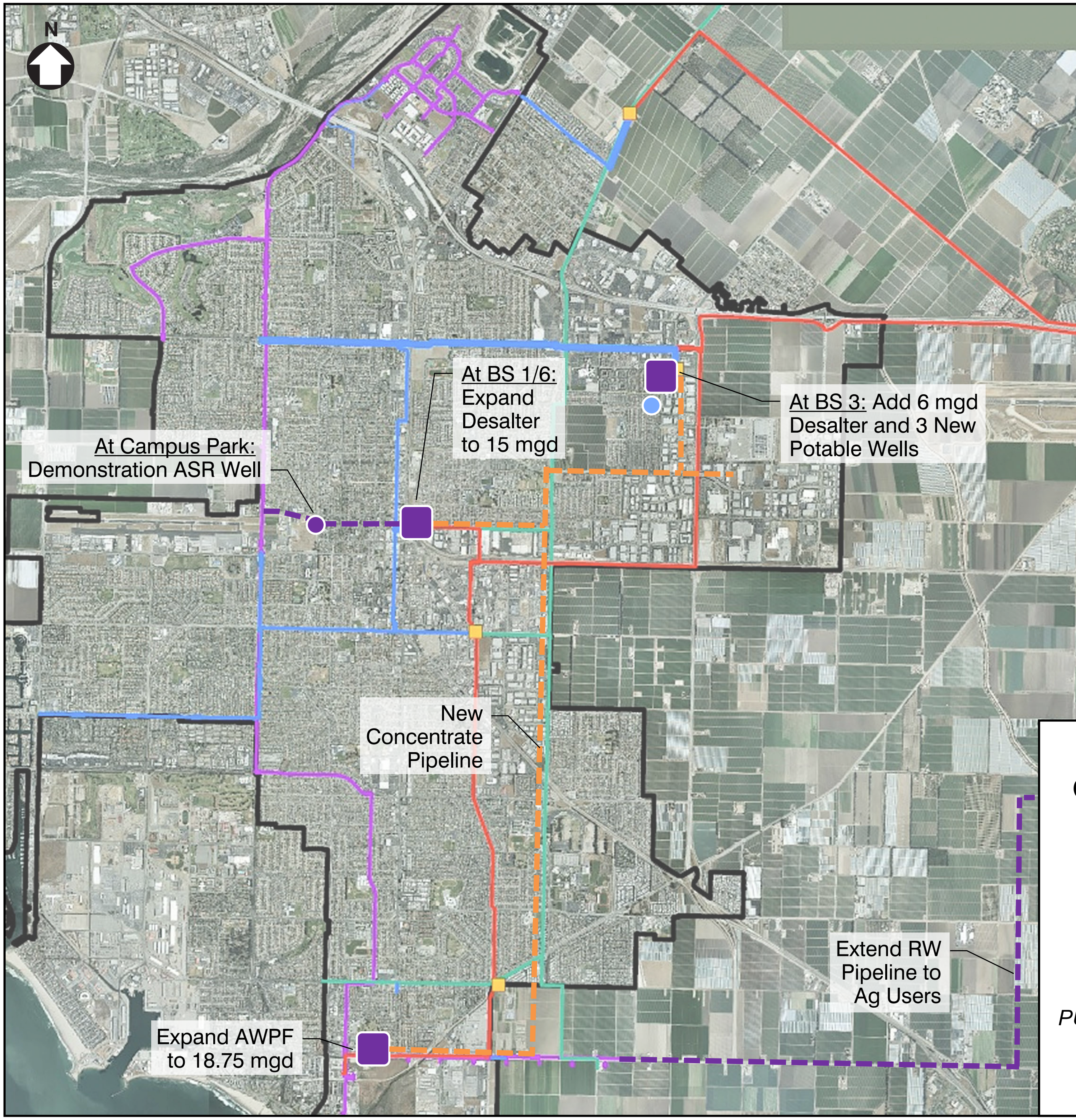
The alternative also requires increased groundwater pumping and due to groundwater quality, this alternative would also need additional desalting capacity to meet blended water quality objectives. The concentrate collection line would be the same as in Alternative 1.

Table 9 summarizes all of the water and recycled water facilities needed to implement Alternative 2. Figure 5 illustrates the location of all of the proposed facilities.

Table 8 Facilities Needed for Alternative 1 - Groundwater Treatment Focused Option[1]
Public Works Integrated Master Plan
City of Oxnard

Facility	Description	Quantity	Unit	Capacity
Water System				
Potable Wells	Blending Well at BS 7[2]	1	gpm	2,000
	Potable Wells to Increase GW pumping capacity at BS 1/6	3	gpm	2,000 (ea.)
Desalter Expansion	Expansion of Existing Desalter at BS 1/6 by 7.5 mgd	1	mgd	15
New Desalter	New desalter install at BS 3[3]	1	mgd	6
Permeate Water Storage	Expand at BS 1/6 by 2.0 MG	1	MG	2.0 + Existing
	New at BS 3	1	MG	1.5
Disinfection	Expansion of Existing Disinfection at BS 1/6	1	--	--
	New desalter install at BS 3	1	--	--
Recycled Water System				
AWPF	Expand existing by 12.5 mgd	1	mgd	18.75
ASR Wells[4]	At Campus Park	1	gpm	2,000
	Well 18 Rehab (at BS 7)[5]	1	gpm	3,000
RW Conveyance Piping				
	Hueneme Phase 2 (24 and 36 inch)	36,700	lf	--
	Connection from Initial ASR Well to RWB Piping in Ventura Road	2,000	lf	--
Concentrate Conveyance				
	OWTP to BS 1/6 (14 and 24 inch)	32,100	lf	--
	BS 1/6 to BS 3 (14)	14,300	lf	--

Notes:
(1) Recommended facilities based on meeting demand requirements and providing water quality objective (TDS ≤ 500 mg/L), unless otherwise noted.
(2) Potable well recommended for blending to combine the low hardness water from ASR well with high hardness untreated groundwater so that the blend water is not too aggressive (corrosive) for the existing potable distribution system.
(3) Additional improvement needed to meet water quality objective (hardness = 100 mg/L) – 2 mgd of the 6 mgd recommended is to achieve water quality objective.
(4) Initial Pilot Well. Each ASR duty well installed will require 3 monitoring wells.
(5) Used for recharge to the upper aquifer only; will not be used for potable withdraw.



LEGEND

Existing Transmission Lines:
- CMWD Pipeline
- O-H Pipeline
- RW Distribution
- Potable Distribution

Recommended New Transmission Lines and Wells:
- New Concentrate Pipeline
- RW Distribution
- New Potable Wells
- New ASR Wells

NOTE:

1. This figure is schematic in nature. The recycled water distribution and potable distribution are independent systems.

ALTERNATIVE 1: GROUNDWATER TREATMENT FOCUSED RECOMMENDED FACILITIES (THROUGH 2040)

FIGURE 4

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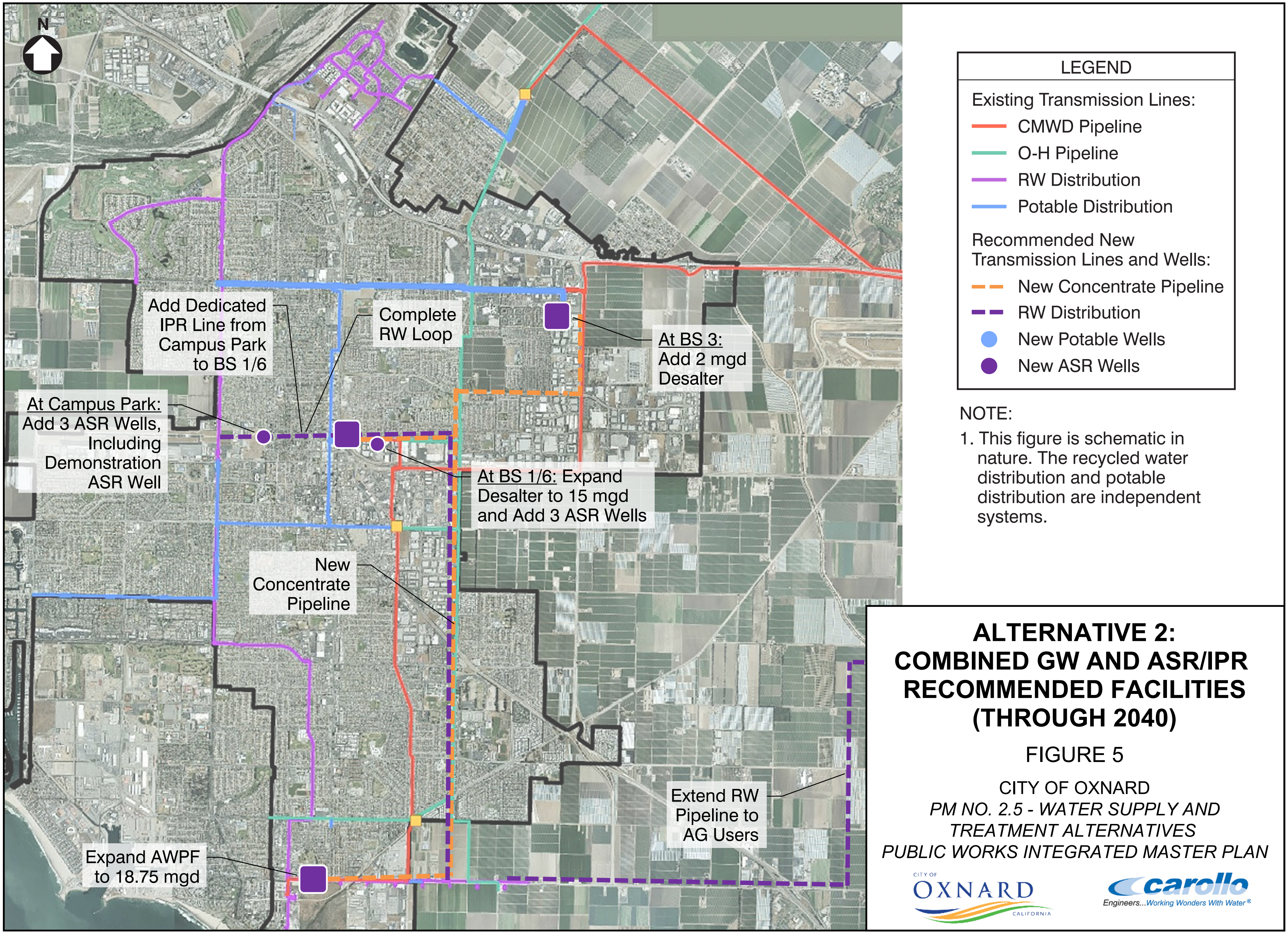
Table 9 Facilities Needed for Alternative 2 – Combination Groundwater Treatment and ASR/IPR[1]
Public Works Integrated Master Plan
City of Oxnard

Facility	Description	Quantity	Unit	Capacity
Water System				
Existing Desalter	Expansion of Existing Desalter at BS 1/6 by 7.5 mgd	1	mgd	15
New Desalter	New desalter install at BS 3[2]	1	mgd	2
Permeate Water Storage	Expand at BS 1/6 by 2.0 MG	1	MG	2.0 + existing
	New at BS 3	1	MG	0.5
Disinfection	Expansion of Existing Disinfection at BS 1/6	1	--	--
	New desalter install at BS 3	1	--	--
Recycled Water System				
AWPF	Expand existing by 12.5 mgd	1	mgd	18.75
ASR Wells[3]	At Campus Park	1	gpm	2,000
	Well 18 Rehab (at Golf Course)[4]	1	gpm	3,000
	At BS 1/6	5 (duty)	gpm	2,000 (ea.)
ASR Support Systems				
Disinfection	Expansion of Existing Disinfection at BS 1/6	1	--	--
Operational Storage	Above-ground storage for daily peaking	1	MG	1.0
Booster Pumping	Pumping out of operational storage into potable distribution system	1	HP	500
Conveyance Piping	Hueneme Phase 2 (24 and 36 inch)	36,700	lf	--
	Connection from Initial ASR Well to RWB Piping in Ventura Road	2,000	lf	--
	Dedicated IPR Line (Conveying IPR water from Campus Park to BS 1/6)	4,000	lf	--
	RW Loop (16, 20 and 30 inch)	37,600	lf	--
Concentrate Conveyance				
	OWTP to BS 1/6 (14 and 24 inch)	32,100	lf	--
	BS 1/6 to BS 3 (14)	14,300	lf	--

Notes:
(1) Recommended facilities based on meeting demand requirements and providing water quality objective (TDS ≤ 500 mg/L), unless otherwise noted.
(2) Additional improvement needed to meet water quality objective (hardness = 100 mg/L).
(3) Each ASR duty well installed will require 3 monitoring wells.
(4) Used for recharge to the upper aquifer only; will not be used for potable withdraw.



ALTERNATIVE 2:
COMBINED GW AND ASR/IPR
RECOMMENDED FACILITIES
(THROUGH 2040)

FIGURE 5

CITY OF OXNARD
PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES
PUBLIC WORKS INTEGRATED MASTER PLAN

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7.4 Alternative 3: ASR/IPR Focused

Alternative 3 seeks to maximize use of the AWPF by sending as much effluent to IPR/ASR wells and meeting all additional potable water demands through the use of IPR. For this alternative, groundwater pumping/treatment would still be utilized and expanded but not to the degree of the other alternatives. Water from the IPR/ASR wells would serve to meet additional potable demands as well as to meet water quality objectives.

The planned Hueneme Phase 2 RW pipeline is also included to send any excess (beyond what is needed to meet potable demands) AWPF effluent to ag users. The RW Loop is also included in this alternative and a connection between the loop and BS 3 would be needed.

Because there is no desalter planned for BS 3, the concentrate line would only need to be constructed as far as BS 1/6 in this alternative.

Table 10 summarizes all of the water and recycled water facilities needed to implement Alternative 3. Figure 6 illustrates the location of all of the proposed facilities.

7.5 IPR vs. DPR

DPR could be considered as an alternative to IPR, which was assumed in all of the alternatives above. The most direct benefit of DPR over IPR is there is no loss of water when injected into the ground (with IPR, typical recovery is between 80 to 85 percent of what is injected due to water quality degradation over time).

Based on recommendations from the PM prepared by Carollo entitled “Summary of IPR and DPR Scenarios for the City of Oxnard” (WRRF, 2013), which included in Appendix G. In order to do DPR at the AWPF facility, engineered storage would need to be added. Significant engineered storage is needed due to the monitoring and testing requirements for DPR, as determined in the WRRF DPR study. AWPF effluent would flow into one of three storage tanks placed after the AWPF. The three tanks are (one) each in the following modes:

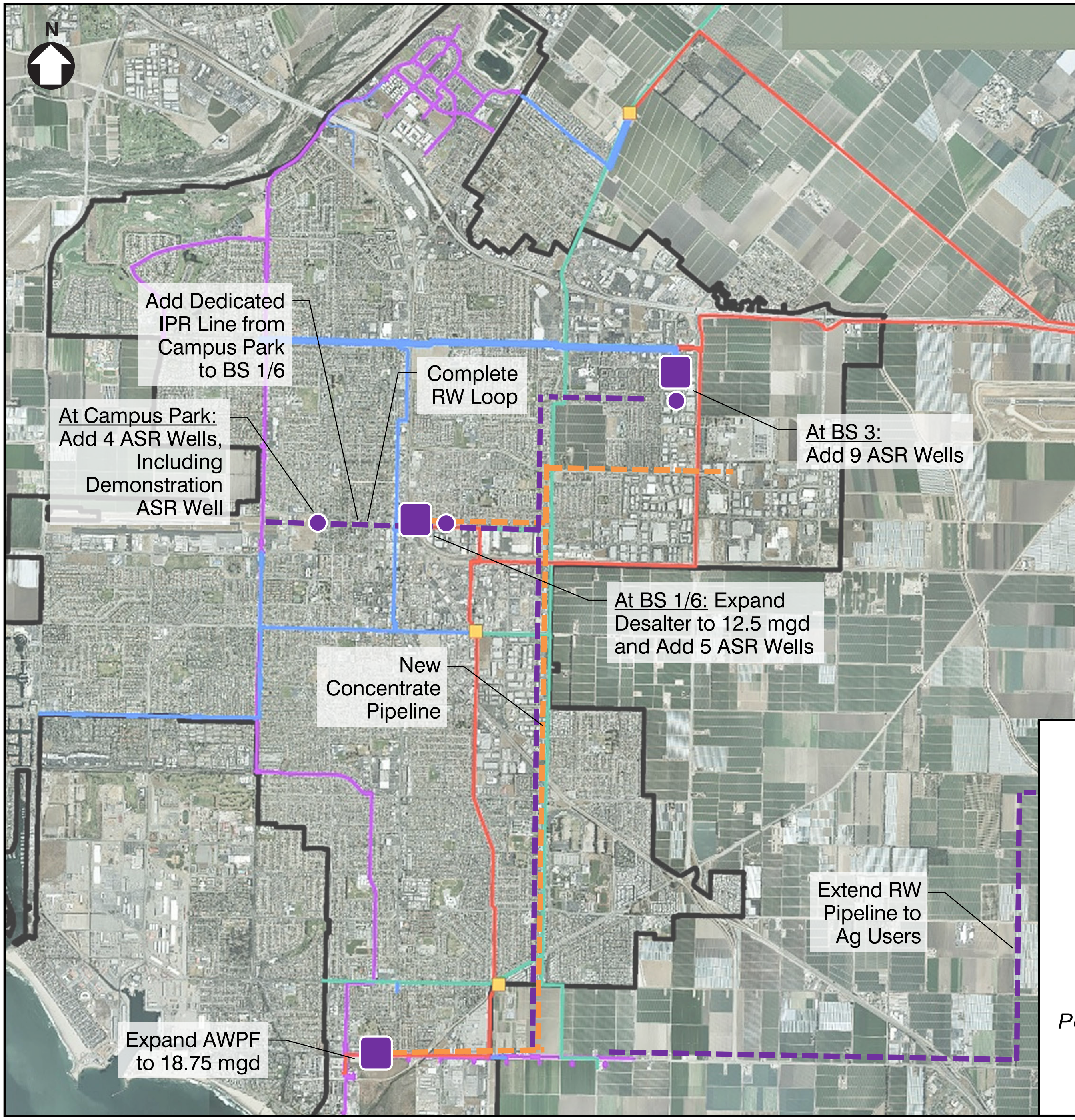
- Filling.
- Holding.
- Emptying.

Storage tank sizing will ultimately depend upon final flows diverted from the AWPF for DPR. Assuming a maximum flow of 6.25 mgd (equivalent to one phase of the AWPF expansion), it is anticipated that each storage tank would have a 3.125 MG capacity and would each occupy approximately 20,000 ft^2. These, however, are preliminary sizings and would need to be confirmed during future phases of the project.

Table 10 Facilities Needed for Alternative 3 – ASR/IPR Focused(1)
Public Works Integrated Master Plan
City of Oxnard

Facility	Description	Quantity	Unit	Capacity
Water System				
Existing Desalter(2)	Expansion of Existing Desalter at BS 1/6 by 5 mgd	1	mgd	12.5
Permeate Water Storage	Expand at BS 1/6 by 1.25 MG	1	MG	1.25 + existing
Disinfection	Expansion of Existing Disinfection at BS 1/6	1	--	--
Recycled Water System				
AWPF	Expand existing by 12.5 mgd	1	mgd	18.75
ASR Wells(3)	At Campus Park	1	gpm	2,000
	Well 18 Rehab (at GC)(4)	1	gpm	3,000
	At BS 1/6	5 (duty) + 3 (standby)	gpm	2,000 (ea.)
	At BS 3	6 (duty) + 3 (standby)	gpm	2,000 (ea.)
ASR Support Systems				
Disinfection	Expansion of Existing Disinfection at BS 1/6	1	--	--
Operational Storage	Above-ground storage for daily peaking			
	At BS 1/6	1	MG	1.0
	At BS 3	1	MG	1.0
Booster Pumping	Pumping out of operational storage into potable distribution system			
	At BS 1/6	1	HP	500
	At BS 3	1	HP	500
Conveyance Piping	Hueneme Phase 2 (24 and 36 inch)	36,700	lf	--
	Connection from Initial ASR Well to RWB Piping in Ventura Road	2,000	lf	--
	Dedicated IPR Line (Conveying IPR water from Campus Park to BS 1/6)	4,000	lf	--
	RW Loop (16, 20 and 30 inch)	37,600	lf	--
	Connect BS 3 to RW Loop (20 inch)	9,900	lf	
Concentrate Conveyance				
	OWTP to BS 1/6 (14 and 24 inch)	32,100	lf	--
	BS 1/6 to BS 3 (14)	14,300	lf	--

Notes:
(1) Recommended facilities based on meeting demand requirements and providing water quality objective (TDS ≤ 500 mg/L), unless otherwise noted.
(2) Additional improvement needed to meet water quality objective (hardness = 100 mg/L).
(3) Each ASR duty well installed will require 3 monitoring wells.
(4) Used for recharge to the upper aquifer only; will not be used for potable withdraw.



NOTE:

1. This figure is schematic in nature. The recycled water distribution and potable distribution are independent systems.

ALTERNATIVE 3: ASR/IPR FOCUSED RECOMMENDED FACILITIES (THROUGH 2040)

FIGURE 6

CITY OF OXNARD

PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES

PUBLIC WORKS INTEGRATED MASTER PLAN

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Table 11 compares facilities needed for an IPR/ASR wellfield versus a DPR facility of the same capacity. Factoring this into the cost analysis, it appears that DPR might be the less expensive option.

Table 11 IPR/ASR vs. DPR Components(1)
Public Works Integrated Master Plan
City of Oxnard

Component	IPR/ASR Wellfield(2)	DPR(3)
Wells	6 (duty)	--
Storage	1.0 MG	3 x 3.1 MG
Booster Pumping	500 HP	500 HP
Conveyance Piping	to BS 1/6	to Potable Distribution System
Land Acquisition	~ 10 acres	~2 acres

Notes:
(1) Assuming a capacity for either option = 6.25 mgd (equivalent to each phase of the AWPF expansion).
(2) Recommended components derived based on the work with this PWIMP.
(3) Recommended components from the DPR study (WRRF, 2013).

However, regulatory acceptance of DPR is progressing at a much slower pace than that of IPR. It is expected that this will change in the intermediate future (next 10 to 15 years). Therefore, this plan recommends keeping DPR as a future option to IPR but to proceed with IPR for the more immediate projects (within the next 10 years).

Table 12 includes a comparison of project costs for IPR versus DPR for a given phase of the AWPF (at a capacity of 6.25 mgd).

7.6 AWPF vs. Desalination

Desalination (desal) of seawater was considered only as a comparative cost to AWPF. The intake infrastructure required to take in seawater into a treatment facility would be both significant (reflected in the costs) and difficult to get permitted, making this alternative even less attractive. However, if, in fact, the expansion capacity of the AWPF is limited by the secondary effluent available, desal could be a more viable alternative in the future.

Carollo's report, *Seawater Desalination Project Overview*, summarized many of the key concerns for desal use in the City and is included in Appendix H (Carollo, 2012). Table 12 compares project costs for AWPF versus desalination for a given phase of the AWPF (at a capacity of 6.25 mgd).

Table 12 Comparison of Options: IPR vs. DPR and AWPF vs. Desal[1]
Public Works Integrated Master Plan
City of Oxnard

Cost ($ M)	IPR vs. DPR		AWPF vs. Desal	
	IPR/ASR Well Field	**DPR**	**AWPF Expansion/IPR**	**Desalination**
Total Construction Cost	$33	$22	$55	$94
Total Project Cost[2]	$41	$27	$68	$117
Annualized Project Cost[3]	$3.3	$2.2	$5.5	$9.4
O&M Costs	$3.5	$0.5	$7.3	$9.1
Total Est Annualized Cost	$6.8	$2.6	$12.8	$18.5
Non-Economic Considerations				
Regulatory	IPR is much closer to regulatory acceptance than DPR; therefore, much less risk to budget and schedule to implement IPR at this point and time		AWPF/IPR is also much more likely to gain regulatory approval faster than desal (largely due to intake concerns)	
Phasing	Implementation of IPR wells can be phased to better match demand needs			

Notes:
(1) Costs derived using the methodology outlined in PM 1.4*, Overall - Basis of Cost.*
(2) Project costs include project cost factor (as outlined in PM 1.4*, Overall - Basis of Cost*) as well as costs for land acquisition.
(3) Annualized at 5% over 20 years.

As discussed earlier due to the Title XVI Report as well as the estimated costs provided here, desal will not be considered further within this plan but could always be re-visited again in the future given a significant change in water supply conditions (i.e., extreme drought, shortage of supply, change in groundwater pumping allocation, etc.).

7.7 Alternative Evaluation

7.7.1 Economic Analysis

A cost estimate of the three main alternatives was developed for facilities needed through the planning period (2040). The costs were developed using factors outlined in PM 1.4, *Overall - Basis of Cost* as well as cost information from past projects and estimates. The economic comparison of the three alternatives considered is in Table 13. From this analysis, it is clear that the cost for providing water supply through the recycled water system will be more costly than through the groundwater. However, the costs do not necessarily reflect the risks involved in relying more heavily on local groundwater supply, especially given the more recent cutbacks on groundwater pumping that have gone into effect.

Table 13 Comparison of Water Supply Alternative Costs ($M)(1)
Public Works Integrated Master Plan
City of Oxnard

Project Description	Alt 1 – GW Treatment Focused	Alt 2 – Combined GW/IPR-ASR	Alt 3 – ASR-IPR Focused
Water System Improvements	$40	$23	$10
Recycled Water System Improvements	$74	$113	$158
Concentrate Conveyance	$20	$20	$20
Total Construction Cost	**$134**	**$156**	**$188**
Total Project Cost(2)	**$175**	**$201**	**$243**
Annual Costs ($ M/yr)			
Annualized Project Cost(3)	$14	$16	$20
Incremental O&M(4)	$19	$19	$19
Total Annual Cost	**$33**	**$35**	**$39**

Notes:
(1) Costs derived using the methodology outlined in PM 1.4, *Overall - Basis of Cost.*
(2) Project costs include project cost factor (as outlined in PM 1.4, *Overall - Basis of Cost*) as well as costs for land acquisition.
(3) Annualized at 5% over 20 years.
(4) O&M costs include energy, maintenance, and chemicals needed for additional facilities; do not include labor costs.

7.7.2 Energy Analysis

Based on the City's Energy Action Plan, completed in April 2013 and summarized in PM 1.1*, Overall - Master Planning Process Overview*, the City has committed to reducing their energy use by 10 percent by 2020. Therefore, a key evaluation criteria used in this PWIMP is to the estimated energy use of various alternatives considered.

Being at the planning level of such an analysis, there are many unknown factors in estimating the energy use of the various alternatives. However, with some basic assumptions about delivery pressure, operability percentage, and efficiencies, a relative comparison could be made. Table 14 summarizes the relative comparison between the three alternatives. The relative energy use of the three alternatives was not estimated to be significantly different

Table 14 Relative Comparison of Estimated Energy Use(1) Public Works Integrated Master Plan City of Oxnard			
Project Description	**Alt 1 – GW Treatment Focused**	**Alt 2 – Combined GW/IPR-ASR**	**Alt 3 – ASR-IPR Focused**
Water Projects			
New Potable Wells		None	None
Desalter	+++	++	+
Recycled Water Projects			
AWPF	Same	Same	Same
ASR Wells	+	++	+++
Booster Pumps	--	+	++
Pumping to Ag	+++++^	++++	+
Pumping to ASR	+	++	+++
Total Relative Energy Use	**11+**	**11+**	**12+**

Notes:
(1) Alternative 3 was used as the baseline alternative. Each of the other alternative's projects were compared to those of Alternative 3 in terms of energy demand. Each project within the alternatives contributes a different proportion of energy to the total energy usage.

In addition to the energy analysis above, a Preliminary Benchmarking Study was performed for the City by Lincus, Inc. and is included in Appendix I (Lincus, 2015) They evaluated the wells and booster pumps within the City's system and recommended System Optimization and Pump Efficiency Improvements that could result in energy savings of between 0.9 and 1.1 MW of power annually at an estimated payback of 3 to 7 years.

As the recommended projects move from the planning phase into design phases, additional energy efficiency/system optimization alternatives/strategies should be reviewed and evaluated so that the City can continue working towards it 10 percent energy reduction target even with the implementation of these new projects.

7.7.3 Water Quality Considerations

Meeting the water quality objectives (WQOs) laid out in the objectives for the water supply will be challenging at best, especially for hardness. However, each of the alternatives considered would be able to meet the water quality objectives once all of the improvements (through 2040) are in place. Predicted water quality was assessed using the WEAP model which is detailed further in Appendix J. In general, water quality considerations for the three alternatives are:

- Alternative 1 - Groundwater Treatment Focused: Because this alternative relies heavily on pumping local groundwater, additional desalting is imperative to meeting the WQOs.

- Alternative 2 – Combined Groundwater Treatment/IPR-ASR: The key to meeting WQOs for this alternative is striking a balance between ASR water, desalted GW and untreated GW to meet the hardness target of 100 mg/L. Some additional desalting is needed to achieve this balance.

- Alternative 3 – IPR-ASR Focused: Because of the high reliance on withdraw of AWPF water through ASR, the AWPF water provides the high quality water source; however, it would be important to balance the ratio of AWPF to untreated GW withdrawal to maintain a minimum water hardness in the blended water.

7.7.4 Non-Economic Considerations

In addition to the economic analysis, non-economic considerations were summarized that relate to the goals and objectives for the PWIMP and the City's water supply, as noted in Section 2.0. That summary is included in Table 15. Using those considerations as well as the established evaluation criteria from PM 1.1, *Overall - Master Planning Process Overview*, an alternatives comparison, summarized in Table 16, was done to determine if there was dramatic difference in the alternatives when taking into account the major PWIMP objectives. The comparison showed a slight advantage to Alternative 2 - Combined GW/ASR – IPR.

This alternative seems to offer the most reliability and resiliency for addressing future impacts (i.e., from potential regulatory changes to climate change impacts) while minimizing the level of risk to future supply. Alternative 2 also allows the City to maintain significant local control of their best water source, the AWPF, while still working with the farmers to provide much needed water for irrigation.

Based upon this assessment, it is recommended to move forward with Alternative 2 – Combined GW/ASR-IPR.

Table 15 Non-Economic Consideration of Water Supply Alternatives
Public Works Integrated Master Plan
City of Oxnard

	Alt 1 – GW Focused	**Alt 2 – Combination GW/IPR-ASR**	**Alt 3 – ASR/IPR Focused**
Approach	• Provide farmers with maximum high quality RW from AWPF • Pump additional GW and treat through desalters - expanded and new • Receive RW pump-back allocation • Maximize GW pumping	• Balance recycled water provided to local famers and distributed within the City (through ASR) • For reliability, install more desalting capacity rather than redundant ASR/IPR wells • Maximize GW pumping	• Send majority of AWPF water to ASR well sites • Construct redundant ASR well site for IPR supply • Provide remaining AWPF water (minimal) to farmers for irrigation • Maximize GW pumping by adding desalting to meet water quality objectives
Risk	**High**	**Moderate**	**Low**
Control of Supply	**Low**	**Moderate**	**High**
Benefits	• Lower initial costs • Less pipeline infrastructure needed – less construction disruption • Maximizes GW pumping allocations	• Provide local farmers additional RW water without compromising potable supply needs • Maximizes GW pumping allocations • Provides reliability in case pump back allocations are reduced in the future •	• Maximize use of AWPF water for supply • Redundant ASR sites provide a high level of reliability • Pump out of GW aquifer at nearly a 1:1 ratio – less loss of supply • Use of high quality water for high quality need (potable supply)
Drawbacks	• Reliance on 1:1 RW pump back allocation (future unknown) • Automatically lose a portion (20-25%) of the RW pump-back allocation by having to desalt the pumped GW • May not be able to ‘recall’ the water contracted to the farmers at a later date, if needed • Use of high quality water for lower quality need (ag irrigation) • Requires meeting water quality goals with added desalters	• Higher initial costs for sake of reliable supply options	• High initial costs • More heavily reliant on ASR/IPR for supply

Note:
(1) All new desalting and/or ASR facilities assumed to be constructed at BS 1/6 (first) and BS 3 (when needed), except for planned ASR well at Campus Park.

Table 16	Overall Comparison of Water Supply Alternatives(1) Public Works Integrated Master Plan City of Oxnard			
No.	**Goal**	**Alt 1 – GW Treatment Focused**	**Alt 2 – Combined GW/ASR-IPR**	**Alt 3 – ASR/IPR Focused**
PWIMP Overall Goals(2)				
#1	Reliability/Redundancy	+	+++	++
#3	Lifecycle Costs	+++	++	+
#2/4	Energy Use/GHGs	+	++	++
#5	Potable Water Offset	+++	++	+
#5	Groundwater Replenishment	+	++	+++
Water Supply Specific Goals				
	Water Quality	+++	+++	+++
	Maximize GW Pumping	+++	+++	+++
	Minimize Imported Water	++	++	++
	Local Control of Water Supply	+	++	+++
Total		**18+**	**21+**	**20+**

Notes:
(1) ‘+’ = good, ‘++” = better, ‘+++’ = best.
(2) (2) From PM 1.1, *Overall Master Plan Screening, Evaluation and Ranking.*

7.8 Low vs. High Pumping Restrictions

Before completing the alternative analysis, one last sensitivity analysis was considered. As noted at the beginning of the alternative analysis, the alternatives were derived based on a groundwater pumping allocation of 75 percent of historical. However, the City wanted to understand the potential impacts on the recommended alternative when the groundwater pumping allocation was at 50 percent of historical. While it is unforeseeable what the actual allocation will be in the future, the City is confident that the upper limit is the current 75 percent but the future could very well be as low as 50 percent.

Qualitatively, a reduction in groundwater pumping allocation to 50 percent of historical would have the following impacts to the recommended alternative:

- AWPF expansion to Phase 3 - 18.75 mgd would need to occur as much as 5 years sooner than planned above.
- Additional facilities would then be needed to meet demand:
  - A second ASR wellfield (or alternatively DPR).
  - Additional desalting.
  - Or a combination of both.

8.0 RECOMMENDED WATER SUPPLY PROJECTS

After discussion with the City, the team recommends proceeding with Alternative 2 – Combined GW Treatment/IPR-ASR but assuming a groundwater pumping allocation of 50 percent of historical. Based on Table 3, this means that approximately 12,000 AFY of additional supply is needed to cover the supply gap projected by 2040. In addition, it was assumed that a cap of 5,200 AFY could be taken to the farmers with the hope of receiving pump-back groundwater credit. This means that more ASR wells will be needed to take full advantage of the AWPF effluent for IPR use.

Therefore, several additional projects need to be added to the list of recommended projects, over and above what was shown in the alternatives analysis. These projects are needed not only for meeting the projected 2040 demand, but also for providing a reliable, redundant and sustainable water supply into the future.

Table 17 summarizes all of the recommended projects needed through 2040. Figure 7 illustrates these same facilities in orientation with the City's existing water and recycled water infrastructure.

9.0 RECOMMENDED PROJECT - COSTS, PRIORITY AND SCHEDULE

Cost estimates, implementation priority and schedule were also developed for the recommended projects for the water supply and treatment projects, as summarized in the previous section. This information will be included in the overall Capital Improvement Program (CIP) and used as the basis for the financial analysis portion of the PWIMP to determine financial impact of the project to the City and its rate payers.

There are three main drivers for the water supply and treatment costs as noted in the sections above: 1) Water Supply, 2) Rehabilitation and Replacement (R&R) and 3) Operations Optimization. Each of the drivers is described in more detail below.

9.1 Water Supply

All of the projects discussed under the Recommended Project are considered needed for water supply. In other words, the projects identified will help the City to maintain a sustainable water supply through the planning period.

9.2 Rehabilitation and Replacement (R&R)

Several analyses conducted as part of the PWIMP have assessed the condition of the City's existing water and infrastructure system assets. In general, the Recycled Water System, being so recently installed, has very little need for R&R type work. However, the

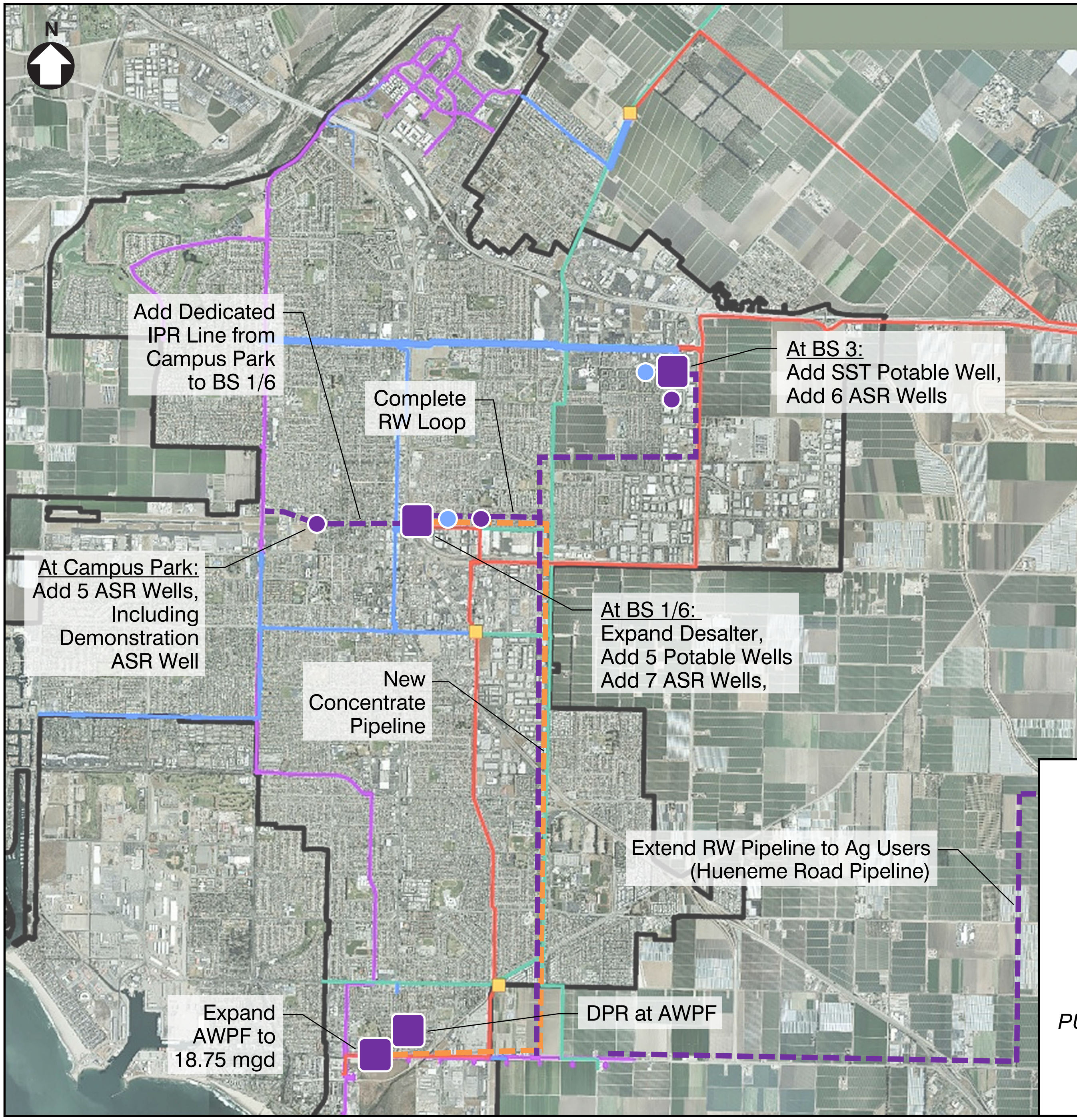
Table 17 Recommended Projects to Meet Water Supply Needs through 2040
Public Works Integrated Master Plan
City of Oxnard

Facility	Description	Location	Quantity	Unit	Capacity
Water System					
Potable Water Wells	Replace GW Wells	BS 1/6	5	wells	2,000 gpm (ea.)
	Replace GW Well (SST)	BS 3	1	wells	2,000 gpm
Existing Desalter(2)	Expand Existing desalter by 7.5 mgd	BS 1/6	1	--	Total: 15 mgd
Permeate Water Storage	Construct a new tank for operational storage	BS 1/6	1	tank	2.0 MG
Disinfection	Expand existing disinfection	BS 1/6	1	--	--
Recycled Water System					
AWPF	Expand existing by 12.5 mgd		1	--	Total: 18.75 mgd
ASR Wells(3)	Demonstration Well	Campus Park	1	well	2,000 gpm
	Well 18 Rehab(4)	River Ridge Golf Course	1	well	3,000 gpm
	Construct 2 duty + 2 standby wells(5)	Campus Park		well	2,000 (ea.)
	Construct 4 duty + 3 standby wells	BS 1/6		well	2,000 (ea.)
	Construct 4 duty + 2 standby wells	BS 3		well	2,000 (ea.)
ASR Support Systems					
Disinfection	Expand existing disinfection	BS 1/6	1	--	--
Operational Storage	Construct above-ground storage for daily peaking	BS 1/6	1	tank	1.0 MG
Booster Pumping	Provide pumping out of operational storage into potable distribution system	BS 1/6	1	--	500 HP

Table 17 Recommended Projects to Meet Water Supply Needs through 2040
Public Works Integrated Master Plan
City of Oxnard

Facility	Description	Location	Quantity	Unit	Capacity
Disinfection	Expand existing disinfection	BS 3	1	--	--
Operational Storage	Construct above-ground storage for daily peaking	BS 3	1	tank	1.0 MG
Booster Pumping	Provide pumping out of operational storage into potable distribution system	BS 3	1	--	500 HP
RW Conveyance Piping(6)	Complete Hueneme Road Pipeline - Phase 2 (24 and 36 inch)		36,700	lf	--
	Connect Demonstration ASR Well to RWBS Piping in Ventura Road		2,000	lf	--
	Construct dedicated IPR Line (Conveying IPR water from Campus Park to BS 1/6)		4,000	lf	--
	Complete RW Loop (16, 20 and 30 inch)		37,600	lf	--
DPR Storage(6)	Construct 3 engineered storage tanks	AWPF	3	ea	3.1 MG
Concentrate Conveyance					
	Construct brine line from OWTP to BS 1/6 (14 and 24 inch)		32,100	lf	--

Notes:
(1) Recommended facilities based on meeting demand requirements and providing water quality objective (TDS ≤ 500 mg/L), unless otherwise noted.
(2) Additional improvement needed to meet water quality objective (hardness = 100 mg/L).
(3) Each ASR duty well installed will require 3 monitoring wells.
(4) Used for recharge to the upper aquifer only; will not be used for potable withdraw.
(5) Two to three standby wells may be converted to duty wells as needed for future demands.
(6) Further details on the RW Conveyance Piping including in PM 4.2, *Recycled Water – Infrastructure Modeling and Alternatives.*



LEGEND

Existing Transmission Lines:
- CMWD Pipeline
- O-H Pipeline
- RW Distribution
- Potable Distribution

Recommended New Transmission Lines and Wells:
- New Concentrate Pipeline
- RW Distribution
- New Potable Wells
- New ASR Wells

NOTE:

1. This figure is schematic in nature. The recycled water distribution and potable distribution are independent systems.

RECOMMENDED WATER/RECYCLED WATER PROJECTS

FIGURE 7

CITY OF OXNARD

PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES

PUBLIC WORKS INTEGRATED MASTER PLAN

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Water System, which is much older, was found to have several areas that are in need of R&R. The following PMs address the existing asset assessments that were made:

- PM 2.4, *Water System - Condition Assessment* – Assessed the R&R needs of and developed priorities for the water blend stations and pipeline infrastructure of the water system.

- PM 2.7, *Water System - Cathodic Protection* – Assessed the cathodic protection needs of the water system and developed a list of recommended projects to address deficiencies.

In addition, some additional R&R items already identified by the City in their current GREAT Program CIP (circa February 2015) were also included and costs provided by the City (per information in Appendix K).

9.3 Operations Optimization

The City is working with another consultant, AECOM, on some optimization projects for their water system operation. These were also identified and included in the CIP summaries. Costs for these projects were provided by the City/AECOM.

9.4 Cost, Priority and Schedule Summary

The Water and Recycled Water project costs are presented in Tables 18 and 19, respectively, and are based on the preliminary layouts, sizing and configuration. Project costs are estimated based on unit costs developed from estimating guides, equipment manufacturer's information, unit prices and construction costs of similar facilities and other locations. A more detailed discussion of the basis of costs is included in PM 1.4, *Overall - Basis of Cost*.

The drivers are noted next to each project along with their anticipated start year and length of project completion. The projects are categorized by priority which loosely also follows timing of the projects: 1) Phase 1 – Immediate Needs (First 2 years); 2) Phase 2 – Near-Term Needs (2 to 10 years); and 3) Phase 3 – Long-Term Needs (Beyond 10 years).

The Overall Project Costs for the Recommended CIPs are summarized in Table 20. Figure 8 illustrates a proposed schedule for the water supply, treatment and conveyance projects (including recycled water distribution).

The costs and timing presented in this PM represent Carollo's best professional judgment of the capital expenditure needs of the City and of the timing needed to maintain a reliable and compliant system that can meet current and future water demands and wastewater generation needs. Timing of the projects was set to align with the seven master plan drivers, namely: R&R, regulatory requirements, economic benefit, performance benefit, growth, resource sustainability, and policy decisions. Project timing is also based on input from City staff and the condition assessments performed.

Table 18 Recommended Project Costs and Priority for Water Supply and Treatment System[(1)]
Public Works Integrated Master Plan
City of Oxnard

Project Name	Driver	Start Year	Years to Implement	Un-escalated Project Cost ($)
Phase 1				
Electrical Rehabilitation - Well Nos. 30, 32, 33 & 34[(2)]	Operations Optimization	2016	1.5	$1,000,000
Sodium Hypochlorite Piping Replacement[(2)]	Operations Optimization	2016	1.5	$30,000
Emergency Turn-outs Service[(2)]	Operations Optimization	2016	1.5	$30,000
Generator and ATS Service[(2)]	Operations Optimization	2016	1.5	$20,000
Blending Station 2 – Mechanical, Electrical and AUX Equipment Replacement[(4)]	R&R	2016	1.5	$100,000
Blending Station 1/6 – Mechanical, Electrical and AUX Equipment Replacement[(4)]	R&R	2016	2	$3,400,000
Water System CMMS	R&R	2016	1	$250,000
Water System SCADA Improvements[(5)]	R&R	2016	2	$5,000,000
Connection to OH/United pipeline	Water Supply	2016	1.5	$310,000
			PHASE 1 TOTAL:	**$10,100,000**
Phase 2				
Ongoing Repair and Replacement of Existing Desalter[(4)]	R&R	2020	--	$21,000,000
Well 23 & 31 Rehab[(2)]	R&R	2018	1.5	$210,000
Wells Electrical & VFD Replacement[(2)]	R&R	2018	1.5	$770,000
Blending Station #3[(4)]	R&R	2019	2	$2,500,000
Blending Station #4[(4)]	R&R	2019	1.5	$370,000
Blending Station #5[(4)]	R&R	2019	1.5	$190,000
BS 1/6 - Install electrical isolation at all steel and cast iron water risers[(3)]	R&R	2018	2	$30,000
BS 1/6 – Cathodic Protection System for Steel Storage Tank[(3)]	R&R	2018	2	$40,000
Expand desalter at BS 1/6 to 11.25 mgd (3.75 mgd expansion)	Water Supply	2022	3	$10,900,000
Blend Station Tie-In (@ BS 1/6)	Water Supply	2022	1	$250,000
Disinfection System Upgrade (@ BS 1/6)	Water Supply	2022	2.5	$190,000
Construct new concentrate line from OWTP to BS 1/6	Water Supply	2018	3	$18,800,000
Construct 3 new potable wells (BS 1/6)	Water Supply	2021	2	$10,100,000
Construct booster pump station (BS 1/6)	Water Supply	2021	2	$3,600,000
Construct 2 new potable wells (BS 1/6) and 1 new stainless steel well at BS 3	Water Supply	2023	2	$11,800,000
			PHASE 2 TOTAL:	**$80,800,000**
Phase 3				
BS 1/6 - Design and install CP on buried water piping[(3)]	R&R	2021	2	$45,000
Expand desalter at BS 1/6 to 15 mgd (3.75 mgd expansion)	Water Supply	2028	3	$7,300,000
			PHASE 3 TOTAL:	**$7,300,000**

Note:
(1) 20-City Average Index ENR CCI of 9,962 was used for February 2015. A R.S. Means Location Factor of 106.6 for Oxnard was used.
(2) Costs derived from the City's GREAT program CIP, 02/18/2015 (included in Appendix K).
(3) Costs derived from Cathodic Protection Recommended Projects outlined in PM 2.7.
(4) Costs based ongoing R&R estimates for existing desalter per Cost of Services (COS) Study.

Table 19 Recommended Capital Improvement Projects for Recycled Water System[1]
Public Works Integrated Master Plan
City of Oxnard

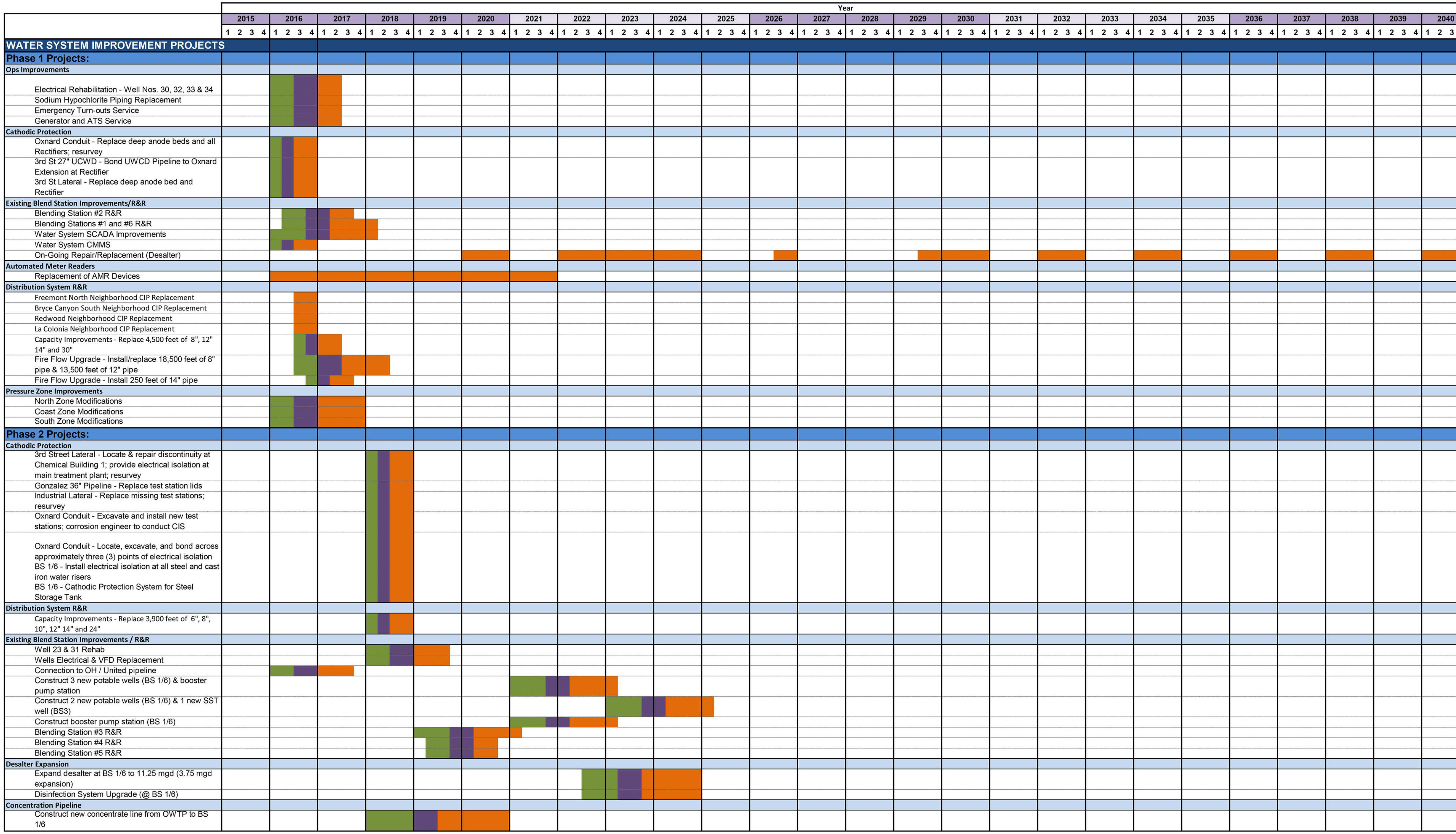
Project Name	Driver	Start Year	Years to Implement	Un-escalated Project Cost ($)
Phase 1				
Recycled Water Retrofits[2]	R&R	2016	--	$4,000,000
Phase 1 Improvements (Disinfection conversion, security, A/V upgrade)[3]	R&R	2015	2	$1,000,000
UV/AOP Brine Treatment	Water Supply	2018	3	$5,700,000
Construct ASR Demonstration Well @ Campus Park Site (and associated monitoring wells)	Water Supply	2015	1	$4,400,000
Land Acquisition and Improvements - Near BS 1/6 & 3	Water Supply	2016	2	$10,000,000
RW Pond for Off-Spec Water at Campus Park	Water Supply	2016	1.5	$1,600,000
			PHASE 1 TOTAL:	**$26,700,000**
Phase 2				
Phase 2 - Expansion to 12.5 mgd (including backup power)	Water Supply	2016	2.5	$27,500,000
RW Storage	Water Supply	2017	2	$8,000,000
Construct 1 duty + 1 standby ASR Wells @ Campus Park[4]	Water Supply	2016	2	$7,800,000
Construct 1 duty + 1 standby ASR Wells @ Campus Park[4]	Water Supply	2017	1.5	$7,800,000
Construct 1 duty + 1 standby ASR Wells @ BS 1/6[4]	Water Supply	2018	2	$7,800,000
Chemical Feed Expansion @ BS 1/6	Water Supply	2018	2	$300,000
Operational Storage for ASR Wells @ BS 1/6	Water Supply	2018	2	$2,100,000
Booster Pumping for ASR @ BS 1/6	Water Supply	2018	2	$7,200,000
Construct 1 duty + 1 standby ASR Wells @ BS 1/6[4]	Water Supply	2019	1.5	$7,800,000
Rehab Well 18 @ RR Golf Course to Groundwater Recharge Well	Water Supply	2020	2	$2,500,000
			Phase 2 TOTAL:	**$78,800,000**
Phase 3				
Phase 3 - Expansion to 18.75 mgd	Water Supply	2027	2.5	$28,100,000
Construct 2 duty + 1 standby ASR Wells @ BS 1/6[4]	Water Supply	2027	2	$11,500,000
Construct 2 duty + 1 standby ASR Wells @ BS 3[4]	Water Supply	2027	2.5	$11,500,000
Chemical Feed Expansion @ BS 3	Water Supply	2027	2.5	$500,000
Operational Storage for ASR Wells @ BS 3	Water Supply	2027	2.5	$2,100,000
Booster Pumping for ASR @ BS 3	Water Supply	2027	2.5	$7,200,000
Construct 2 duty + 1 standby ASR Wells @ BS 3[4]	Water Supply	2029	1.5	$11,500,000
			Phase 3 TOTAL:	**$72,400,000**

Notes:
(1) 20-City Average Index ENR CCI of 9,962 was used for February 2015. A R.S. Means Location Factor of 106.6 for Oxnard was used.
(2) Assumes 10 retrofits per year for 4 years at a total of $1,000,000 per year.
(2) Costs derived from the City's GREAT program CIP, 02/18/2015 (included in Appendix K).
(3) Each ASR well installed will have 3 associated monitoring wells installed.

Table 20	Overall Project Costs(1) Public Works Integrated Master Plan City of Oxnard		
Phase	**Water System**	**Recycled Water System**	**Total Phase Cost**
1	$10 M	$27 M	$37 M
2	$81 M	$79 M	$160 M
3	$7 M	$72 M	$79 M
Total	**$98 M**	**$178 M**	**$276 M**

Notes:
(1) 20-City Average Index ENR CCI of 9,962 was used for February 2015. A R.S. Means Location Factor of 106.6 for Oxnard was used.

Though the costs developed in this PM match the costs analyzed as part of the Cost of Service (COS) Study (Carollo, 2015), the timing presented may differ. The COS Study will balance not only the CIP projects identified but also the rates and rate payer affordability based on a yearly balance along with the integrated costs for the different City funds and enterprises.



RECOMMENDED WATER/RECYCLED WATER PROJECT SCHEDULE (Part 1)

FIGURE 8A

CITY OF OXNARD

PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES

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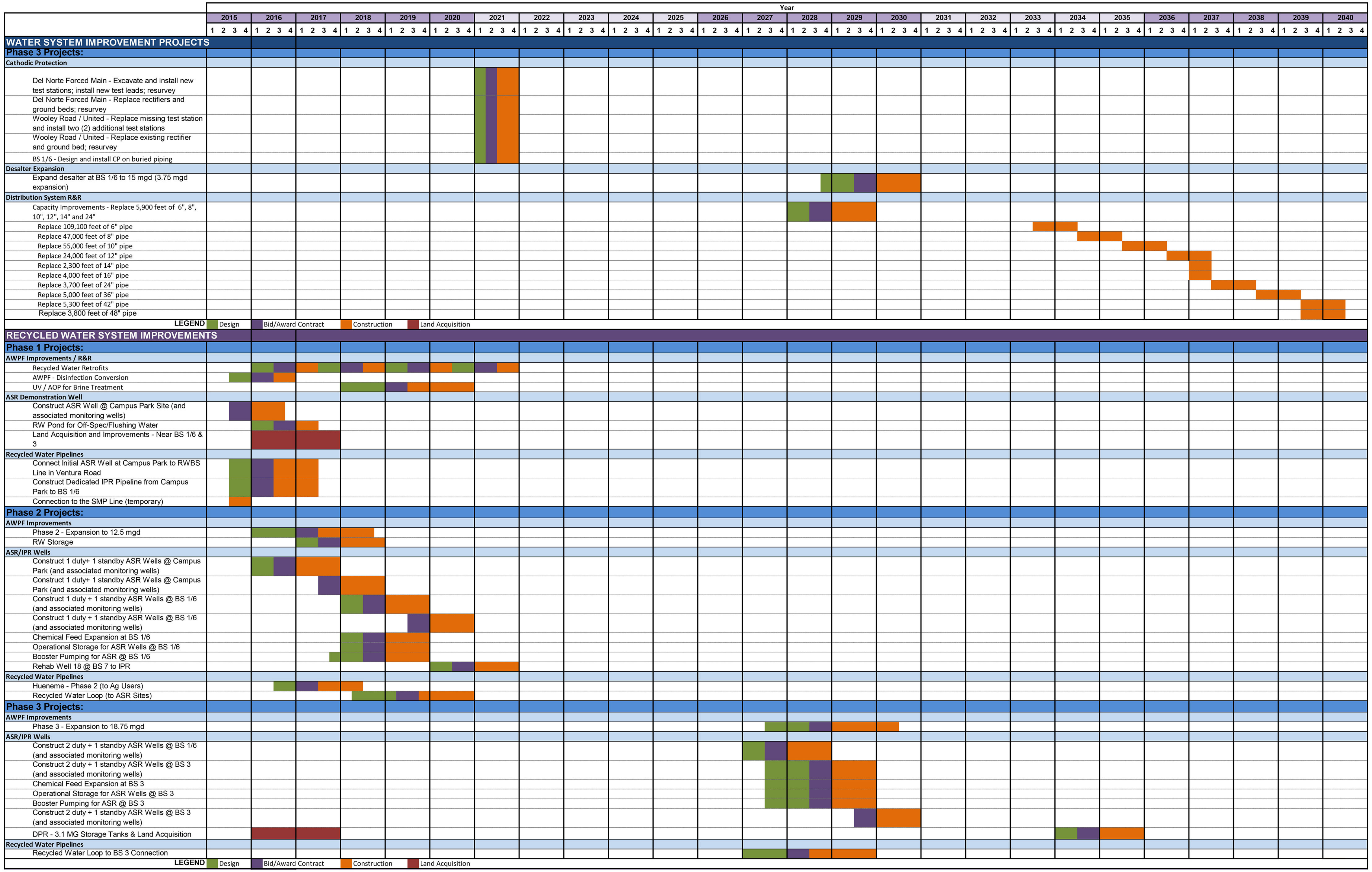

RECOMMENDED WATER/RECYCLED WATER PROJECT SCHEDULE (Part 2)

FIGURE 8B

CITY OF OXNARD

PM NO. 2.5 - WATER SUPPLY AND TREATMENT ALTERNATIVES

PUBLIC WORKS INTEGRATED MASTER PLAN

Engineers...Working Wonders With Water®

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APPENDIX A – EMERGENCY ORDINANCE

EMERGENCY ORDINANCE – E

AN EMERGENCY ORDINANCE LIMITING EXTRACTIONS FROM GROUNDWATER EXTRACTION FACILITIES, SUSPENDING USE OF CREDITS AND PROHIBITING CONSTRUCTION OF ANY GROUNDWATER EXTRACTION FACILITY AND/OR THE ISSUANCE OF ANY PERMIT THEREFOR

The Board of Directors of the Fox Canyon Groundwater Management Agency, State of California, ordains as follows:

ARTICLE 1. Findings

The Board of Directors hereby finds that:

A. On January 17, 2014, the Governor of the State of California proclaimed a state of emergency due to current drought conditions and called on Californians to reduce their water usage by 20 percent. On March 1, 2014, the Governor signed into law emergency drought legislation that finds and declares that California is experiencing an unprecedented dry period and shortage of water for its citizens, local governments, agriculture, environment, and other uses.

B. The U.S. Drought Monitor has designated the territory of the Agency to be currently in a condition of exceptional drought.

C. The United Water Conservation District has reported that groundwater storage in the Oxnard Plain Basin Forebay dropped by 32,200 acre feet in the past year and groundwater levels are currently below sea level. Continued dry conditions and regulatory restrictions on diversions from the Vern Freeman Diversion will result in less water available for recharge of the Forebay.

D. On February 25, 2009, the Fox Canyon Groundwater Management Agency Board of Directors in response to a serious water resource problem constituting a very real and immediate threat to groundwater quality and quantity to the West, East, and South Las Posas Basins and any and all basins tributary thereto adopted Emergency Ordinance D, entitled An Emergency Ordinance to Impose a Temporary Moratorium on Construction of New Wells and to Provide an Upper Limitation to Efficiency Extraction Allocation Within the West, East, and South Las Posas Groundwater Basins Pending Development of a Basin-Specific Management Plan.

E. Emergency Ordinance D was replaced by Ordinance 8.6 which presumed the development of a Basin-Specific Management Plan. However, the threats to groundwater quality and quantity in the Las Posas Basins remain and have increased due to persistent drought conditions, and the lack of a Basin-Specific Management Plan.

F. The Agency's 2007 Update to its Groundwater Management Plan established basin yield at 100,000 acre-feet per year; however, average annual total extractions within the Agency for Calendar Years 2003 through 2012 were 124,586 acre-feet.

G. Due to persistent dry conditions, the Department of Water Resources on January 31, 2014, announced a 2014 State Water Project Allocation of zero percent.

H. The cumulative use of conservation credits has reduced the benefit of previous reductions in historical allocations, and could limit any benefit derived through this Emergency Ordinance.

I. The Board may adopt ordinances for the purpose of regulating, conserving, managing, and controlling the use and extraction of groundwater within the territory of the Agency.

J. The measures adopted in this emergency ordinance are necessary in order to improve and protect the quantity and quality of groundwater supplies within the territory of the Agency, to prevent a worsening of existing conditions, to allow time to implement a definite and long-term solution to improve groundwater conditions in the Agency and to bring groundwater extractions into balance with recharge.

K. This emergency ordinance is exempt from the California Environmental Quality Act pursuant to CEQA Guidelines Sections 15307 and 15308 as an action taken "to ensure the maintenance, restoration, or enhancement of natural resources or the environment."

ARTICLE 2. Reduction of Groundwater Extractions

A. For the duration of this emergency ordinance, all Municipal and Industrial Operators' extraction allocations, regardless of type, shall be replaced with a Temporary Extraction Allocation (TEA) based on an operator's average annual reported extractions, not including any extractions that incurred surcharges, for Calendar Years 2003 through 2012.

B. For the Port Hueneme Water Agency (PHWA), their TEA shall be established according to the Agency's approved July 24, 1996 agreement and allocations contained within.

C. Temporary Extraction Allocations (TEA) shall be reduced in order to eliminate overdraft from the aquifer systems within the boundaries of the Agency for municipal and industrial uses. The reductions shall be as follows:

1. Beginning July 1, 2014	10% (TEA x 0.90/2)
2. Beginning January 1, 2015	15% (TEA x 0.85/2)
3. Beginning July 1, 2015	20% (TEA x 0.80/2)
4. Beginning January 1, 2016	20% (TEA x 0.80)

D. For reported extractions starting on August 1, 2014, all Agricultural Operators' extraction allocations, regardless of type, shall be replaced with an Annual Efficiency Allocation as provided in Section 5.6.1.2. of the Agency Ordinance Code, except that the annual irrigation allowances used to calculate the Irrigation Allowance Index shall be adjusted downward 25% from the allowances set forth in Resolution No. 2011-04 (Exhibit No. 1). For computing the irrigation allowance, the definition of Planted Acre may include designated areas that grew irrigated crops in the twelve months prior to August 1, 2014, but have subsequently been fallowed or are growing a non-irrigated crop.

E. On February 1, 2015, the Board may by Resolution undertake an additional adjustment to the annual irrigation allowances used to calculate the Irrigation Allowance Index, or other pumping restrictions in order to achieve a cumulative 10% reduction in pumping by Agricultural Operators.

F. On August 1, 2015, the Board may by Resolution undertake an additional adjustment to the annual irrigation allowances used to calculate the Irrigation Allowance Index, or other pumping restrictions in order to achieve a cumulative 20% reduction in pumping by Agricultural Operators.

G. Notwithstanding the extraction allocations established pursuant to Chapter 5.0 of the Agency Ordinance Code, all extractions in excess of the allocations established and adjusted by this emergency ordinance shall be subject to extraction surcharges.

H. The Executive Officer may, on written request from a land owner or operator, grant a variance from the requirements of this article based on a showing:

    1. That there are special circumstances or exceptional characteristics of the owner or operator which do not apply generally to comparable owners or operators in the same vicinity; or
    2. That strict application of the reductions as they apply to the owner or operator will result in practical difficulties or unnecessary hardships inconsistent with the general purpose of this emergency ordinance; or
    3. That the granting of such variance will result in no net detriment to the aquifer systems.

ARTICLE 3. Limitation on Accrual and Use of Credits

Notwithstanding Section 5.7 of the Agency Ordinance Code, conservation credits shall not be obtained and may not be used to avoid paying surcharges for extractions while this emergency ordinance is in effect.

ARTICLE 4. Prohibition on New Extraction Facilities

The Board prohibits the issuance of any permit for construction of a groundwater extraction facility, other than a replacement, backup or standby facility which does not allow the initiation of any new or increased use of groundwater, within the territory of the Agency. The prohibition set forth shall not apply to any permit for which a completed application is on file with the Agency on or before February 26, 2014, or for any permit in furtherance of a pumping program approved by the Board. For the purpose of this Article 4, a new or increased use is one that did not exist or occur before the effective date of this emergency ordinance. The Board may grant exceptions to the prohibition set forth in this Article 4 on a case-by-case basis. Applications for exceptions shall conform to the requirements of Section 5.2.2.3. of the Agency Ordinance Code and will be approved only if the Board makes the findings set forth in Section 5.2.2.4. of the Agency Ordinance Code.

ARTICLE 5. Duration

This emergency ordinance shall remain in effect from the date of adoption and reviewed every eighteen months, unless superseded or rescinded by action of the Board or a finding by the Board that the drought or emergency condition no longer exists.

ARTICLE 6. Effective Date

This ordinance shall become effective immediately upon adoption by the vote of at least four members of the Board; otherwise it shall become effective on the thirty-first day after adoption.

PASSED AND ADOPTED this 11th day of April 2014 by the following vote:

AYES: 5
NOES: 0
ABSENT: 0

By: _______________________
Lynn Maulhardt, Chair, Board of Directors
Fox Canyon Groundwater Management Agency

ATTEST: I hereby certify that the above is a true and correct copy of Emergency Ordinance E.

By: _______________________
Jessica Kam, Clerk of the Board

Exhibit No. 1 – Current Irrigation Allowance Index and - Proposed Allowance Index Values (Adjusted 25%)

Irrigation Allowance Index Values (Adjusted 25%)*

Acre-Feet/Acre

		Oxnard (Z1)			Camarillo (Z2)			Santa Paula (Z3)		
		Typical	Dry	Wet	Typical	Dry	Wet	Typical	Dry	Wet
Includes leaching and DU = 0.8	**# of Crops**	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*
Spring Veg./Fall Celery	2	2.7	2.8	2.5	3.0	3.2	2.8	3.3	3.4	3.0
Summer Veg./Fall Veg	2	2.5	2.7	2.4	2.8	3.0	2.7	3.0	3.2	2.9
Spring Veg./Late Summer Veg./+part Late Fall Veg*	**2+plus**	2.9	3.1	2.8	3.3	3.5	3.1	3.6	3.8	3.4

		Oxnard (Z1)			Camarillo (Z2)			Santa Paula (Z3)		
		Typical	Dry	Wet	Typical	Dry	Wet	Typical	Dry	Wet
Crop		*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*	*Total AF/A*
Avocado - 20% Ground Shading	1	1.4	1.5	1.3	1.6	1.7	1.5	1.7	1.9	1.6
Avocado - 50% Ground Shading	1	2.0	2.2	1.9	2.3	2.5	2.1	2.5	2.8	2.3
Avocado - 70% Ground Shading	1	2.7	3.1	2.6	3.1	3.5	3.0	3.4	3.8	3.2
Blueberries 20% Ground Shading	1	1.4	1.4	1.3	1.5	1.8	1.5	1.8	1.9	1.7
Blueberries 50% Ground Shading	1	2.0	2.1	1.9	2.2	2.3	2.2	2.4	2.5	2.4
Blueberries 70% Ground Shading	1	2.7	2.9	2.6	3.1	3.3	3.0	3.4	3.6	3.2
Celery - Single Crop	1	1.5	1.6	1.4	1.7	1.8	1.5	1.8	1.9	1.6
Citrus - 20% Ground Shading	1	1.4	1.6	1.3	1.6	1.8	1.5	1.8	1.9	1.6
Citrus - 50% Ground Shading	1	1.9	2.0	1.8	2.2	2.3	2.0	2.4	2.5	2.2
Citrus - 70% Ground Shading	1	2.6	2.7	2.4	2.9	3.0	2.7	3.2	3.3	2.9
Lima Beans	1	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0	0.9
Misc. Veg Greenhouse - Fall	1	0.9	0.9	0.8	1.0	1.0	0.9	1.0	1.1	1.0
Misc. Veg Greenhouse - Spr	1	1.0	1.1	0.9	1.1	1.2	1.1	1.2	1.3	1.2
Misc. Veg Greenhouse - Summer	1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4
Misc. Veg Single Crop - Fall	1	1.0	1.1	1.0	1.1	1.2	1.0	1.2	1.3	1.1
Misc. Veg Single Crop - Spr	1	1.2	1.3	1.1	1.3	1.4	1.2	1.5	1.6	1.4
Misc. Veg Single Crop - Summer	1	1.5	1.5	1.5	1.7	1.7	1.6	1.8	1.9	1.8
Nursery (Non-Greenhouse)	1	3.2	3.4	3.1	3.6	3.8	3.5	4.0	4.2	3.8
Nursery (Greenhouse)	1	3.4	3.5	3.3	3.8	3.9	3.7	4.2	4.3	4.0
Raspberries - Tunnel	1	3.2	3.4	3.1	3.7	3.8	3.6	4.0	4.2	3.9
Sod	1	3.0	3.2	2.9	3.4	3.6	3.3	3.7	3.9	3.6
Strawberries-Main Season	1	2.3	2.5	2.2	2.6	2.7	2.4	2.8	2.9	2.6
Strawberries-Summer	1	1.4	1.4	1.3	1.5	1.6	1.4	1.6	1.7	1.5
Tomatoes - Peppers	1	1.7	1.7	1.6	1.9	1.9	1.8	2.1	2.1	2.0

*Adopted by FCGMA Board on April 11, 2014

APPENDIX B – SUMMARY OF POTENTIAL WATER CONSERVATION MEASURES

Table 1 Summary of Potential Conservation Measures Recommended in 2010 Study

Conservation Measure	Description	Est. Annual Potable Water Offset, AF	Annual Cost, $/AF	Advantages	Disadvantages
HE Nozzle Direct Installation Program	Retrofit landscape irrigation nozzles with HE alternative	134	$292	Cost effective Big savings potential Water savings more certain	Higher cost than distribution-type program Increase implementation difficulty
HE Nozzle Distribution Program	Distribute HE nozzles for customer retrofit	134	$195	Cost effective Big savings potential	Managing inventory – type and quantity Relies on customers installing correctly to realize savings
HE Toilet Distribution Program	Distribute ultra low flush toilets	568	$324	Targets large use of water within City Long term water savings	Difficult to implement Potential for replacement of already efficient toilets
Industrial Process Water Use & Cooling Tower Audit & Incentive Program	Survey and incentivize lower water use for industry/commercial	132	$311	Large potential savings per site Program drives market for water reuse and water reduction	High initial survey costs Large incentive required to drive down payback to under 2 years
MWD Save a Buck Program	Incentives to commercial customers for a variety of outdoor/indoor devices	N/A	$44-$450	75% of funding from MWD Cost effective Easy implementation (run by MWD)	Uncertain MWD funding levels Many measures do not have significant savings potential in Oxnard

Table 1 Summary of Potential Conservation Measures Recommended in 2010 Study

Conservation Measure	Description	Est. Annual Potable Water Offset, AF	Annual Cost, $/AF	Advantages	Disadvantages
SoCal Water$mart	Incentives to residential customers for a variety of outdoor/indoor devices	4	HE Nozzles: $292 All other: N/A	Majority of funding from MWD Easy implementation (run by MWD)	Uncertain MWD funding levels
Smart Controller Direct Installation Program	Direct installation of smart controllers and HE nozzles for irrigated landscaping (greater than 1 ac)	50	~$370	Targets large water use High water savings per site Focus on landscape water use	Limited number of large residential customers
Water Budget	Provide customers their water usage vs. their 'budget'	49	$59	Targets landscape market Educated customers will initiate changes on their own	No verifiable cost savings Savings duration is unknown 100% Oxnard funded
Multi-Family and Hotel/Motel HET Direct Installation Program	Direct install of ultra low flush toilets in multi-family and hotels/motels	821	$658	Cost effective Ease of operation High water savings	Erratic funding Saturation rate is at 50% for multi-family toilets
Estimated Total		**1,892**	**$2,550 - 2,950**		

Notes:

(1) Based on Conservation Programs & Implementation Plan developed in the 2010 Draft Conservation Plan.

APPENDIX C – 3RD STAGE RO FOR GROUNDWATER DESALTER FACILITY MEMO

Engineers...Working Wonders With Water®

TECHNICAL MEMORANDUM

Project Name:	Public Works Integrated Master Plan	**Date:**	December 4, 2015
Client:	City of Oxnard	**Project Number:**	9587A.00
Prepared By:	Dustin Whynman		
Reviewed By:	Tracy Clinton, Brandon Yallaly, Tom Seacord		
Subject:	3rd Stage RO for Groundwater Desalter Facility		
Distribution:	City of Oxnard - Daniel Rydberg, Thien Ng,		

1.1 Introduction

The City of Oxnard requested that Carollo evaluate the possibility of increasing recovery at the Groundwater Desalter Facility (GDF), that feeds Blending Stations 1 & 6, by adding a third stage of reverse osmosis (RO) membranes. The goal of this change to the GDF would be to reduce the amount of brine (waste) water produced, thereby resulting in a greater utilization of the City's groundwater resources.

1.2 Background

The GDF was commissioned in 2008 and ran for three years until it was decommissioned in 2011 due to operational issues with City wells. The facility was re-commissioned in June 2014 and has been operating since. The GDF treats brackish groundwater by RO membranes. Feed water for the GDF is pumped from three (3) wells which draw water from the Mugu and Oxnard aquifers, characterized by high nitrate and dissolved mineral concentrations. Treated water is blended with un-chlorinated water from existing city wells or water purchased from United Water Conservation District.

The treatment train at the GDF primarily consists of:

- Three feed water well pumps,
- Four RO feed filters (cartridge filters), and
- Three RO trains equipped with 2nd stage booster pumps

Each RO train is capable of producing 2.5 MGD of RO permeate at 80% recovery. The trains are configured in a 46 x 23 pressure vessel array with 7-RO elements per pressure vessel. The facility is designed to produce up to 7.5 MGD of RO permeate with two RO trains in service.

The maximum recovery that an RO train can achieve is based upon the raw water quality (i.e., dissolved salts) and pretreatment capabilities of the facility. As recovery increases, dissolved salts are concentrated on the feed side of the membrane. If the solubility limit of these dissolved salts is exceeded, salts can precipitate on the membrane and downstream pipes (e.g., brine lines). Solubility of some dissolved salts can be adjusted by changing the feed water pH (i.e., typically reducing the pH) and by adding antiscalants. Currently, antiscalant is dosed prior to the RO trains, however, there is no pH adjustment.

Raw water quality data collected during the design of the GDF was used in our analysis to determine if the recovery of the RO trains can be increased. Feed water quality data and a solubility analysis is provided in the RO system design projection attached to this memorandum.

1.3 Analysis

IMS Design Software version 2012 was used in Carollo's analysis to evaluate the maximum recovery and solubility limits in the RO brine stream (a.k.a, "RO concentrate). Based on this analysis, the groundwater plant appears to be at its maximum recovery already (i.e., 80%). There are 2 salts that appear to limit the recovery:

1. Silica – At the current recovery of 80%, the brine concentration is already over 180 mg/L. This is probably at the safe side of the “threshold” but any increase in recovery could put the City over the solubility limit, resulting in silica salt precipitation on the RO membranes or downstream pipelines.
2. Calcium Carbonate – At a brine LSI of 2.5, calcium carbonate is also at its solubility limit at an 80% recovery. If calcium carbonate was the only potential scaling salt, the City could add acid to increase its solubility; however, the silica limits the recovery to 80%.

1.4 Findings

The finding of this analysis is that the GDF is already at the edge of its recovery capability unless the groundwater quality has significantly changed (improved) since the facility was designed. Therefore, simply adding a third stage to the existing RO trains is not a feasible option for the City to increase the RO recovery.

The only way that the City can reliably increase RO recovery from the GDF is to chemically treat the RO brine prior to the third stage (i.e., precipitating and removing salts) before concentrating further using secondary RO trains. Such a facility is under construction at the Chino II Desalter in Mira Loma California. The Chino II Concentrate Reduction Facility (CRF) consists of:

- Lime softening to remove calcium carbonate and silica, followed by
- Granular media filtration to remove particles and residual calcium carbonate and silica solids, followed by
- Final RO brine volume reduction using a secondary RO process that is similar to a 3rd stage RO train.

The Chino II CRF will have the ability to take treated RO brine and produce up to 2.3 MGD of RO permeate at 85% recovery, reducing the Chino II Desalter's brine volume from 2.7 to 0.4 MGD. The Chino CRF has a total project construction cost of $50 million.

Less reliable alternatives for increasing the GDF RO recovery rate may include using alternative antiscalants that may increase silica solubility to as high as 240 mg/L, resulting in an 85% RO recovery rate. With minor mechanical modifications to the existing trains, this may even be implemented without adding an additional stage; however:

1. A pilot study would be required to demonstrate the efficacy of these alternative antiscalants at controlling silica precipitation at this high of a concentration.

2. Even if these alternative antiscalants are successful at controlling RO process scaling, it is likely (i.e., inevitable) that silica and other salts will precipitate downstream of the RO in the concentrate piping and brine disposal pipelines. Such scaling has been demonstrated to be a problem for other agencies in the Inland Empire area of California, which is one reason why the Chino II CRF is being constructed.

BOOSTER PUMP AND PERMEATE THROTTLING(ALL STAGES)

RO program licensed to:					
Calculation created by:	D. Whynman				
Project name:	Oxnard GDF		Permeate flow:	1737.00	gpm
HP Pump flow:	2171.3	gpm	Raw water flow:	2171.3	gpm
Feed pressure:	121.4	psi	Permeate throttling(All st.)	15.0	psi
Feedwater Temperature:	18.0	C(64F)	Permeate recovery:	80.0	%
Feed water pH:	7.50		Element age:	0.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	7.0	
			Fouling Factor	1.00	
			Salt passage increase, %/yr:	10.0	
Average flux rate:	12.9	gfd	Feed type:	Well Water	

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Booster Pressure psi	Element Type	Elem. No.	Array
1-1	1299.4	47.2	19.0	14.5	1.15	96.8	15.0		ESPA1	322	46x7
1-2	437.6	37.9	18.9	9.8	1.10	109.2	15.0	35.0	ESPA2	161	23x7

	Raw water		Feed water		Permeate		Concentrate	
Ion	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3
Ca	213.3	531.9	213.3	531.9	2.462	6.1	1056.7	2635.0
Mg	73.0	300.4	73.0	300.4	0.843	3.5	361.6	1488.2
Na	126.7	275.4	126.7	275.4	6.970	15.2	605.6	1316.6
K	6.0	7.7	6.0	7.7	0.407	0.5	28.4	36.4
NH4	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
Ba	0.510	0.4	0.510	0.4	0.006	0.0	2.5	1.8
Sr	1.380	1.6	1.380	1.6	0.016	0.0	6.8	7.8
CO3	0.8	1.3	0.8	1.3	0.000	0.0	4.0	6.7
HCO3	298.9	245.0	298.9	245.0	17.786	14.6	1423.4	1166.7
SO4	730.0	760.4	730.0	760.4	4.437	4.6	3632.3	3783.6
Cl	63.7	89.8	63.7	89.8	1.283	1.8	313.4	442.0
F	0.6	1.6	0.6	1.6	0.028	0.1	2.9	7.6
NO3	26.2	21.1	26.2	21.1	5.228	4.2	110.1	88.8
B	0.87		0.87		0.797		1.16	
SiO2	38.0		38.0		0.85		186.61	
CO2	15.11		15.11		15.11		15.11	
TDS	1580.0		1580.0		41.1		7735.4	
pH	7.50		7.50		6.32		8.12	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	27%	27%	202%
SrSO4 / Ksp * 100:	11%	11%	82%
BaSO4 / Ksp * 100:	6635%	6635%	41467%
SiO2 saturation:	33%	33%	144%
Langelier Saturation Index	0.54	0.54	2.47
Stiff & Davis Saturation Index	0.47	0.47	2.04
Ionic strength	0.04	0.04	0.19
Osmotic pressure	9.2 psi	9.2 psi	44.5 psi

BOOSTER PUMP AND PERMEATE THROTTLING(ALL STAGES)

RO program licensed to:					
Calculation created by:	D. Whynman				
Project name:	Oxnard GDF		Permeate flow:	1737.00	gpm
HP Pump flow:	2171.3	gpm	Raw water flow:	2171.3	gpm
Feed pressure:	121.4	psi	Permeate throttling(All st.)	15.0	psi
Feedwater Temperature:	18.0	C(64F)	Permeate recovery:	80.0	%
Feed water pH:	7.50		Element age:	0.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:	7.0	
			Fouling Factor	1.00	
			Salt passage increase, %/yr:	10.0	
Average flux rate:	12.9	gfd	Feed type:	Well Water	

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	Conc.&Throt. Pressures psi	Booster Pressure psi	Element Type	Elem. No.	Array
1-1	1299.4	47.2	19.0	14.5	1.15	96.8	15.0		ESPA1	322	46x7
1-2	437.6	37.9	18.9	9.8	1.10	109.2	15.0	35.0	ESPA2	161	23x7

Stg	Elem no.	Feed pres psi	Pres drop psi	Perm flow gpm	Perm Flux gfd	Beta	Perm sal TDS	Conc osm pres	Cumulative Perm Ion levels Ca	Mg	Cl	B	SiO2
1-1	1	121.4	5.5	4.9	17.7	1.10	21.1	10.2	0.66	0.22	1	0.61	0.29
1-1	2	115.8	4.7	4.6	16.5	1.10	22.0	11.4	0.73	0.25	1	0.64	0.33
1-1	3	111.2	4.0	4.3	15.4	1.12	24.1	12.8	0.83	0.28	1	0.68	0.37
1-1	4	107.1	3.4	4.0	14.4	1.12	27.0	14.6	0.94	0.32	1	0.70	0.42
1-1	5	103.8	2.8	3.7	13.5	1.13	30.5	16.6	1.07	0.37	1	0.73	0.48
1-1	6	101.0	2.3	3.5	12.6	1.14	34.9	19.2	1.24	0.42	1	0.76	0.55
1-1	7	98.7	1.9	3.2	11.6	1.15	40.5	22.3	1.45	0.50	1	0.79	0.65
1-2	1	128.8	4.1	3.4	12.4	1.09	38.2	25.0	0.78	0.27	1	0.61	0.40
1-2	2	124.7	3.6	3.2	11.4	1.10	37.9	27.6	0.87	0.30	1	0.64	0.45
1-2	3	121.1	3.1	2.9	10.5	1.10	37.9	30.4	0.98	0.34	1	0.67	0.50
1-2	4	118.0	2.7	2.7	9.7	1.10	38.4	33.5	1.12	0.38	1	0.71	0.57
1-2	5	115.3	2.4	2.5	8.9	1.10	39.3	37.0	1.27	0.43	1	0.74	0.65
1-2	6	113.0	2.0	2.2	8.0	1.10	40.4	40.9	1.45	0.50	1	0.77	0.74
1-2	7	110.9	1.8	2.0	7.2	1.10	41.9	45.1	1.67	0.57	2	0.80	0.85

Stage	NDP psi
1-1	79.0
1-2	72.5

BOOSTER PUMP AND PERMEATE THROTTLING(ALL STAGES)

RO program licensed to:						
Calculation created by:	D. Whynman					
Project name:	Oxnard GDF		Permeate flow:		1737.00	gpm
HP Pump flow:	2171.3	gpm	Raw water flow:		2171.3	gpm
Feed pressure:	121.4	psi	Permeate throttling(All st.)		15.0	psi
Feedwater Temperature:	18.0	C(64F)	Permeate recovery:		80.0	%
Feed water pH:	7.50		Element age:		0.0	years
Chem dose, ppm (100%):	0.0	H2SO4	Flux decline % per year:		7.0	
			Fouling Factor		1.00	
			Salt passage increase, %/yr:		10.0	
Average flux rate:	12.9	gfd	Feed type:	Well Water		

****

**** THE FOLLOWING PARAMETERS EXCEED RECOMMENDED DESIGN LIMITS: ***

****

Concentrate saturation of $BaSO_4$ too high (41467%)

Concentrate saturation of SiO_2 too high (144%)

Concentrate Langelier Saturation Index too high (2.47)

The following are recommended general guidelines for designing a reverse osmosis system using Hydranautics membrane elements. Please consult Hydranautics for specific recommendations for operation beyond the specified guidelines.

Feed and Concentrate flow rate limits

Element diameter	Maximum feed flow rate	Minimum concentrate rate
8.0 inches	75 gpm (283.9 lpm)	12 gpm (45.4 lpm)
8.0 inches(Full Fit)	75 gpm (283.9 lpm)	30 gpm (113.6 lpm)

Concentrate polarization factor (beta) should not exceed 1.2 for standard elements

Saturation limits for sparingly soluble salts in concentrate

Soluble salt	Saturation
$BaSO_4$	6000%
$CaSO_4$	230%
$SrSO_4$	800%
SiO_2	100%

Langelier Saturation Index for concentrate should not exceed 1.8

The above saturation limits only apply when using effective scale inhibitor.
Without scale inhibitor, concentrate saturation should not exceed 100%.

APPENDIX D – POTENTIAL WELL FIELD LOCATION STUDY

HOPKINS
GROUNDWATER
CONSULTANTS, INC.
THE WATER RESOURCE SPECIALISTS

January 5, 2015
Project No. 01-011-07J

City of Oxnard
305 West Third Street, Second Floor, East Wing
Oxnard, California 93030

Attention: Mr. Daniel Rydberg
Utilities and Engineering Manager

Subject: Preliminary Hydrogeological Review, City of Oxnard Groundwater Replenishment Reuse Project, Potential Wellfield Location Study, Oxnard, California.

Dear Mr. Rydberg:

As requested, Hopkins Groundwater Consultants, Inc. (Hopkins) is pleased to submit this letter-report summarizing the findings, conclusions, and recommendations developed from a preliminary study evaluating the potential feasibility of conducting a Groundwater Replenishment Reuse Project (GRRP) at various locations within the City of Oxnard (City). The purpose of the study is to review readily available information and provide a general summary about the hydrogeological suitability of each location for the proposed GRRP of purified recycled water. The potential aquifer storage and recovery (ASR) wellfield locations being considered by the City are shown on Figure 1 – Potential ASR Well Sites. Table 1 – ASR Well Site Identification summarizes the seven locations shown on Figure 1 and identifies the site names used throughout this study.

Available data are not sufficient to fully summarize detailed operational capacities or identify all existing conditions that may impact utilization of the proposed sites to establish an ASR wellfield. The study infers that historical data from proximate wells sufficiently identifies subsurface aquifer zones that will be encountered beneath the proposed sites. For the purpose of this fatal-flaw level of analysis, we assumed water quality related issues would not be a factor in assessing the feasibility of the sites. Future detailed hydrogeological studies of each site will be required for the Title 22 engineering reports that will be necessary to proceed with the proposed GRRP. The ASR well sites were evaluated to identify a range of replenishment and reuse capacities and to estimate aquifer storage potential. This analysis does not identify potential impacts to or from the proposed City GRRP from existing or potential future wells.

Each well site has its potential benefits for future City GRRP operations which will include Indirect Potable Reuse (IPR) and possibly Direct Potable Reuse (DPR) of purified recycled water. In the following section of this report, the benefits and limitations of each well site are estimated for use by the City in its master planning efforts. Table 2 – Production Capacity of Potential ASR Well Sites summarizes the information discussed in the following sections.

P.O. Box 3596, Ventura, California 93006 Phone: (805) 653-5306 e-mail: chop4@earthlink.net

Figure 1 – Potential ASR Well Sites

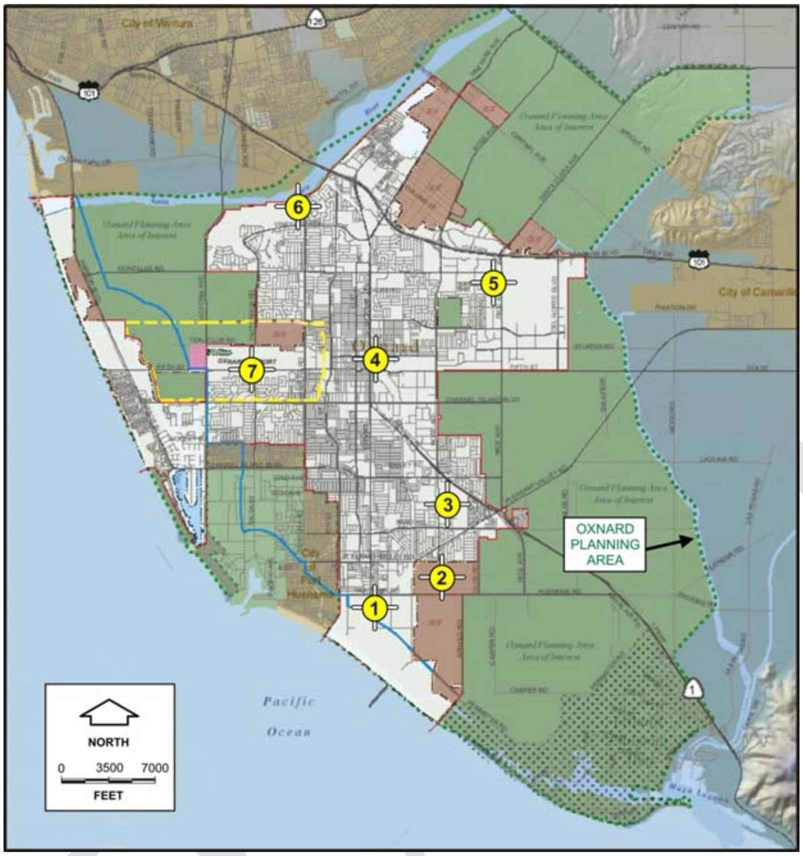


Table 1 – ASR Well Site Identification

SITE NUMBER	SITE IDENTIFICATION
1	ADVANCED WATER PURIFICATION FACILITY
2	SOUTH SHORE DEVELOPMENT
3	COLLEGE PARK
4	BLENDING STATION NO. 1
5	BLENDING STATION NO. 3
6	RIVER RIDGE GOLF COURSE
7	SOUTHWEST COMMUNITY PARK

Table 2 – Production Capacity of Potential ASR Well Sites

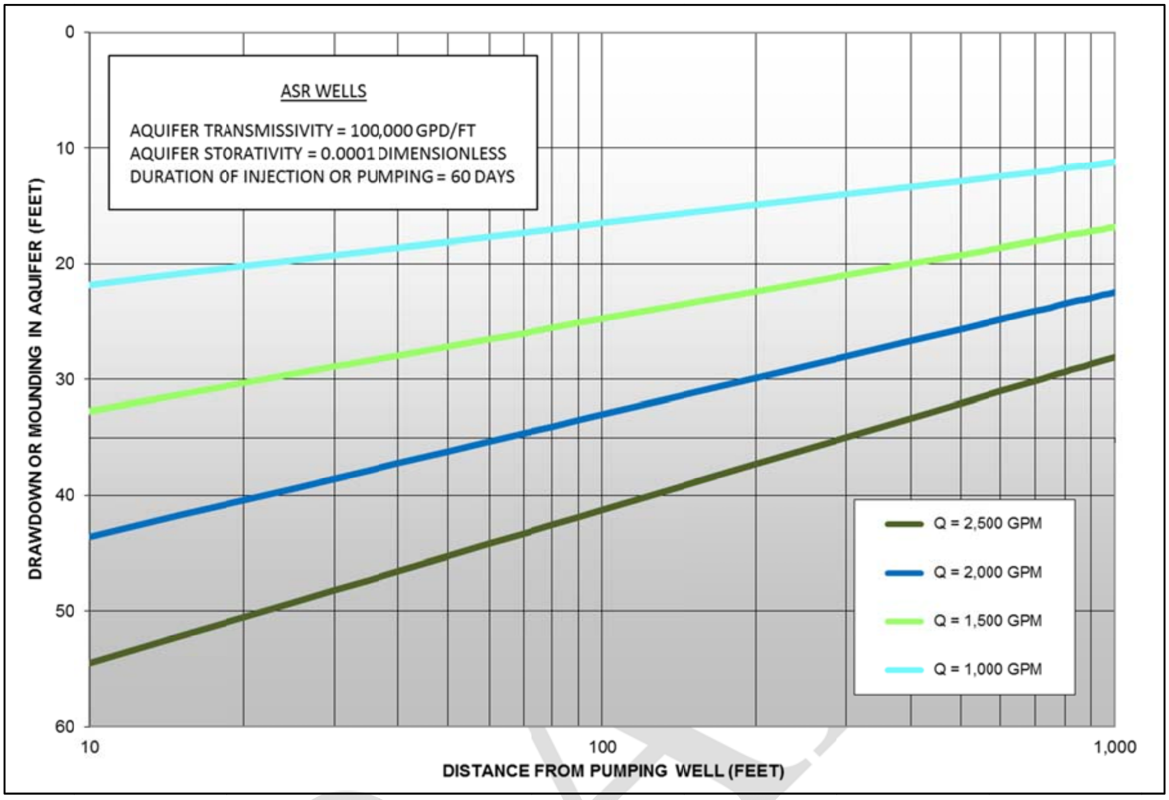
SITE NUMBER	SINGLE WELL REPLENISHMENT CAPACITY (GPM)	ESTIMATED NUMBER OF WELLS	DISCRETE ZONES AVAILABLE FOR GRRP OPERATIONS	ASR WELLFIELD INJECTION CAPACITY (GPM)[1]	POTENTIAL ANNUAL WELLFIELD CAPACITY (ACRE-FEET)
1	1,000 – 2,000	2 TO 3	1 TO 2	3,000 – 6,000	3,000
2	1,000 – 2,000	2 TO 3	1 TO 2	3,000 – 6,000	3,000
3	1,500 – 2,000	6 TO 9	3 OR MORE	4,000 – 6,000	7,000
4	1,500 – 2,500	6 TO 9	3 OR MORE	4,500 – 7,500	7,000(+)
5	1,500 – 2,500	6 TO 9	3 OR MORE	4,500 – 7,500	7,000(+)
6	1,500 – 2,500	6 TO 9	3 OR MORE	4,500 – 7,500	7,000(+)
7	1,500 – 2,500	6 TO 9	3 OR MORE	4,500 – 7,500	7,000(+)

[1] – ASR INJECTION CAPACITY PER DISCRETE ZONE(S) USING MULTIPLE WELLS

The estimates shown in Table 2 include the use of a single or multiple wells producing from discrete aquifer zones (1 to 3 zones per wellfield). The estimates also reflect a cyclical operational scheme that includes purified recycled water; a) injection for 2 months, b) remaining in aquifer for 2 months (response retention time), and c) recovery from the wells for 2 months. This operational scenario allows two of these cycles to be conducted per year.

During well operation (injection or production) the water level in the aquifer will be affected and result in mutual interference between wells. The aquifer zone(s) response to GRRP operations will be directly related to the rate of injection or production and the aquifer parameters of transmissivity and storativity (storage coefficient). Figure 2 – Theoretical Well Interference shows the estimated aquifer response under variable rates of replenishment or extraction. These projections utilized a transmissivity value of 100,000 gallons per day per foot of aquifer (gpd/ft) and believed reasonable based on historical well performance data. If the aquifer zones have a higher or lower transmissivity than the 100,000 gpd/ft used in these projections, the aquifer response will accordingly be less or greater than those estimated. Well interference considerations were included in the estimation of the wellfield capacities shown in Table 2 where multiple wells (2 or 3) could be completed in discrete zones to increase wellfield capacity.

Figure 2 – Theoretical Well Interference



Annual well field production of purified recycled water will be governed by factors that include; a) the number of available discrete aquifer zones, b) single well production/injection capacity, c) availability of land for well construction and operation, d) IPR versus DPR operation, e) the water quality standard desired by the City, and f) percentage of water lost as the water quality is degraded due to migration in the aquifer and localized mixing. Available data provide a fair level of confidence in the aquifer zones available and the well performance anticipated, however, the loss factor of injected water cannot be determined at this time. The amount of unrecoverable water for potable reuse may be 20 percent or higher depending on actual site conditions and the City's water quality objectives. This consideration could require an additional wellfield to maintain a constant supply of high quality IPR/DPR water. It is assumed that the lost replenishment water could be recovered as groundwater at another location, however, it would require treatment/purification to improve its quality.

The cost to construct and operate well facilities at the various wellfield locations will vary depending largely on well depth and the sensitivity of surrounding land uses. Site No. 1 will require all wells constructed to depths greater than 1,000 feet because there are no shallower aquifer zones available. Wells on Site Nos. 1 and 2 will all be deep constructions using aquifer zones between 1,000 and 1,500 feet below ground surface. The aquifer materials are anticipated to be a fine to medium-grained marine sand with a reduced hydraulic conductivity. The other sites will potentially allow construction of multiple wells completed to variable depths with the average well construction cost related to the average well depth.

This report has been prepared for the exclusive use of the City of Oxnard and its agents for specific application to the City of Oxnard Integrated Water Master Plan and the potential for ASR well sites to conduct a Groundwater Replenishment Reuse Project with purified recycled water. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeological planning and engineering practices. No other warranty, express or implied is made.

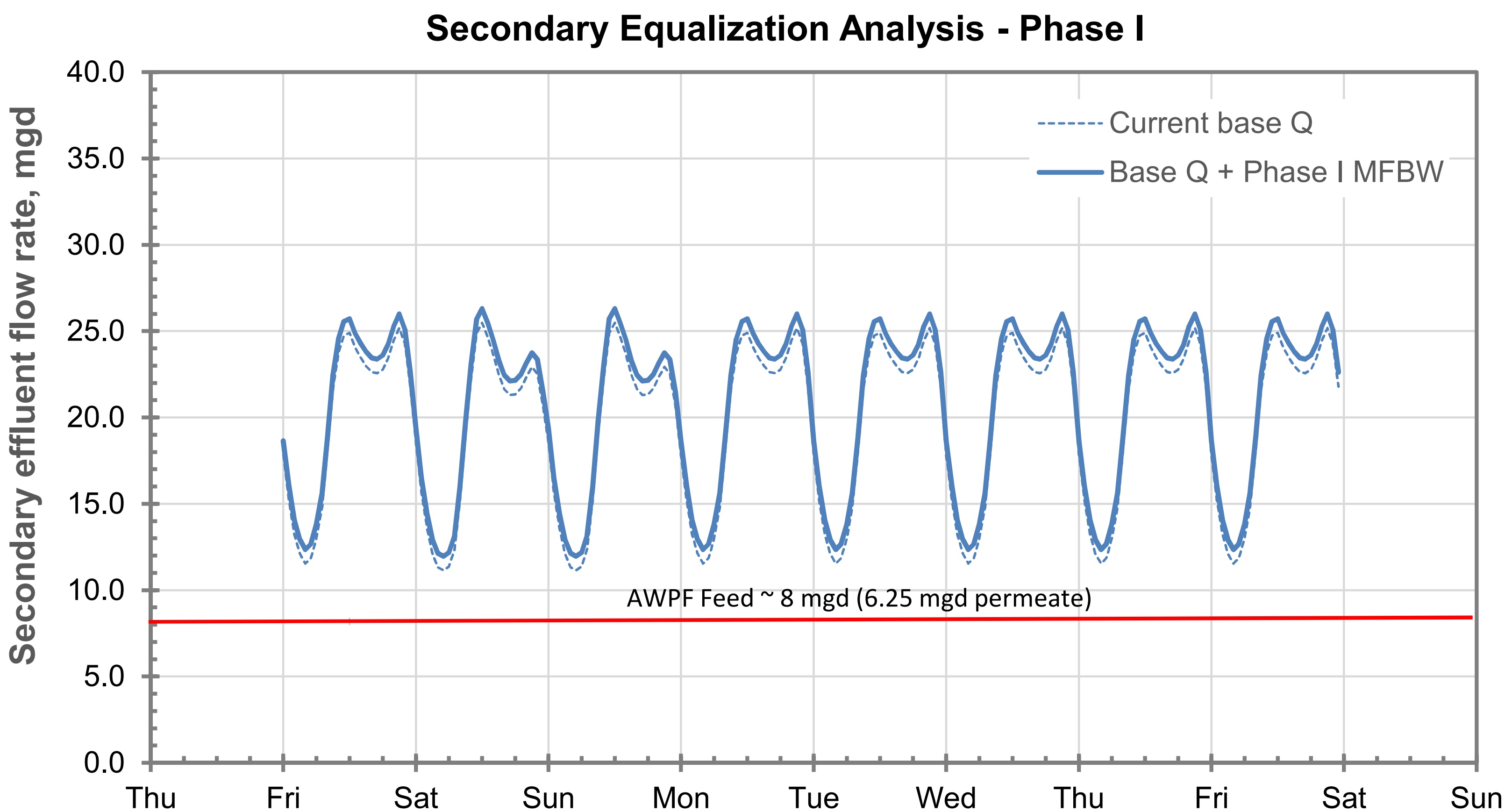
As always, Hopkins is pleased to be of service. If you have any questions or need any additional information, please give us a call.

Sincerely,

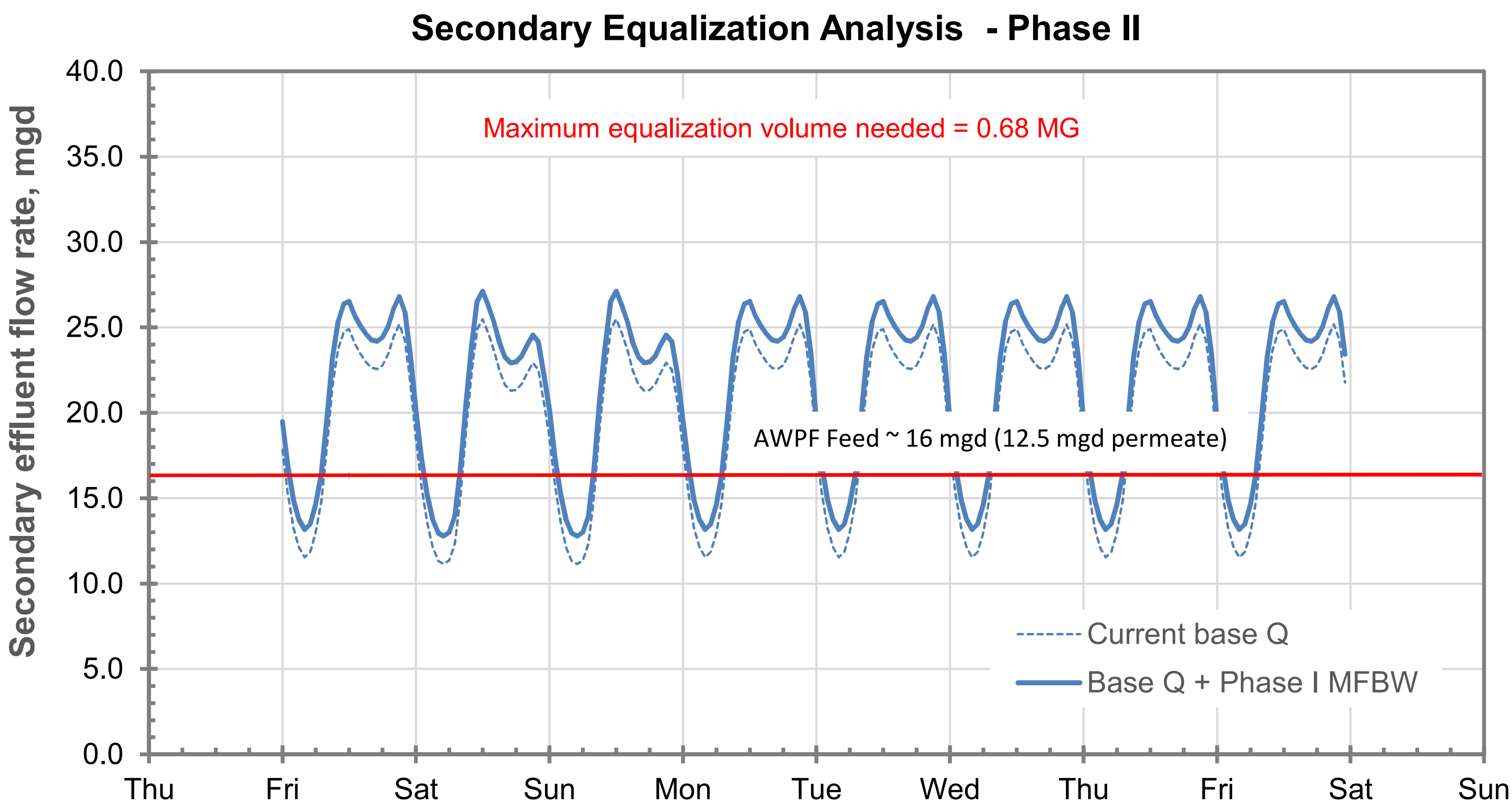
HOPKINS GROUNDWATER CONSULTANTS, INC.

Curtis J. Hopkins
Principal Hydrogeologist
Professional Geologist PG 5695
Certified Hydrogeologist HG 114
Certified Engineering Geologist EG 1800

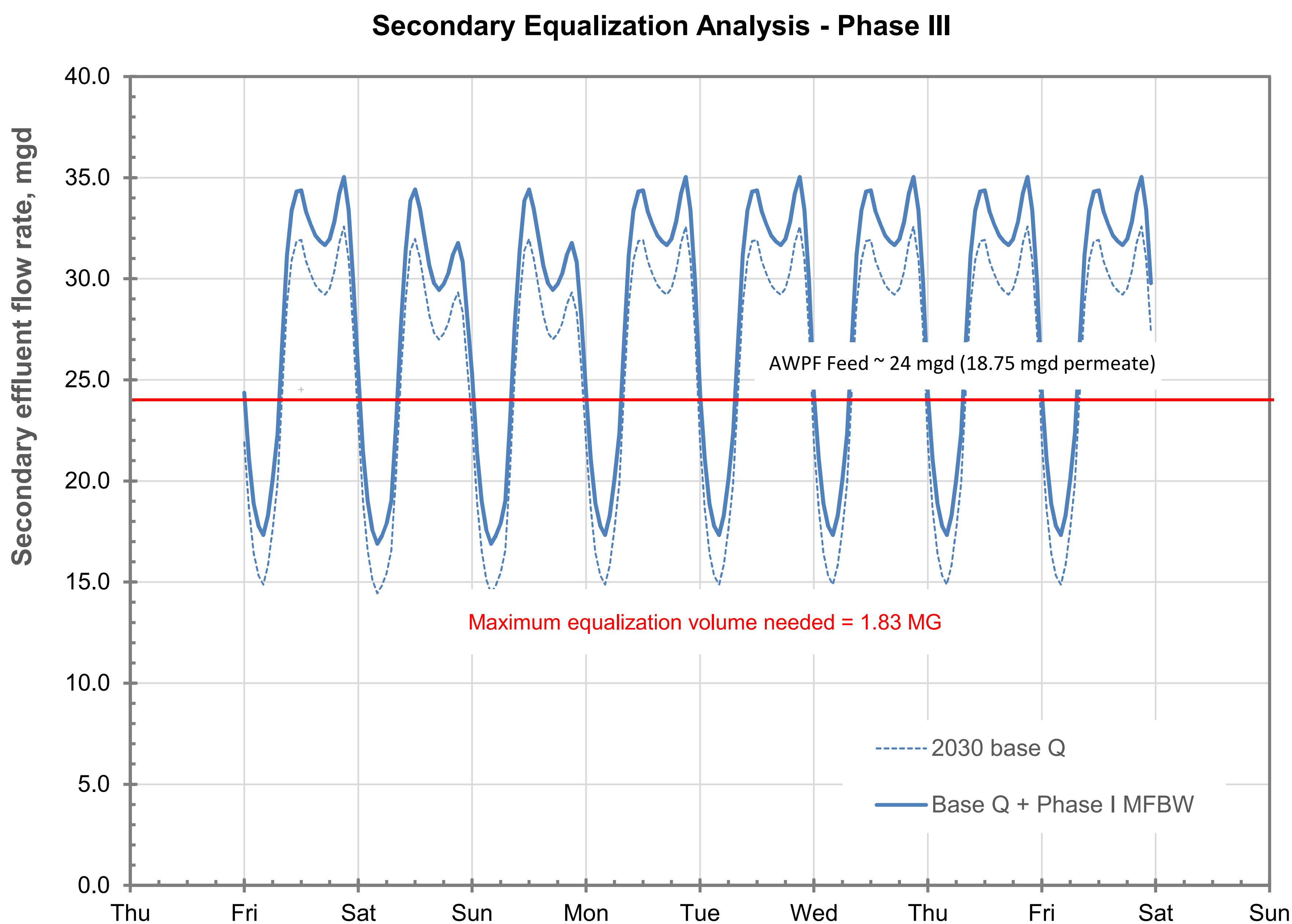
APPENDIX E – SECONDARY EFFLUENT STORAGE GRAPHS



Secondary Equalization Analysis - Phase I
Secondary effluent flow rate, mgd
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Current base Q
Base Q + Phase I MFBW
AWPF Feed ~ 8 mgd (6.25 mgd permeate)



Secondary Equalization Analysis - Phase II
Maximum equalization volume needed = 0.68 MG
AWPF Feed ~ 16 mgd (12.5 mgd permeate)
Secondary effluent flow rate, mgd
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Current base Q
Base Q + Phase I MFBW



Secondary Equalization Analysis - Phase III
Secondary effluent flow rate, mgd
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Thu
Fri
Sat
Sun
Mon
Tue
Wed
Thu
Fri
Sat
Sun
AWPF Feed ~ 24 mgd (18.75 mgd permeate)
Maximum equalization volume needed = 1.83 MG
2030 base Q
Base Q + Phase I MFBW

APPENDIX F – ASR DEMONSTRATION HYDROGEOLOGY REPORT

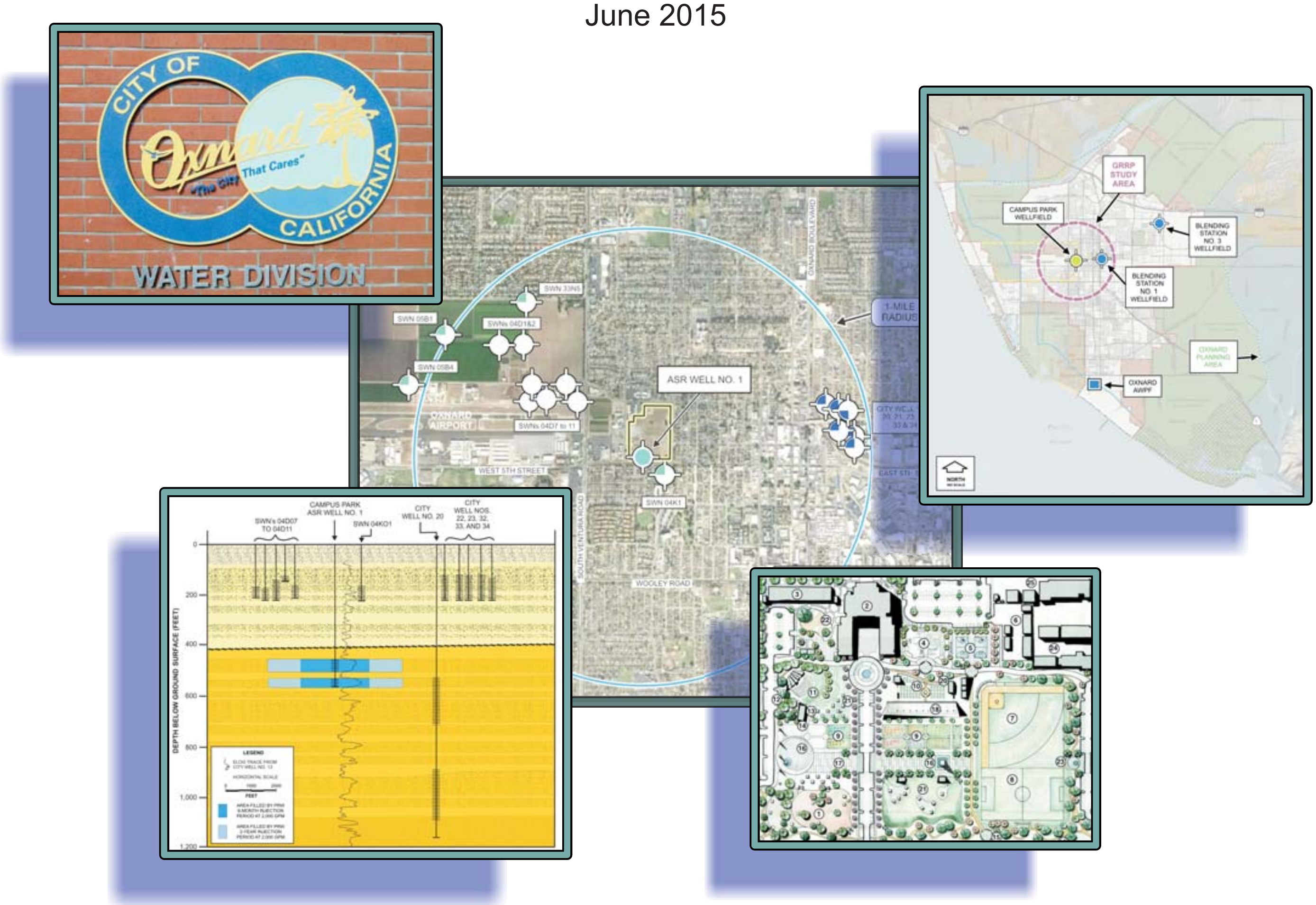
HOPKINS GROUNDWATER CONSULTANTS, INC.

PRELIMINARY HYDROGEOLOGICAL STUDY

CITY OF OXNARD GREAT PROGRAM
CAMPUS PARK GROUNDWATER
REPLENISHMENT AND REUSE PROJECT
OXNARD, CALIFORNIA

Prepared for:
City of Oxnard

June 2015



HOPKINS
GROUNDWATER
CONSULTANTS, INC.
THE WATER RESOURCE SPECIALISTS

June 30, 2015
Project No. 01-011-09E

City of Oxnard
305 West Third Street, Second Floor, East Wing
Oxnard, California 93030

Attention: Mr. Daniel Rydberg
Interim Utilities Director

Subject: Preliminary Hydrogeological Study, City of Oxnard Great Program, Campus Park Groundwater Replenishment and Reuse Project, Oxnard, California.

Dear Mr. Rydberg:

Hopkins Groundwater Consultants, Inc. (Hopkins) is pleased to submit this final report summarizing the findings, conclusions, and recommendations developed from a preliminary study evaluating the feasibility of a Groundwater Replenishment Reuse Project (GRRP) that is proposed as part of the City of Oxnard Groundwater Recovery Enhancement and Treatment (GREAT) Program. The study findings indicate that the Campus Park GRRP site proposed for Indirect Potable Reuse is a feasible location and that the replenishment and recovery of groundwater with an improved quality could be achieved by the project for Indirect Potable Reuse. The study provides detailed hydrogeological findings in compliance with Groundwater Replenishment Using Recycled Water regulations designated DPH-14-003E, dated June 18, 2014, to augment the Indirect Potable Reuse engineering report required for the project, and to facilitate discussion with State regulatory agencies, local groundwater management agencies, and stakeholder groups that may have a direct interest in the project.

As always, Hopkins is pleased to be of service. If you have questions or need additional information, please give us a call.

Sincerely,
HOPKINS GROUNDWATER CONSULTANTS, INC.

REGISTERED GEOLOGIST
CURTIS J. HOPKINS
EG NO. 1800
CERTIFIED
ENGINEERING
GEOLOGIST
STATE OF CALIFORNIA

Curtis J. Hopkins
Principal Hydrogeologist
Professional Geologist PG 5695
Certified Hydrogeologist HG 114
Certified Engineering Geologist EG 1800

E:\COVER LETTER 6-30-15.DOCX

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ACRONYM LIST

AFY – Acre-Feet Per Year

ASR – Aquifer Storage and Recovery

AWPF – Advanced Water Purification Facility

BGS – Below Ground Surface

BS-1 – Blending Station No. 1

BS-3 – Blending Station No. 3

CRWQCB – California Regional Water Quality Control Board

DDW – California Department of Drinking Water

FCGMA – Fox Canyon Groundwater Management Agency

GPM – Gallons Per Minute

GREAT – Groundwater Recovery Enhancement and Treatment

GRRP – Groundwater Replenishment Reuse Project

GRURW – Groundwater Replenishment Using Recycled Water

IPR – Indirect Potable Reuse

LAS – Lower Aquifer System

MSL – Mean Sea Level

MG/L – Milligrams Per Liter

PRW – Purified Recycled Water

PSI – Pounds Per Square Inch

TDS – Total Dissolved Solids

UAS – Upper Aquifer System

UWCD – United Water Conservation District

VCWPD – Ventura County Watershed Protection District

CITY OF OXNARD GREAT PROGRAM
CAMPUS PARK GROUNDWATER
REPLENISHMENT AND REUSE PROJECT

INTRODUCTION

GENERAL STATEMENT

Presented in this report are the findings, conclusions, and recommendations developed from a preliminary hydrogeological study conducted by Hopkins Groundwater Consultants, Inc. (Hopkins) to assist the City of Oxnard (City) in evaluating the feasibility of a Groundwater Replenishment Reuse Project (GRRP) using purified recycled water (PRW). This hydrogeological study was conducted to support the City's Groundwater Recovery Enhancement and Treatment (GREAT) Program by developing an aquifer storage and recovery (ASR) project that will provide Indirect Potable Reuse (IPR) of the PRW produced at the City's Advanced Water Purification Facility (AWPF).

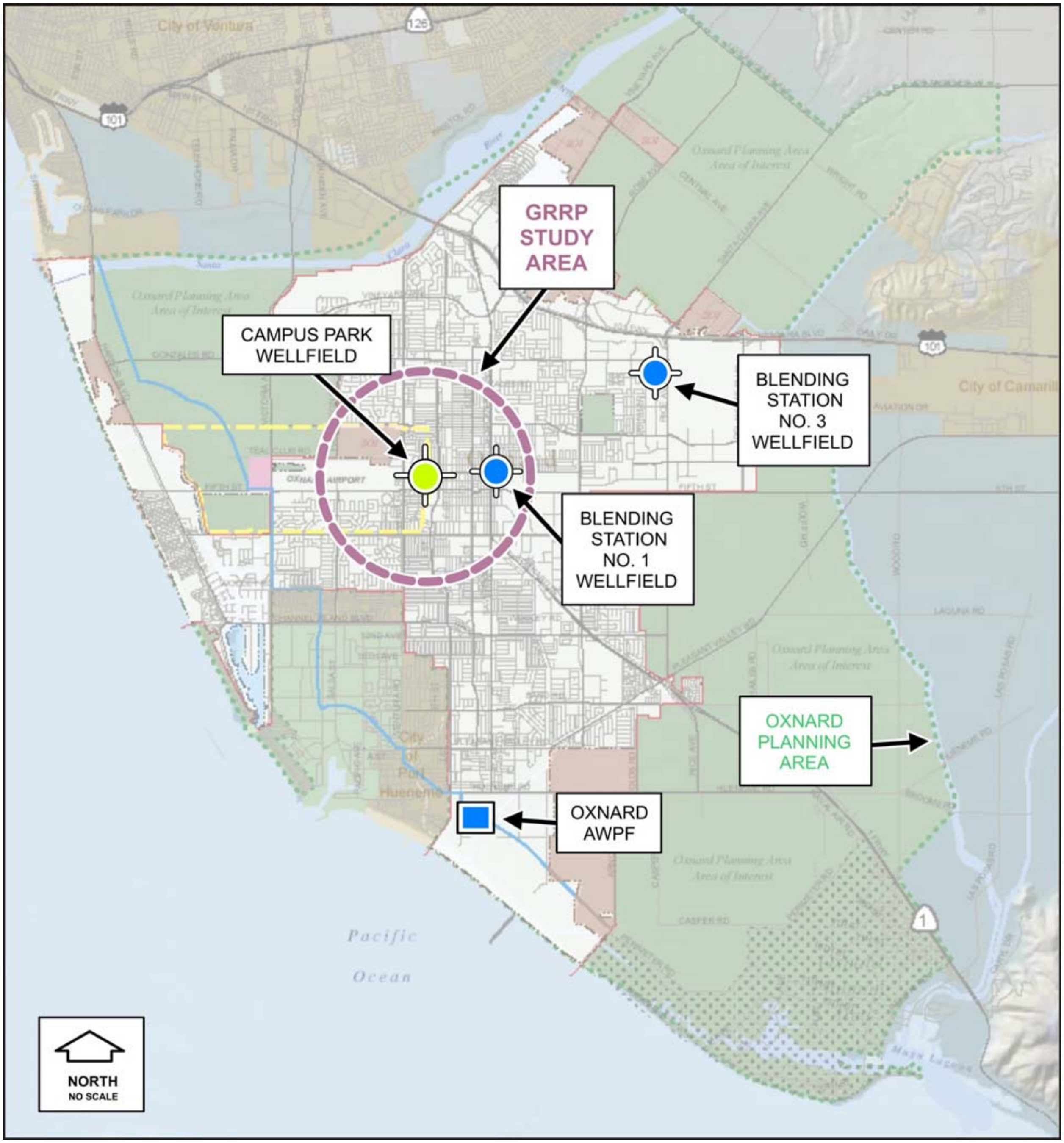
The proposed City GRRP includes developing a sustainable program for groundwater replenishment and IPR of PRW using aquifer units located in the Oxnard Plain Groundwater Basin. The proposed GRRP is intended to augment the City's potable water system by; 1) improving the delivered water quality, 2) increasing the available supply, and 3) providing greater reliability through source redundancy. The GRRP study area is indicated on Figure 1 – Study Area Location Map.

BACKGROUND

The present City water supply is a combination of sources including; a) imported water from the State Water Project, b) groundwater produced by the United Water Conservation District (UWCD), and c) groundwater produced by the City wellfields at Blending Station Nos. 1 and 3 (BS-1 and BS-3). Historically, the City has improved the quality of its municipal supply by blending the higher quality imported water with its local groundwater supplies. The recent construction of the brackish groundwater desalter facilities located at BS-1 has provided the City with the means to further improve its water quality through the desalination of poor quality groundwater. During the desalination process, approximately 20 percent of the produced groundwater feeding the desalter is lost as brine reject that is discharged to the sewer ocean outfall.

The present operation of the City's groundwater desalter has allowed the City to shift groundwater production from the higher quality aquifer zones in the Lower Aquifer System (LAS) to the poorer quality aquifer zones in the Upper Aquifer System (UAS). This shift of pumping was designed to comply with the most recent groundwater management strategies of the Fox Canyon Groundwater Management Agency (FCGMA).

Figure 1 – Study Area Location Map



The GREAT Program was originally developed at a time when recycled water regulations treated all recycled water in the same manner. State regulations required onerous project development studies, monitoring and reporting programs, and dilution requirements utilizing another potable supply. Soil and aquifer treatment criteria could require extended retention times and travel distances through an aquifer to provide additional treatment prior to beneficial potable reuse. With these regulations, the City believed the best approach was to inject the PRW into the local aquifer system at a location that optimized basin management strategies, and extract a like amount of native groundwater from another area of the basin for municipal use. Consistent with this approach, the City proposed the direct use of the PRW for permissible agricultural purposes. Subsequently, a transfer of the unused groundwater would be provided to the City for municipal uses. Both of these strategies would provide the City with a source of potable groundwater in exchange for its recycled water.

This original approach required that the City purify a greater portion of the groundwater with a desalter and resulted in additional treatment costs and a loss of approximately 20 percent of the produced groundwater supply. The present approach for IPR would eliminate the additional step of desalting groundwater by allowing the indirect reuse of the high quality PRW. This will conserve energy and prevent wasting 20 percent of the supply as part of the redundant treatment process. The stored and recovered PRW by the GRRP can be blended with lower quality groundwater to achieve the City's water quality objectives.

Since construction of the GREAT Program AWPF, Federal and State recycled water regulations have been updated to the present Groundwater Replenishment Using Recycled Water (GRURW) regulations designated DPH-14-003E, dated June 18, 2014. These regulations accommodate the use of highly treated effluent produced by the PRW process by reducing or eliminating the requirement for soil/aquifer treatment. The State has recognized that the threat to public health is significantly lower after municipal wastewater receives advanced purification and disinfection using reverse osmosis, advanced oxidation, and ultraviolet radiation treatment processes. Because of the PRW extreme high quality, the new GRURW regulations significantly reduce the requirements for IPR compared to wastewater treated to secondary or tertiary standards.

PURPOSE

The purpose of this hydrogeological assessment of the proposed GRRP is to provide specific information to comply with the GRURW regulations pursuant to section 60320.200(h) and permit the preliminary investigation to develop site specific information that is required for the GRRP Title 22 engineering report. The findings of this study are also intended to further define the conceptual components of the ASR program that will be necessary to implement the IPR of PRW as a municipal supply in accordance with regulation provisions.

As part of the GRRP, the City proposes a project that:

1) utilizes (to the extent practicable) existing pipelines and facilities to control potential costs,

2) recharges aquifer zones that preserve the water quality during underground storage,

3) minimizes the risk to other potable well facilities,

4) is consistent with the FCGMA and UWCD groundwater management strategies,

5) has operational flexibility to adapt to changing system demands and aquifer conditions,

6) demonstrates the ASR capacity of the Oxnard Plain LAS,

7) can be increased to facilitate future AWPF expansion, and

8) can simplify monitoring and reporting to UWCD, the FCGMA, the California State Water Resources Control Board Division of Drinking Water (DDW), and the California Regional Water Quality Control Board (CRWQCB).

This hydrogeological study utilizes the City GREAT Program Update, dated June 25, 2012, as the guide for the anticipated capacity of the AWPF and the initial availability of PRW. This study is intended to provide the mandatory hydrogeological assessment to accompany the engineering report required pursuant to section 60323 of the Title 22, California Code of Regulations, GRURW regulations for a new GRRP.

Additionally, this hydrogeological assessment is intended to provide operational criteria based on aquifer parameters estimated from historical well data, which will define the range of ASR capacity that can be reasonably anticipated from the underlying aquifer system. Subsequently, a conceptual GRRP operational schedule can be developed for the ASR operations to comply with the response retention time requirements of the GRURW regulations for IPR that is based on reasonable expectations of the natural aquifer system constraints.

Sources of available data and published information that were used for the study include; a) City data and reports, b) UWCD data and reports, c) United States Geological Survey, and d) Ventura County Watershed Protection District (VCWPD) databases.

HYDROGEOLOGICAL CONDITIONS

The City recognizes that the threat of seawater intrusion is a regional issue. The City has historically complied with FCGMA regulations and participated in UWCD groundwater supply management programs. Implementation of the GREAT Program is intended to continue this cooperative management effort and the beneficial use of the local groundwater resources in the vicinity of the City. The proposed GRRP using PRW includes ASR wells constructed in aquifer zones that comprise the LAS. Recharge into the LAS will store water in aquifer zones that receive significantly less groundwater recharge than the UAS because of the regional confined aquifer conditions. The UAS readily receives groundwater recharge derived from natural percolation of rainwater and Santa Clara River flows in the Oxnard Forebay Basin, as well as from river flow diversions into the engineered recharge facilities operated by UWCD.

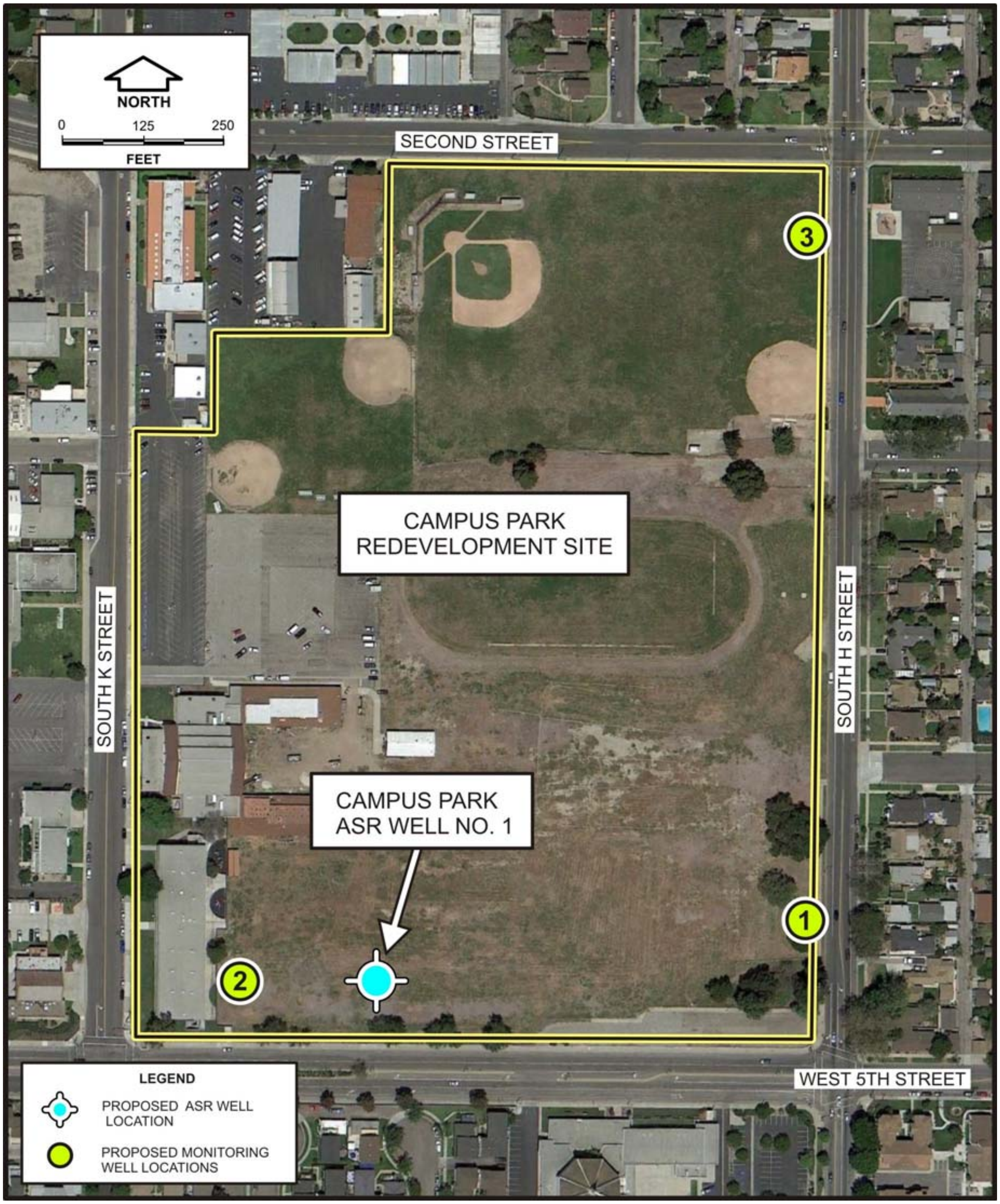
The GRRP ASR Well will be designed to inject PRW into discrete aquifer zones in the LAS and subsequently facilitate groundwater extraction after the response retention time is achieved and regulatory approval is granted. The proposed ASR Well No. 1 is anticipated to be constructed with a completion depth of about 580 feet below ground surface (bgs) and with a screened interval limited to a discrete aquifer zone(s) in the LAS. The well will be designed for an injection capacity of up to 2,000 gallons per minute (gpm). Plate 1 – Preliminary ASR Well No. 1 Design Drawing provides preliminary design details that reflect the anticipated hydrogeology and comply with the VCWPD sealing zone requirements.

Water to be injected during initial testing is proposed to be 100 percent PRW. Initially, the water may be conveyed to the ASR well from the City recycled water system using temporary piping. The initial phase of aquifer testing will determine the percentage of recovery that occurs prior to evidence of native groundwater mixing with the PRW along with any change in the PRW chemistry that could occur as it travels through the aquifer matrix. During the test period, PRW that is extracted from the ASR well will be discharged back into the recycled water transmission main and subsequently used for irrigation.

The ASR demonstration program, as developed, will comply with GRURW regulations and last for an anticipated period of between 2 and 4 months. During the initial demonstration period, monitoring well data and water quality samples will be collected and analyzed to verify the preliminary estimations of aquifer parameters, groundwater storage volumes, and groundwater travel times effectuated by PRW recharge. These data will be utilized to finalize the permit application required for full-scale project operation using the PRW generated by the AWPF.

The proposed GRRP would ultimately be sized to accommodate the first phase of the AWPF, providing the ability to store and reuse up to 1,500 acre-feet per year (AFY). The GRRP location identified for groundwater recharge wells is indicated in Figure 2 – Proposed GRRP ASR Well Site Location Map. This location serves to isolate City groundwater facilities within the City boundaries where it has control of surrounding land uses and future groundwater development.

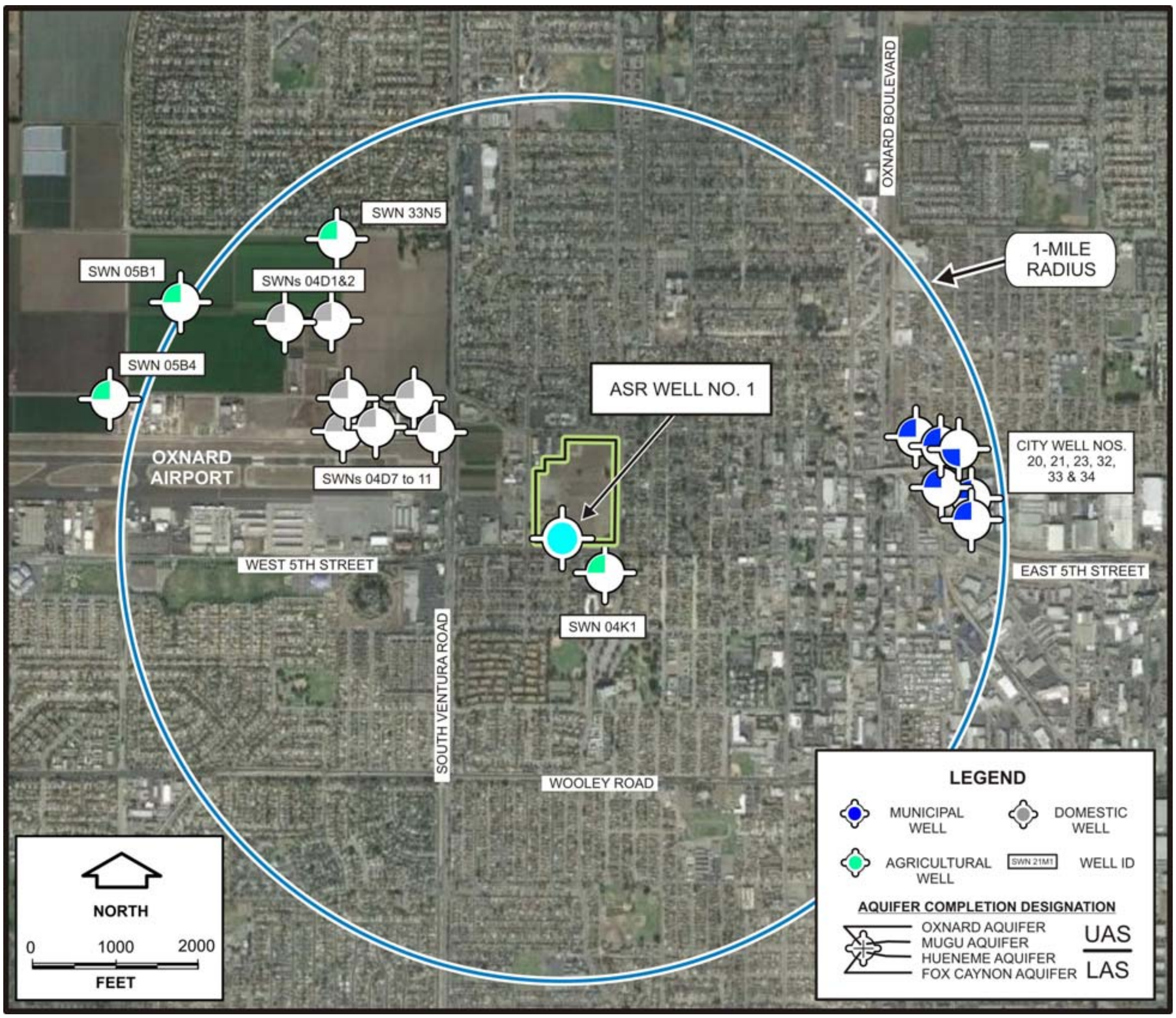
Figure 2 – Proposed GRRP ASR Well Site Location Map



Note: This figure has been updated in the most recent draft. Refer to Figure 3 in PM 2.5

The property selected for installation and operation of the GRRP ASR Well is owned by the City and had an existing City well proximately located and constructed in the LAS (City Well No. 13). While the old City well has since been destroyed, several smaller wells are presently active in the unincorporated area north of the Oxnard Airport along the western City limit. Figure 3 – Existing Well Location Map shows all the active wells within a 1-mile-radius of the GRRP ASR well location.

Figure 3 – Existing Well Location Map



As shown, many proximate wells are constructed in the UAS and as such will not be hydraulically connected with the LAS aquifer zones proposed for use by the GRRP. Review of available data indicates that the nearest well constructed in the LAS is almost 1 mile away and is a municipal supply well owned by the City. The closest existing LAS well is City Well No. 20 located at BS-1. As such, the City ASR well location appears to provide more than a sufficient distance from existing LAS wells to allow GRRP operations without interference.

HYDROGEOLOGY AND AQUIFER DELINEATION

Geology

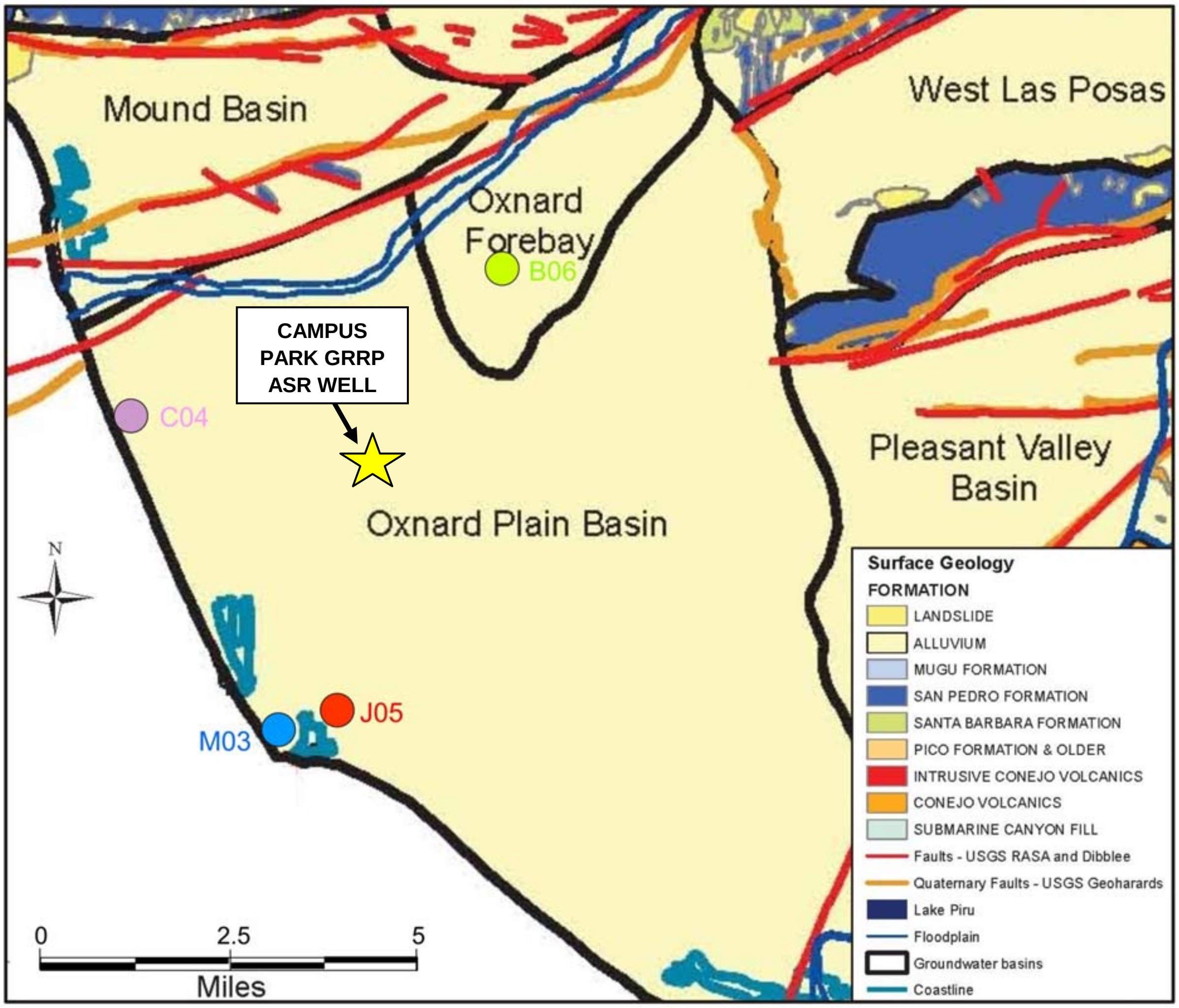
The proposed City project is located in the Oxnard Plain Groundwater Basin, which is part of the Transverse Ranges geologic/geomorphic province and defined by a number of geologic structures and features that separate it from the adjacent groundwater basins. The geology of the Oxnard Plain Basin has been described in detail by several authors including the California State Water Resources Board (SWRB, 1953), Turner (1975), and UWCD (2012). Figure 4 – Generalized Geologic Map and Oxnard Plain Basin Boundaries shows the project location in relation to the adjacent boundaries of the Oxnard Plain Basin with the Mound, Oxnard Forebay, West Las Posas, and Pleasant Valley Basins.

Plate 2 – Hydrogeological Cross-Section Location Map shows the location of cross-sections constructed from available well data to illustrate the subsurface profiles of the geological formations that comprise the underlying aquifer systems. Plate 2 also shows the location of wells that provided geophysical data near the Campus Park GRRP site. Plates 3 and 4 – Hydrogeological Cross-Section A-A' and B-B', respectively, provide an interpretation of the hydrostratigraphy in the study area. This conceptual understanding of the confined Oxnard Plain Basin aquifer system is key to the understanding of how the GRRP potential impacts are limited by natural conditions. It also illustrates how the GRRP was developed to utilize discrete aquifer zones that will allow rotation of the three phases of project operations; 1) injection/recharge of the PRW produced from the AWPF, 2) storage/response retention time, and 3) recovery and reuse/IPR.

Aquifer Zone Designation

The subsurface geology that controls groundwater flow in the study area is differentiated into two primary geologic units that include; the Holocene and late Pleistocene alluvium, and the San Pedro Formation. The first unit is comprised largely of unconsolidated sedimentary deposits and includes all older and Recent alluvial deposits. These shallower units are coarse-grained sand and gravel layers that form the Oxnard and Mugu Aquifers and comprise the UAS in the Oxnard Plain Basin (see Plates 3 and 4). The San Pedro Formation consists of consolidated marine and nonmarine clay, silt, sand, and gravel deposits that comprise the Hueneme and Fox Canyon Aquifers that are designated as the LAS. The low permeability geologic formations underlying the San Pedro Formation are generally considered to be non-water-bearing and effectively define the base of fresh water.

Figure 4 – Generalized Geologic Map and Oxnard Plain Basin Boundaries

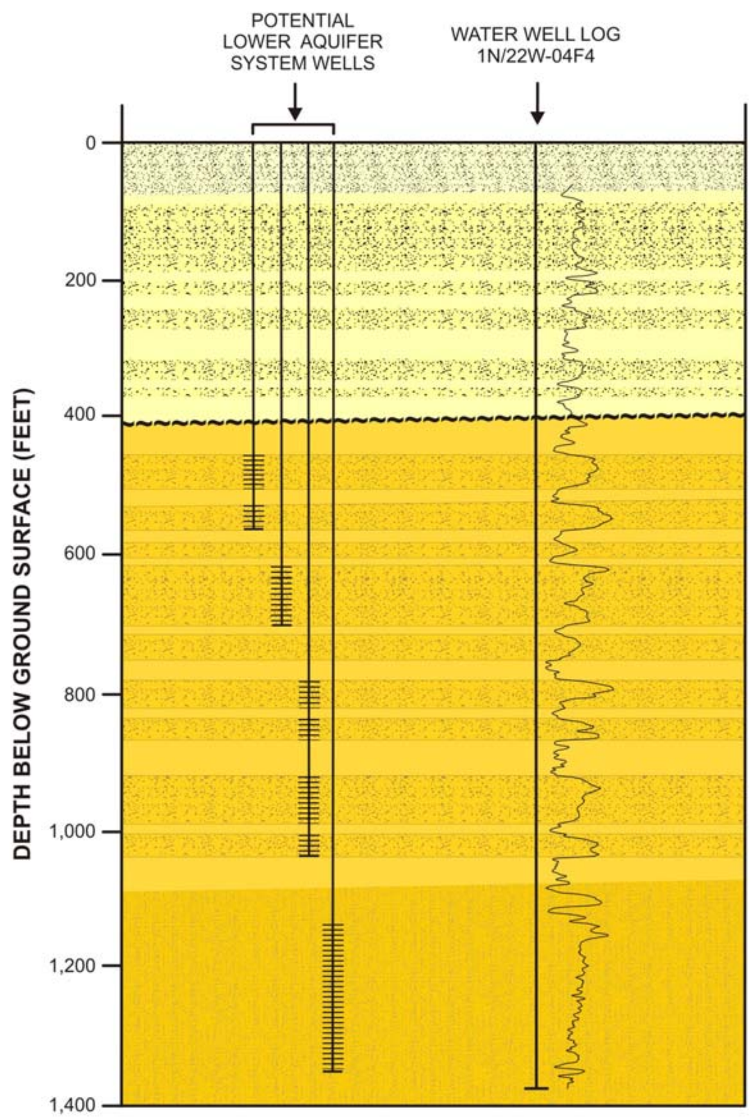


FROM UWCD, 2012

The groundwater in the Oxnard Plain Basin LAS is isolated from overlying land uses by the laterally extensive aquitard (silt and clay) layers that separate and confine the Hueneme and Fox Canyon Aquifer zones. The conceptual subsurface profile shown in Figure 5 – Discrete Aquifer Zone Delineation uses the geophysical survey (electric log) from the proximate City Well No. 13 to show the anticipated geology and aquifer zones beneath the Campus Park GRRP site. The aquifer zones shown in Figure 5 are discretely separated by clay layers that are laterally continuous and appear as marker beds in other well logs shown in Plates 3 and 4. The significance of the highly confined condition that results from the discretely layered aquifer system is that wells located in close proximity (50 feet apart) but producing from different aquifer layers, do not have hydraulic connectivity with each other.

Figure 5 shows a series of proposed wells that could be designed to utilize the storage capacity of discrete aquifer units while being effectively isolated from each other by the natural confining clay layers. This concept can allow the design and use of discrete aquifer zones as individual storage units, as demonstrated by Well Nos. 28, 29, 30, and 31 located at City BS-3. One aquifer zone can be filled without affecting wells that are competently constructed in other aquifer zones. The benefit of this natural condition to the GRRP is that multiple wells can be operated on the same site with a rotating schedule which allows discrete recharge, storage (response retention time), and recovery from separate aquifer zones.

Figure 5 – Discrete Aquifer Zone Delineation

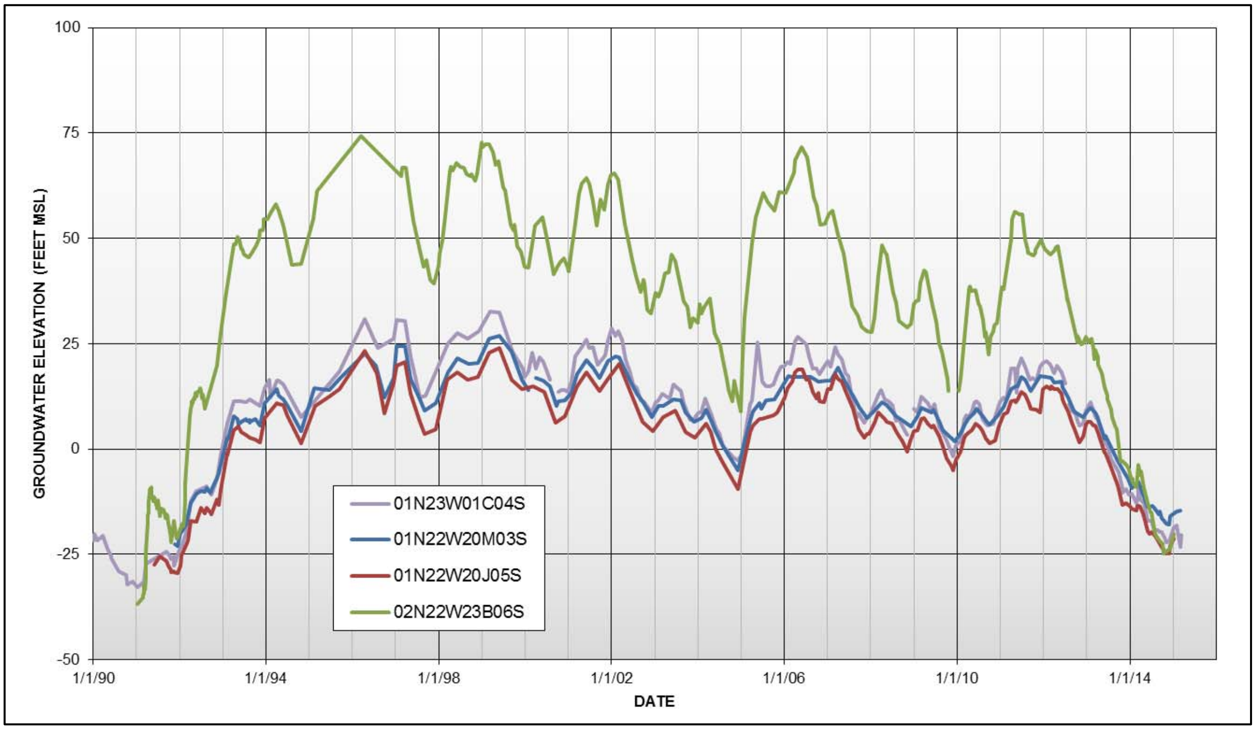


The proposed GRRP utilizes this natural confined aquifer condition to develop an operational scenario that is unique in its application. It can satisfy the GRURW regulations that require a minimum 2-month retention response time, while optimizing the proposed ASR well facilities at a single site. It can operate independent of groundwater flow direction and serve to minimizing the potential risk and consequence of PRW treatment violations (to be explained in following sections).

Groundwater Levels

Groundwater elevations in the Oxnard Plain Basin vary over time. Figure 6 – Groundwater Elevation Hydrograph shows the fluctuation of water levels in the upper Hueneme Aquifer zones in LAS. These data are from discretely screened monitoring wells in aquifer zones that correlate to the aquifer zones proposed for use by ASR Well No. 1. The location of the wells is shown on Figure 4 using the same color for the well symbols as is used for the water levels in the Figure 6 graph. Three of the wells are coastal monitoring wells, and one is located in the Oxnard Forebay where the upper Hueneme Aquifer zones lie unconformably beneath the overlying alluvium of the UAS. The Oxnard Forebay Basin is the primary source of recharge to the LAS.

Figure 6 – Groundwater Elevation Hydrograph



The groundwater elevation in the LAS proximate to the GRRP study area has dropped to approximately 25 feet below mean sea level (msl) during the 1986 to 1990 drought and has risen as high as 20 to 25 feet above msl in wet years. These available data indicate that seasonal fluctuations in the Oxnard Plain Basin groundwater levels are typically around 5 to 10 feet. Dry climatic conditions result in consecutive annual declines in the coastal water levels of up to 45 feet (see Figure 6). These same dry climatic conditions result in water level declines in the Oxnard Forebay Basin on the order of 100 feet. These groundwater level conditions indicate that ASR well operation may require the ability to operate/inject under pressure during high water level conditions while gravity-flow injection operations may be sustained during dry climatic periods.

Combining these water level conditions with the depth to the top of the proposed aquifer units, an injection pressure of 20 pounds per square inch (psi) should be allowable without adverse consequences. The deeper the aquifer zone(s), the greater the operational pressure that is allowable for recharge without creating the potential for adverse effects.

Groundwater Gradient and Flow Velocity

Utilizing data provided by the UWCD, the groundwater elevations in the vicinity of the GRRP were contoured quarterly for 2011 and 2013. These years are believed representative of normal to wet groundwater conditions (2011) and dry year groundwater conditions (2013). Water level data from August 2014 were also contoured and represent groundwater flow conditions after multiple dry years. A series of quarterly groundwater elevation contour maps for the years selected are provided in Appendix A – Groundwater Elevation Contour Maps. Table 1 – Groundwater Gradient and Flow Direction summarizes the results of groundwater gradient estimations using the maps in Appendix A.

For the purpose of the Campus Park GRRP study, the use of the groundwater gradients provided by these data are believed sufficient for understanding the seasonal and climatic changes that occur to the groundwater gradient and the approximate prevailing flow directions in the upper Hueneme Aquifer zones of the LAS.

Table 1 – Groundwater Gradient and Flow Direction

OBSERVATION PERIOD	ASR WELL NO. 1	
	FLOW DIRECTION	GRADIENT
JANUARY 2011	S 43º W	0.0008
APRIL 2011	S 41º W	0.0011
JULY 2011	S 44º W	0.0011
OCTOBER 2011	S 43º W	0.0009
JANUARY 2013	S 44º W	0.0004
APRIL 2013	S 47º W	0.0004
JULY 2013	S 67º W	0.0003
OCTOBER 2013	N 74º W	0.0002
AUGUST 2014	N 04º E	0.0002

TABLE DATA DISPLAYED GRAPHICALLY ON PLATES IN APPENDIX A

As shown, during normal and wet years, recharge in the Oxnard Forebay Basin is significant and establishes a predominant southwesterly groundwater flow direction in the Oxnard Plain Basin (see Appendix A). During the Spring of 2011, the upper Hueneme Aquifer groundwater gradient was generally 0.0011 (dimensionless) and the flow direction was S 41º W as shown on Figure 7 - LAS Groundwater Elevation Contour Map April 2011. The fall gradient in October 2011 was observed to flatten out to a value of 0.0009 (see Table 1).

During dry years like 2013, the groundwater flow direction was observed to be roughly the same as 2011 but the gradient continued to flatten out and the groundwater elevations were closer to sea level. This prevailing flow pattern continues until inland pumping causes water levels to fall below sea level. The lack of recharge during repeated dry years can result in inland groundwater elevations that are substantially below sea level. Figure 8 – LAS Groundwater Elevation Contour Map August 2014 shows the groundwater elevations and flow direction that developed under a 3-year-drought condition.

Figure 7 – LAS Groundwater Elevation Contour Map April 2011

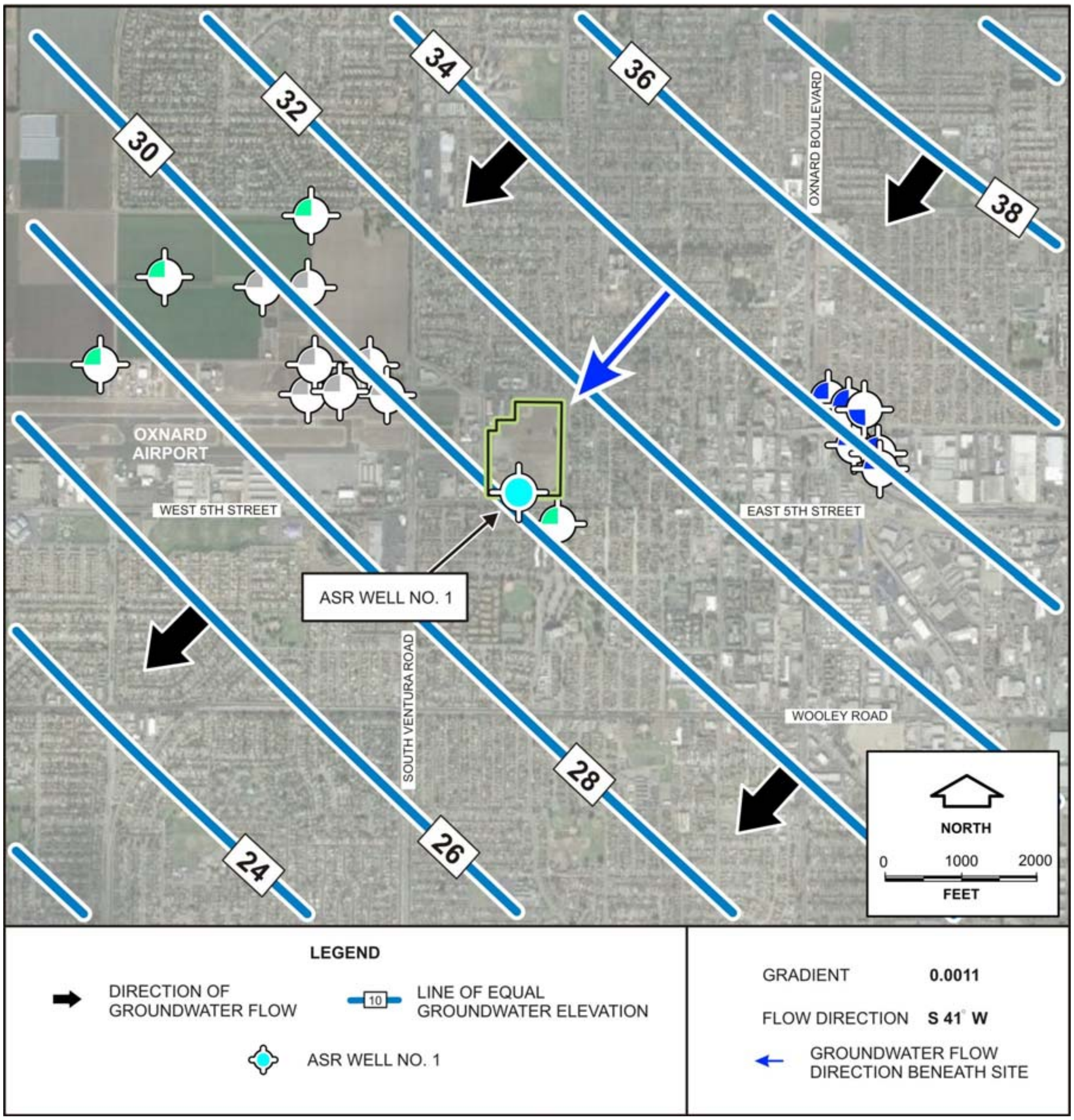
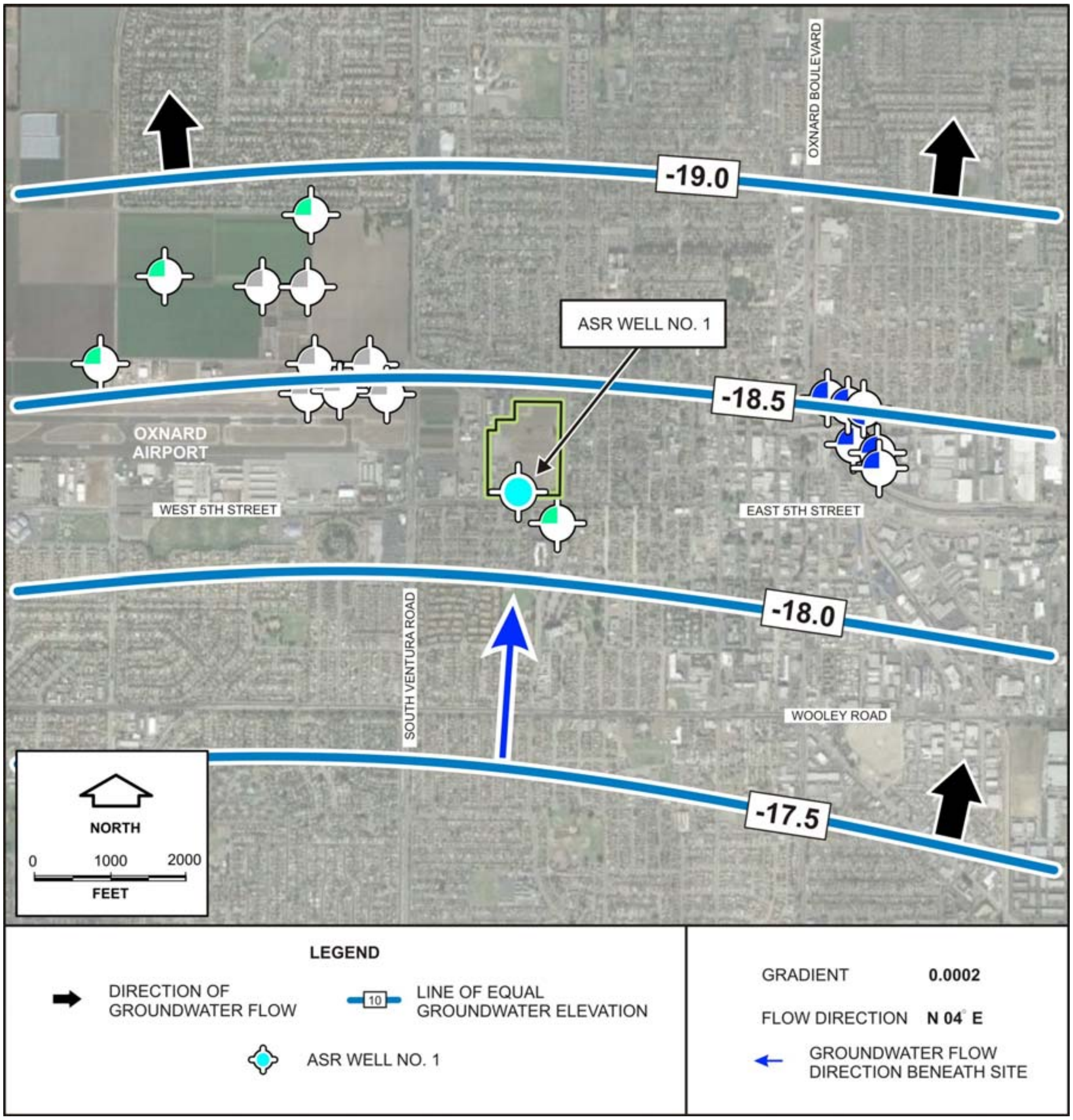


Figure 8 – LAS Groundwater Elevation Contour Map August 2014



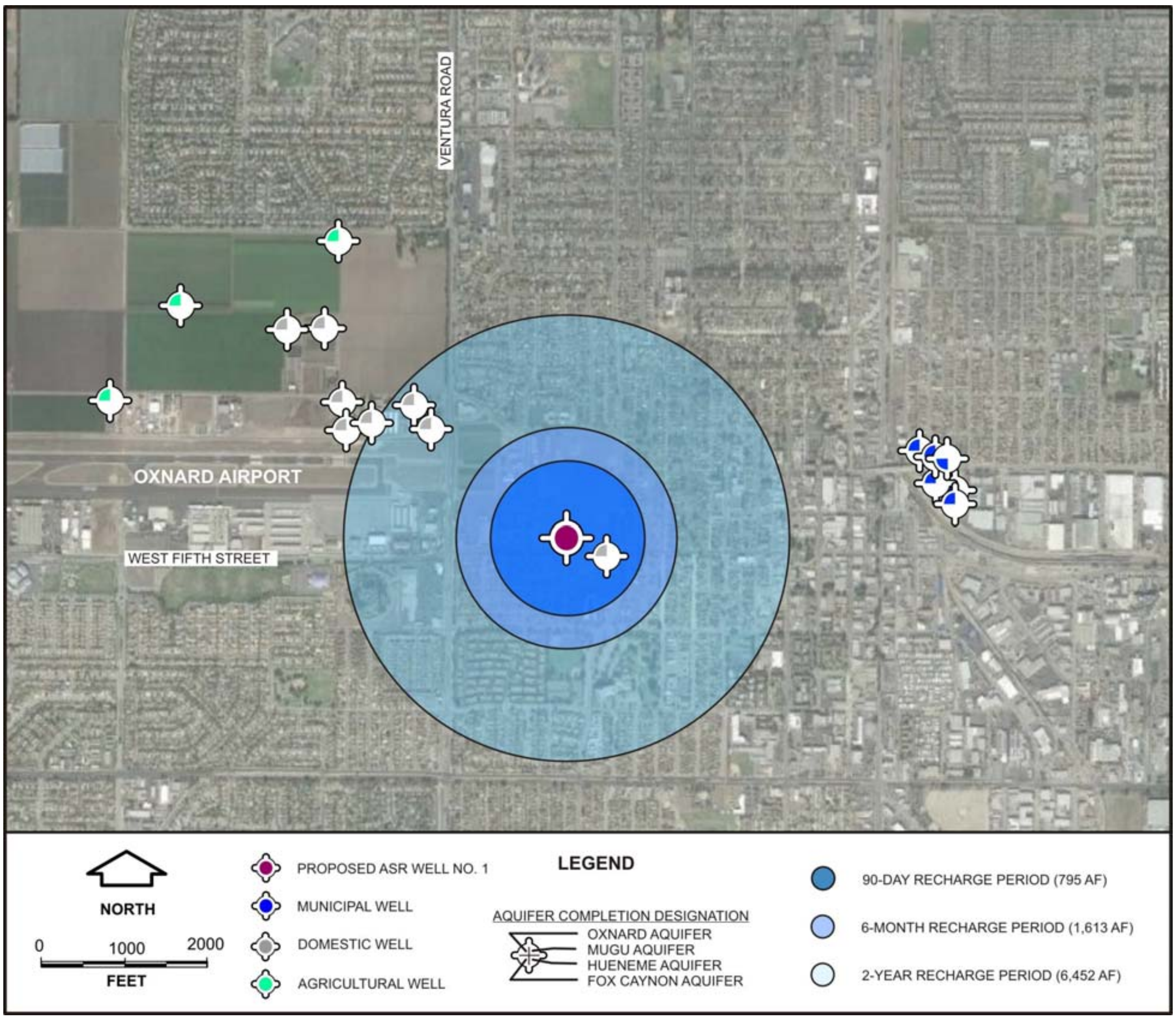
Aquifer Recharge and Retention

The area potentially influenced by recycled water recharge in the vicinity of the ASR well is determined by the aquifer area filled with the PRW during injection and the rate and direction of groundwater flow while it is in storage. The aquifer area filled by PRW replenishment was estimated by using;

- a discrete aquifer thickness of 85 feet,
- radial flow in the aquifer away from the center of recharge, and
- an average aquifer porosity of 15 percent (to be conservative).

The resulting aquifer area filled after injection of PRW at a rate of 2,000 gpm for a period of; 90 days (795 AF), 6 months (1,613 AF) and a period of 2 years (6,452 AF) is shown in Figure 9 – Aquifer Area Filled With Purified Recycled Water.

Figure 9 – Aquifer Area Filled With Purified Recycled Water



The aquifer area filled by these injection volumes would be proportionally less than those shown in Figure 9 as the porosity of the aquifer increases. Table 2 – Radial Distance Calculations shows the magnitude of change in the size of the recharge bubble within a range of typical aquifer porosity values.

Table 2 – Radial Distance Calculations

POROSITY	30-DAY RADIAL DISTANCE (FEET)	60-DAY RADIAL DISTANCE (FEET)	90-DAY RADIAL DISTANCE (FEET)	6-MONTH RADIAL DISTANCE (FEET)	2-YEAR RADIAL DISTANCE (FEET)
15 %	537	759	930	1,324	2,649
20%	465	658	806	1,147	2,294
25%	416	588	720	1,026	2,052
30%	380	537	658	937	1,873

AQUIFER THICKNESS IS 85 FEET AND THE INJECTION RATE IS 2,000 GPM

While the proposed City ASR operation will recharge the aquifer for a period of up to 3-months, a 6-month and 2-year-period of recharge were provided for comparison of potential project impacts. The estimated aquifer area filled with PRW in Figure 9 is believed conservative because a larger porosity value is highly likely. As shown, the nearest drinking water supply well (municipal well) constructed in the LAS is the City's and is beyond the 2-year aquifer replenishment area.

To approximate the area potentially influenced by PRW as it flows away from the point of recharge under the local groundwater gradient, the linear groundwater flow velocity was estimated by using;

- an average hydraulic conductivity value estimated from City Well No. 13 production test data (125 feet/day),
- the groundwater gradient at representative points in time (see Table 1),
- an average aquifer porosity of 15 percent (to be conservative), and
- the average linear flow velocity equation:

$$V = K\ I/\eta$$

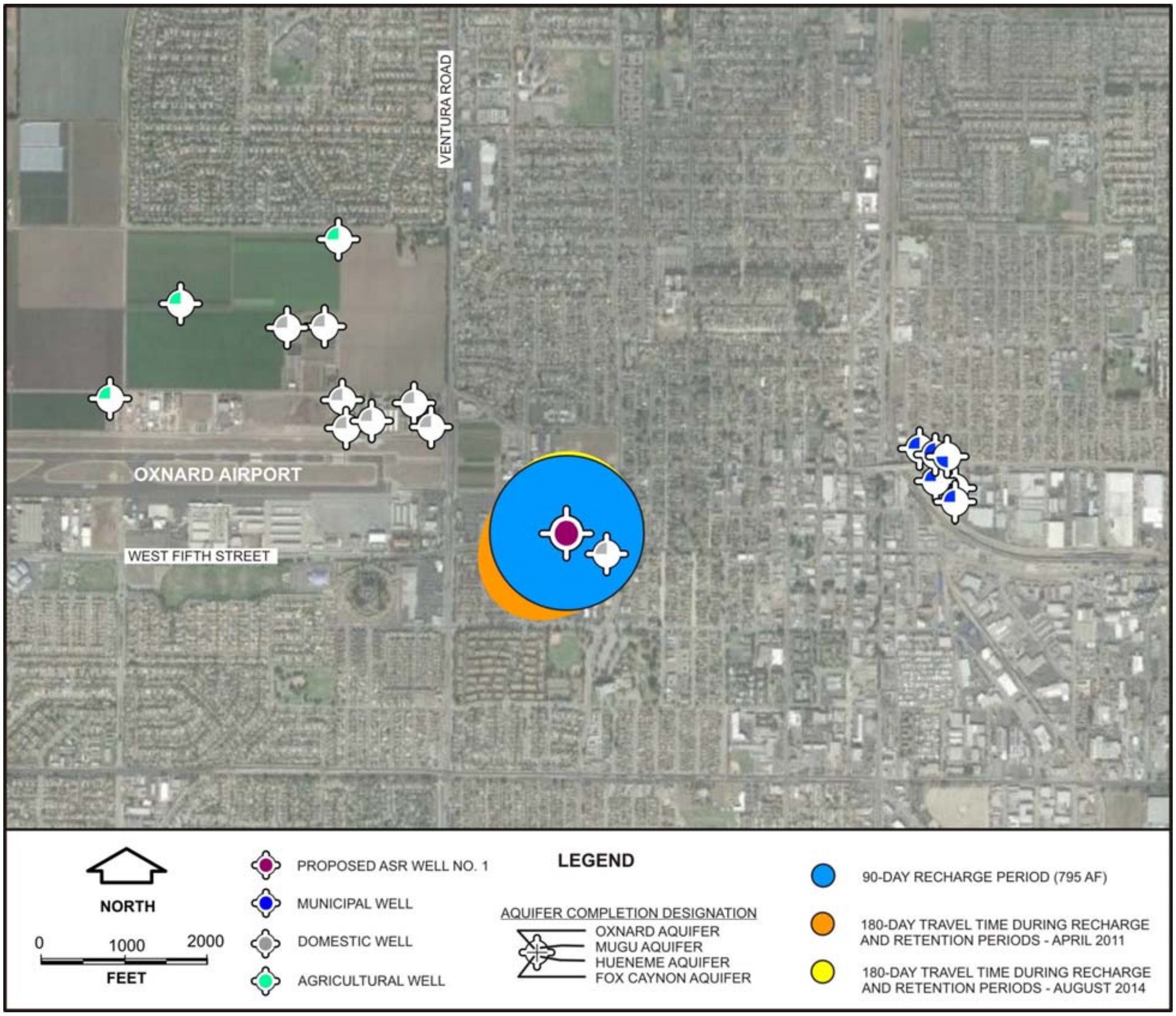
V	=	GROUNDWATER FLOW VELOCITY
K	=	AQUIFER HYDRAULIC CONDUCTIVITY
I	=	GROUNDWATER GRADIENT
η	=	AQUIFER POROSITY

The hydraulic conductivity of the upper Hueneme Aquifer zones was estimated from well production test data provided from City Well No. 13 combined with our experience and knowledge of wells in the Oxnard Plain Basin. The hydraulic conductivity of the aquifer zones that are proposed for ASR Well No. 1 was estimated to be 125 feet per day (ft/d). Using this hydraulic conductivity value and the range of groundwater gradients that are shown in Table 1, results in groundwater flow velocity estimates that range between 0.17 ft/d and 0.92 ft/d. Applying these two linear groundwater flow velocities over a 6-month period that includes the 3-month recharge period and the 3-month retention time, results in groundwater movement of a total distance between 30 feet and 165 feet.

The relative movement of the PRW from the ASR well during these 2 extreme conditions (April 2011 and August 2014) is shown in Figure 10 – Range of Purified Recycled Water Movement From ASR Well Location. These extremes are believed to bracket the actual anticipated movement of the recharge bubble in these aquifer zones. Because the quarterly groundwater measurements indicate a gradient of less than approximately 0.0011 exists a majority of the time (see Table 1), the transient groundwater gradient and flow direction will likely result in a cumulative movement that is between the two extremes indicated in Figure 10.

The result of this analysis indicates that the volume of water proposed for cyclical storage in the upper Hueneme Aquifer zone(s) of the LAS at the Campus Park GRRP well site will not have an adverse effect on any existing wells. Because of the assumptions stated above, these estimates are believed to be conservative and the area filled by PRW would likely be smaller. Based on the proposed cyclical recovery of the PRW for IPR, the distance of movement from the ASR well location could be significantly shorter. These factors indicate that the potential area of impact from the proposed GRRP presents little risk to existing well facilities.

Figure 10 – Range of Purified Recycled Water Movement From ASR Well Location



Water Quality

Review of historical water quality data indicate that groundwater in the LAS is generally a calcium sulfate chemical character of fair to poor quality with total dissolved solids (TDS) concentrations in the range of 900 to 1,300 milligrams per liter (mg/l) and sulfate concentrations that range from 400 to 650 mg/l. These historical data indicate that the storage of the proposed recycled water will improve the general mineral quality of groundwater in the LAS (a beneficial impact) and that injection water chemistry can likely be controlled (buffered) to be compatible with native groundwater and avoid degradation.

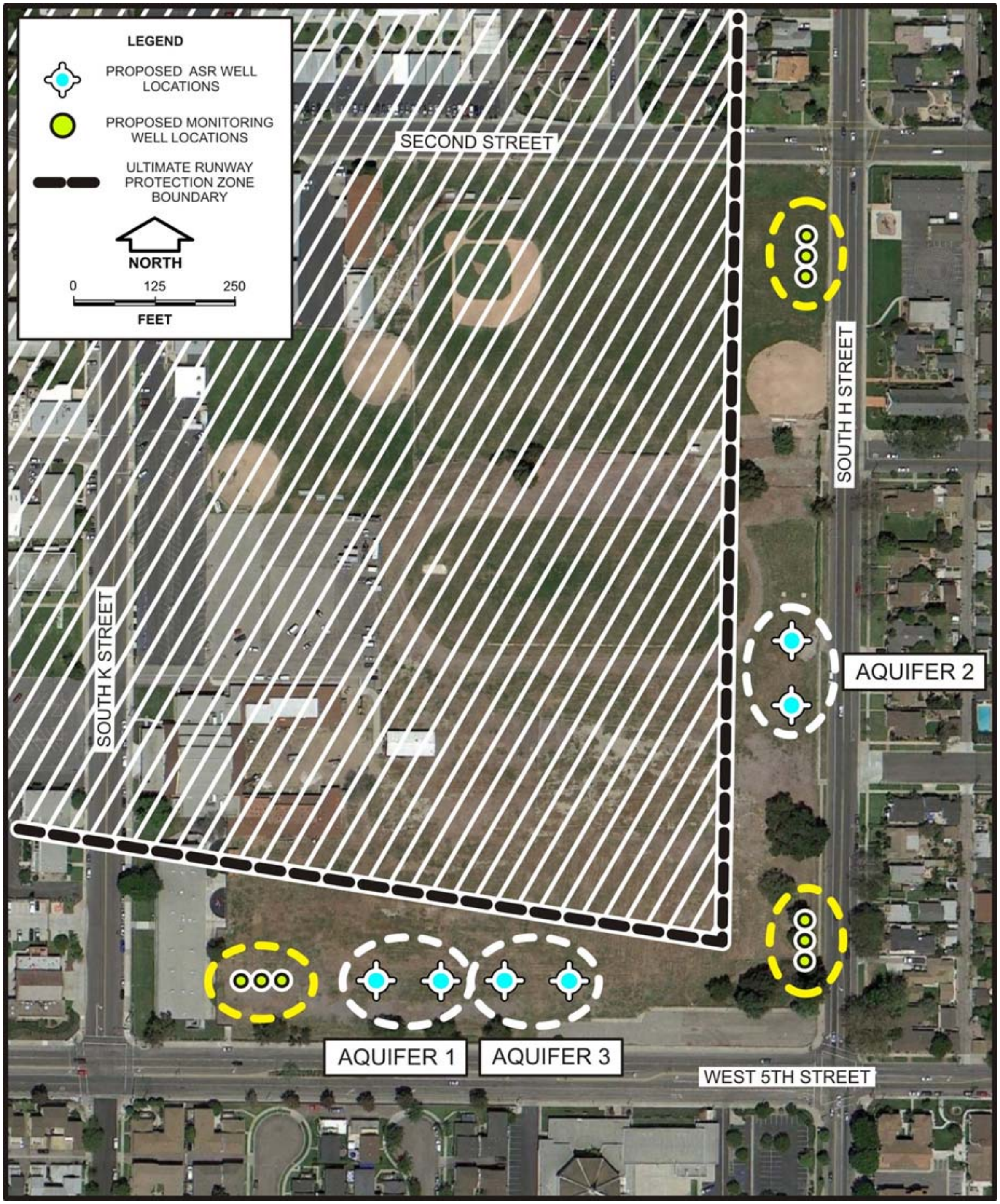
SITE LAYOUT AND FACILITIES DESIGN

To fully develop the Campus Park GRRP location, the City will utilize ASR well facilities that are constructed in discrete aquifer zones. These facilities will be used to conduct the demonstration testing required for final permitting of the IPR GRRP. The site specific groundwater data generated will further define the groundwater gradient, the aquifer materials, the site specific hydrogeology available for GRRP operations, local water quality, and ultimately the aquifer replenishment potential at the ASR well location. Initially, the proposed upper Hueneme Aquifer zone ASR well will be constructed along with 3 monitoring wells to develop information that establishes site specific data. Figure 11 – Proposed Campus Park ASR Wellfield Location Map shows the approximate location of the proposed ASR Wells and Monitoring Wells as they are positioned in the proposed City park development plan.

The proposed well locations were selected to construct facilities that will accomplish wellfield construction and data collection that complies with GRURW regulations and still be within the City property on the Campus Park site. As shown on Figure 11, the well locations are designed to be outside the ultimate runway protection zone boundary proposed by the County of Ventura Department of Airports for Federal Aviation Administration approval. This wellfield layout is designed to accommodate present and future conditions that may restrict the use of the Campus Park Property where drilling equipment of up to 60 feet high may be allowed to operate.

As shown, it is ultimately anticipated that a minimum of two wells will be required in each discrete aquifer zone(s) to achieve the full recharge and extraction capacities desired by the City. ASR Well No. 1 is located in the group labeled Aquifer 1 (see Figure 11). Aquifer 2 is the designated site for the wells that will utilize an aquifer(s) immediately below the Aquifer 1 wells. Accordingly, Aquifer 3 will utilize a deeper aquifer(s) to provide the final ASR capacity required for the recharge, retention, and recovery cycle to support continuous utilization of PRW produced from the AWPF. The initial demonstration ASR well location (see Figure 2) is within the Aquifer 1 area and the 3 monitoring wells are located within each of the monitoring well locations at variable distances from the ASR well.

Figure 11 – Proposed Campus Park ASR Wellfield Location Map



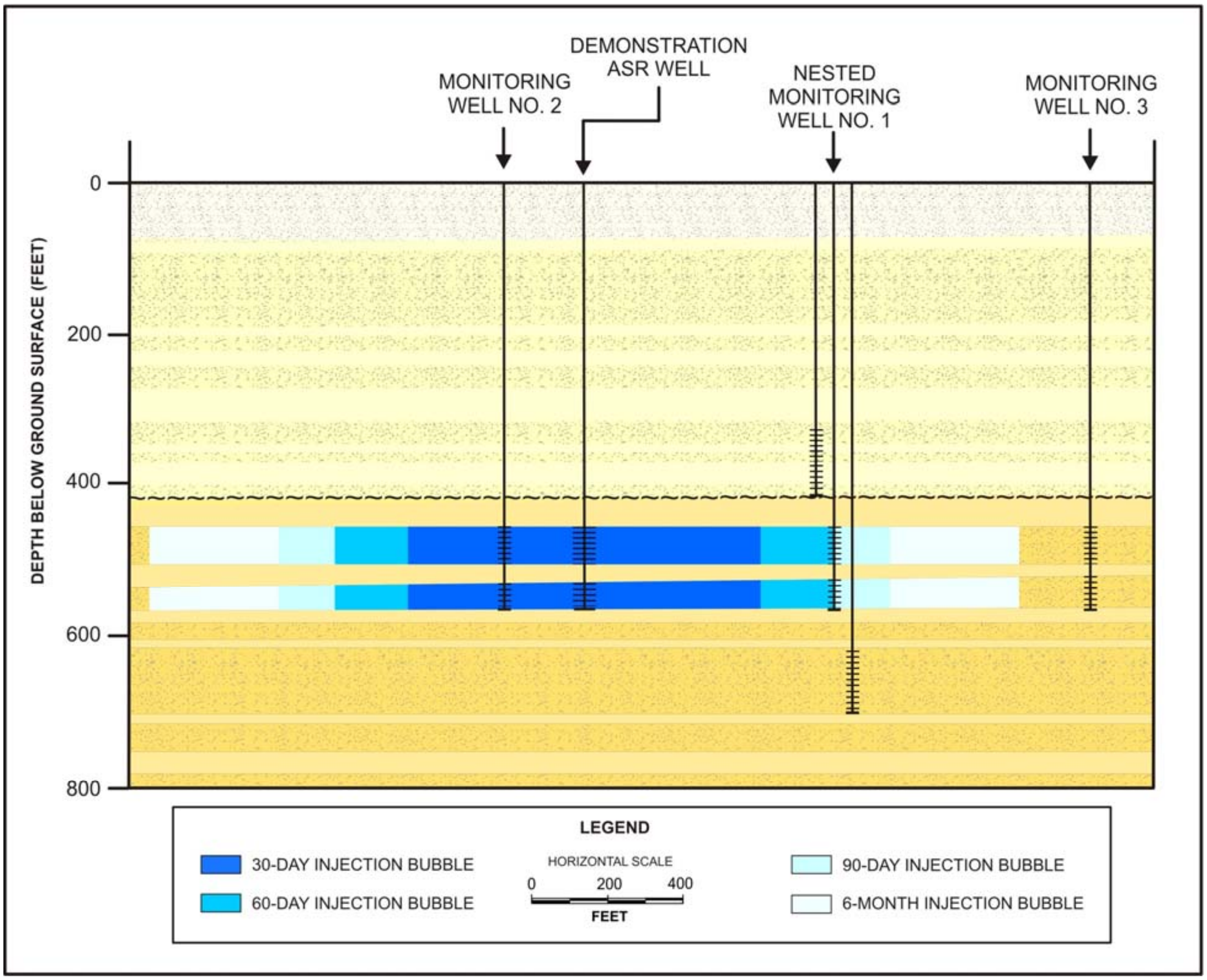
Well construction will be conducted by drilling and logging a pilot hole to select the aquifer(s) to be utilized by the ASR well(s). Based on these data, the final design of the demonstration ASR well and monitoring wells will be provided in the uppermost aquifer unit. The monitoring well locations selected are designed to test the aquifer properties and confirm groundwater travel time estimates at the Campus Park site in compliance with the GRURW regulations. Upon completion of well construction, groundwater tracer testing using an intrinsic tracer will be conducted to satisfy regulation provisions and obtain a CRWQCB permit for operation of the GRRP. Additional analyses to be conducted during the site investigation will include evaluating the geochemical compatibility of the PRW with the native groundwater and with the lithology of aquifer materials through direct sample analysis of the PRW during the recovery phase of the initial recharge cycle.

The locations of the monitoring wells are designed to; a) be far enough apart to collect water levels that will define the site specific groundwater gradient, b) be close enough to comply with GRURW regulation monitoring well requirements for GRRP permitting including a travel time of greater than 2 weeks and less than 6 months, and c) utilize the City owned parcel and minimize impacts to airport operations and future park development to be planned. The location of the demonstration ASR well is presently on the periphery of the future park property and positioned to allow the additional ASR wells to be constructed on the site.

Figure 12 – Subsurface Profile of PRW Travel Time Estimates shows the radial distances estimated that will be filled with PRW during replenishment in the discrete aquifer zones identified for storage using Campus Park ASR Well No. 1. These estimations were calculated using an aquifer porosity of 20 percent (which is believed a reasonable value for this purpose) and a test injection rate of 2,000 gpm. Variations in aquifer porosities will either decrease or increase the estimated travel time proportionally as shown in Table 2. As shown, the displacement volume from ASR Well No. 1 replenishment is anticipated to fill the aquifer at radial distances that will reach Monitoring Well No. 2 within approximately 2 weeks and Monitoring Well No. 1 in approximately 60 days. The estimated displacement volume from the proposed injection rate is not anticipated to reach Monitoring Well No. 3 for over 6 months and would likely be on the order of 9 months.

Based on the regional groundwater gradient, the travel time of PRW will be primarily dominated by the rate of injection and the displacement of native groundwater in the aquifer and not by the background flow of groundwater through Aquifer No. 1. Because the GRRP Wellfield is located within an area of the City where it has control over water well permitting, a prohibition of private wells constructed in the LAS can be implemented and prevent potential impacts to private well owners during the lifetime of the project. This condition effectively establishes the required isolation zone for future well construction.

Figure 12 – Subsurface Profile of PRW Travel Time Estimates

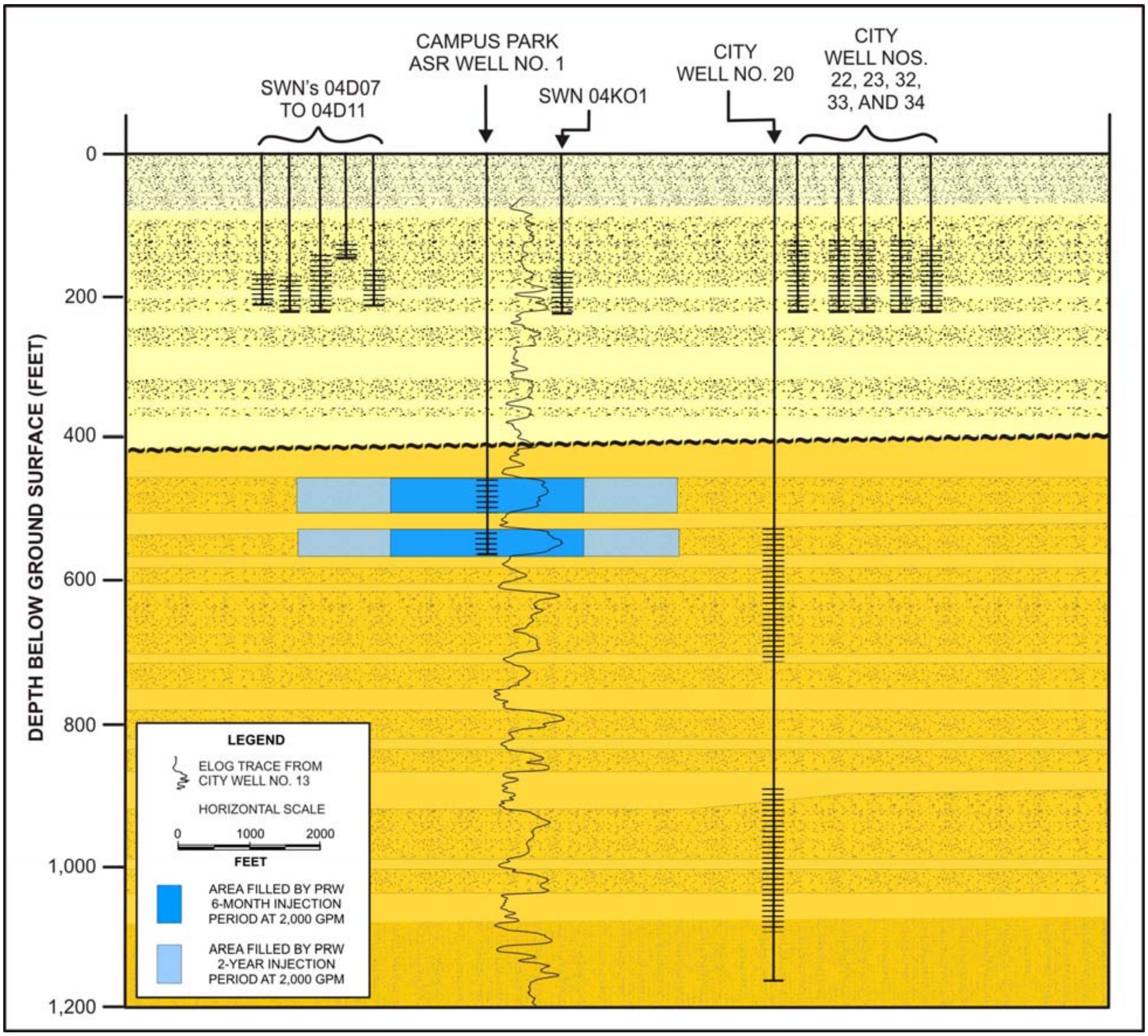


GRRP OPERATION AND VIOLATION MITIGATION

GRRP OPERATIONS

The conceptual design of the GRRP includes the cyclical recharge and storage of PRW in the discrete aquifer zones utilized by each ASR well. While it is anticipated that the majority of the recycled water produced by the AWPF during the first phase of production will be sold for in-City uses or for agricultural purposes, winter season demand will likely require injection and storage of the PRW to prevent plant shutdown or discharge to the ocean. The proposed use of the well is cyclical in nature, however, the actual amount that will be required for storage under full plant capacity is unknown and operational flexibility is always desirable. This study evaluated the merit of a 6-month and 2-year recharge/storage cycle (see Figure 9). The results indicated that these volumes can be accommodated if required, without adverse impacts to proximal well facilities. Figure 13 – Profile of Existing Wells shows the closest wells to the Campus Park site along with their approximate distance and completed depth. As indicated, City Well No. 20 is the only well within a mile of the site that is constructed in the LAS.

Figure 13 – Profile of Existing Wells



The injection volumes shown on the scaled drawing represent the radii of a 6-month and 2-year recharge period. This clearly indicates the low risk of the 3-month ASR cycle proposed. In addition, it illustrates the multiple confining layers and aquifer zones between the proposed ASR well constructed in the upper Hueneme Aquifer and the existing shallow 200- to 230-foot-deep wells constructed in the Oxnard Aquifer.

Preliminary analysis of the GRURW regulation requirements for treatment credits was performed by the City to understand the ability of the designed AWPF treatment process to satisfy the minimum 12-log reduction of enteric virus, 10-log reduction of Giardia cyst, and 10-log reduction of Cryptosporidium oocyst. The findings of that review indicated that the treatment process is capable of achieving the credits required for an IPR project for Giardia and Cryptosporidium, but is approximately 3-log reduction short of the requirement for enteric virus. Because of this finding, the aquifer used for storage may also be used for soil aquifer treatment to obtain the additional credit required for virus removal to achieve the IPR requirement (if no other treatment process is added to obtain additional credit). Based on the information in Table 60320.208 in the GRURW regulations, the necessary retention time will be approximately 3 months. The primary assessment of this hydrogeological study was to accommodate planned ASR operations on a 3-month cycle until treatment process improvements are implemented.

For initial GRRP operations, the City proposes to recharge the well for approximately 3 months with PRW. Upon completion of the recharge cycle, the City will allow a 3-month retention time (or less if additional treatment is provided) where the PRW will continue to move through the aquifer under the influence of the regional groundwater gradient (whichever direction that may be) and receive soil aquifer treatment throughout the retention time. Upon completion of the retention time necessary to achieve the required 3-log reduction credit, the stored water will be produced over an approximate 2- to 3-month recovery period. During recovery of the PRW, the well will discharge into the recycled water system and the recovered groundwater will be utilized for irrigation. Upon approval of use for IPR purposes, the groundwater will be recovered and conveyed to BS-1 for blending and use in the City municipal system.

Additional wells can be added to accommodate greater recharge and storage volumes or achieve higher retention time, as desired.

WATER QUALITY VIOLATION MITIGATION

The proposed GRRP is designed to allow rapid response and mitigation in the event of a AWPF treatment failure resulting in a water quality violation. Because the GRRP is designed to recapture the stored PRW at the point of replenishment, the ability for recapture of all of the water has a high level of certainty regardless of changes in the groundwater gradient direction. The steps toward mitigation at the time of violation detection would include the following components:

1. Stop aquifer recharge into the specific well(s) receiving the unsuitable water upon immediate discovery of a violation.

2. Address the treatment plant problem and supplement the recycled system, if necessary, with a potable supply.

3. Immediately begin removal/recapture of the tainted groundwater (if necessary) and discharge to a location other than the municipal water supply system until all the water has been removed from the aquifer system. The recovered water would be discharged either back into the recycled water system and used for irrigation (if suitable) or discharged to the sewer for disposal.

4. Initiate injection into another ASR well after the AWPF treatment problem has been solved and until the tainted groundwater in the previously active well has been remediated.

5. Allow the stored volume of water to remain in the aquifer for a greater response/retention time to receive additional soil aquifer treatment for the required time necessary based on the specific violation prior to subsequent removal and reuse.

Well discharge can be conducted until the affected aquifer zone is completely purged. Discharge from the affected well(s) can be directed to the most beneficial use allowable for its determined quality. City facilities provide multiple locations for discharge of the inadequately treated water, which include the City:

- sanitary sewer

- recycled water system for permitted irrigation reuse

- IPR after additional response retention time or aquifer travel time (soil aquifer treatment) has been achieved to mitigate the violation.

CONCLUSIONS AND RECOMMENDATIONS

In June 2014, the DDW released the final GRURW regulations that reflect its current thinking on the regulation for replenishing groundwater with PRW and the subsequent reuse as a potable supply. Based on the findings of this study, we conclude that available data indicate the proposed GRRP is feasible and that replenishment and recovery of groundwater with an improved quality could be accomplished in this portion of the Oxnard Plain Basin that would be consistent with the current GRURW regulations.

It is anticipated that properly designed and constructed ASR wells located at the proposed Campus Park GRRP site will provide operational well capacities beneficial for the proposed IPR program. Injection into the LAS in the Oxnard Plain Basin will require multiple wells that will likely be capable of sustained injection rates between 1,500 to 2,000 gpm. While the initial proposed demonstration project includes a single ASR well to achieve permitting, and a total of 3 ASR wells to achieve cycling for continual operation, additional wells can be added to facilitate a higher capacity GRRP operation in each of the aquifer storage units.

The City's review of the DDW regulations indicates that IPR operations may require a response retention time that achieves a 3-log removal credit for enteric virus and that the retention time of the PRW in the aquifer will likely be 3 months prior to reuse until additional treatment at the AWPF is provided. We conclude that it is feasible to inject PRW over a 3 to 6-month period into any discrete aquifer zone(s) and expect a high percentage of recovery after a 3-month retention period that allows full compliance with permit conditions. The proposed GRRP has direct control over the response retention time in that the ASR well facility that replenishes the aquifer(s) will remain off until the specified retention time has been achieved. Recovery of the final portion of the PRW will likely produce a component of groundwater with a reduced quality as a result of mixing with the native groundwater. Recovery percentages can be improved with the establishment of a buffer zone around the recharge bubble by originally using a greater quantity of the PRW than planned for recovery.

We conclude that while zone specific water level data from the Campus Park site are not available, the prevailing groundwater conditions indicated by available data in the Oxnard Plain Basin support the ability for effective capture and reuse of the higher quality recharge water from the Campus Park ASR Wellfield. As designed, the project does not rely on horizontal movement through an aquifer in any specific direction to allow capture at some distance away from the point of recharge. The point of capture is anticipated to be near the center of the PRW recharge bubble. We also conclude that in the event of a water quality violation where non-compliant water is injected in the aquifer system, the GRRP design will allow immediate mitigation and, as necessary, recapture of the non-compliant volume of PRW. There are no drinking water wells constructed in the LAS within ¾ of a mile of the proposed GRRP location. The only potable well in the LAS within a mile of the Campus Park is City Well No. 20.

Anticipated travel time to the nearest potable water supply well is greater than 2 years, if the PRW is not recovered for IPR. Because the City is the permitting agency and can control well construction within its limits, the proposed IPR operation has an effectively established isolation zone from future well construction.

We recommend the City drill a pilot borehole to a depth of 580 feet to define the site specific aquifer zone depths for use in final design of the GRRP ASR Well No. 1 in the upper Hueneme Aquifer zones (see Plate 1). We also recommend the City construct 3 monitoring wells at the designated locations which are preliminarily identified on Figures 2 and 11 to allow collection of groundwater data in compliance with the GRURW regulation pursuant to section 60320.200(h)(4). We recommend Monitoring Well No. 1 be constructed as a nested monitoring well to allow monitoring of the aquifer zones above and below the depths of Aquifer Storage Unit No. 1 during the operation of ASR Well No. 1.

PERSONNEL QUALIFICATIONS

The assessment of hydrogeological conditions for the proposed GRRP was conducted by and under the direction of Mr. Curtis J. Hopkins, Principal Hydrogeologist with Hopkins Groundwater Consultants, Inc. Mr. Hopkins is the company's president and is certified as a Professional Geologist (PG 5695), Certified Engineering Geologist (EG 1800) and Certified Hydrogeologist (HG 114) in the State of California. Mr. Hopkins has over 27 years of work experience on groundwater development projects performed throughout the Southern and Central California area and specifically, the Oxnard Plain Basin. Mr. Hopkins has extensive experience with water supply studies to establish municipal wellfields and with design and management of well construction projects.

CLOSURE

This report has been prepared for the exclusive use of the City of Oxnard and its agents for specific application to the City of Oxnard GREAT Program utilization of PRW treated at the AWPF and properly applied at the proposed Campus Park GRRP site for IPR. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeological planning and engineering practices. No other warranty, express or implied is made.

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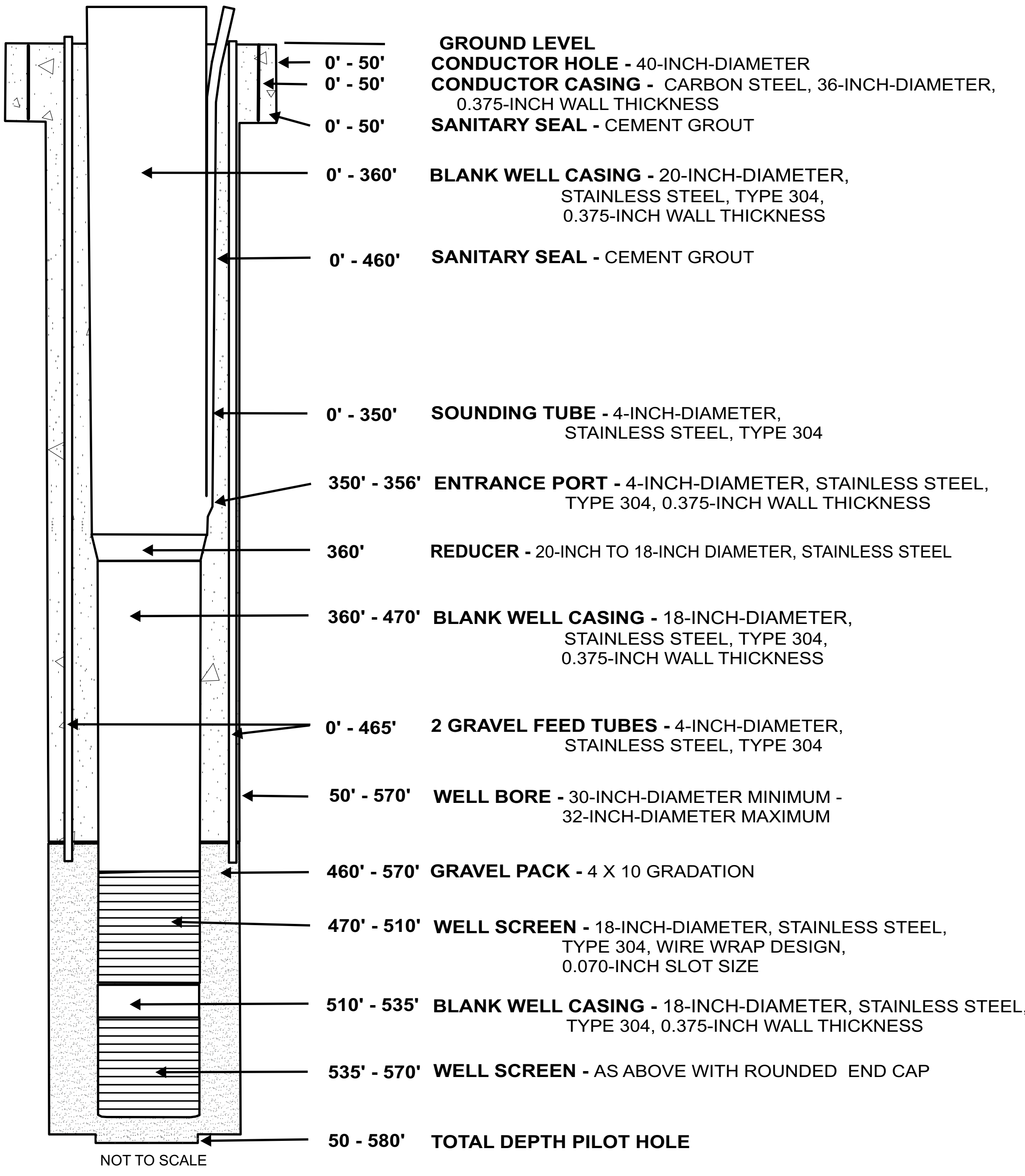
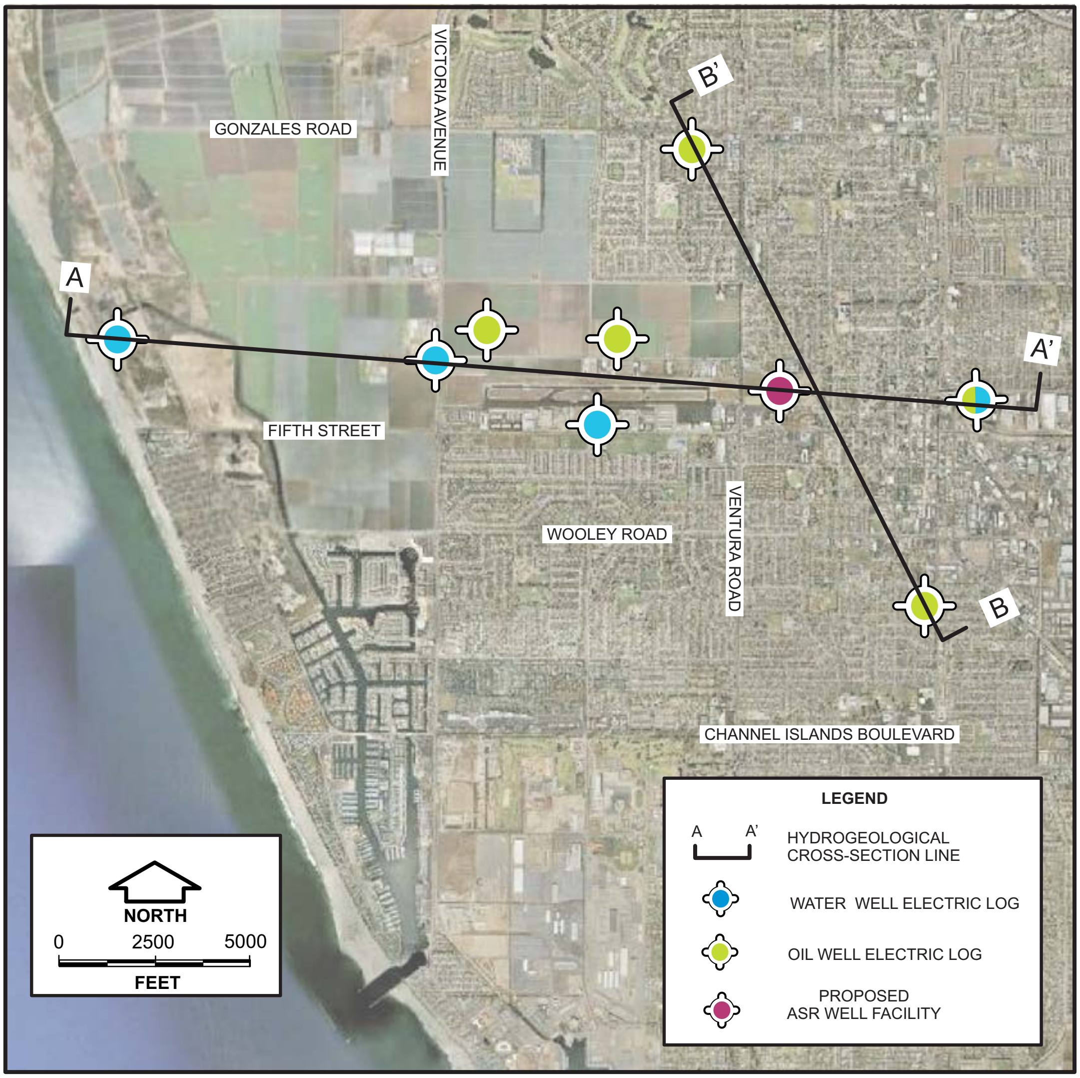
PLATES

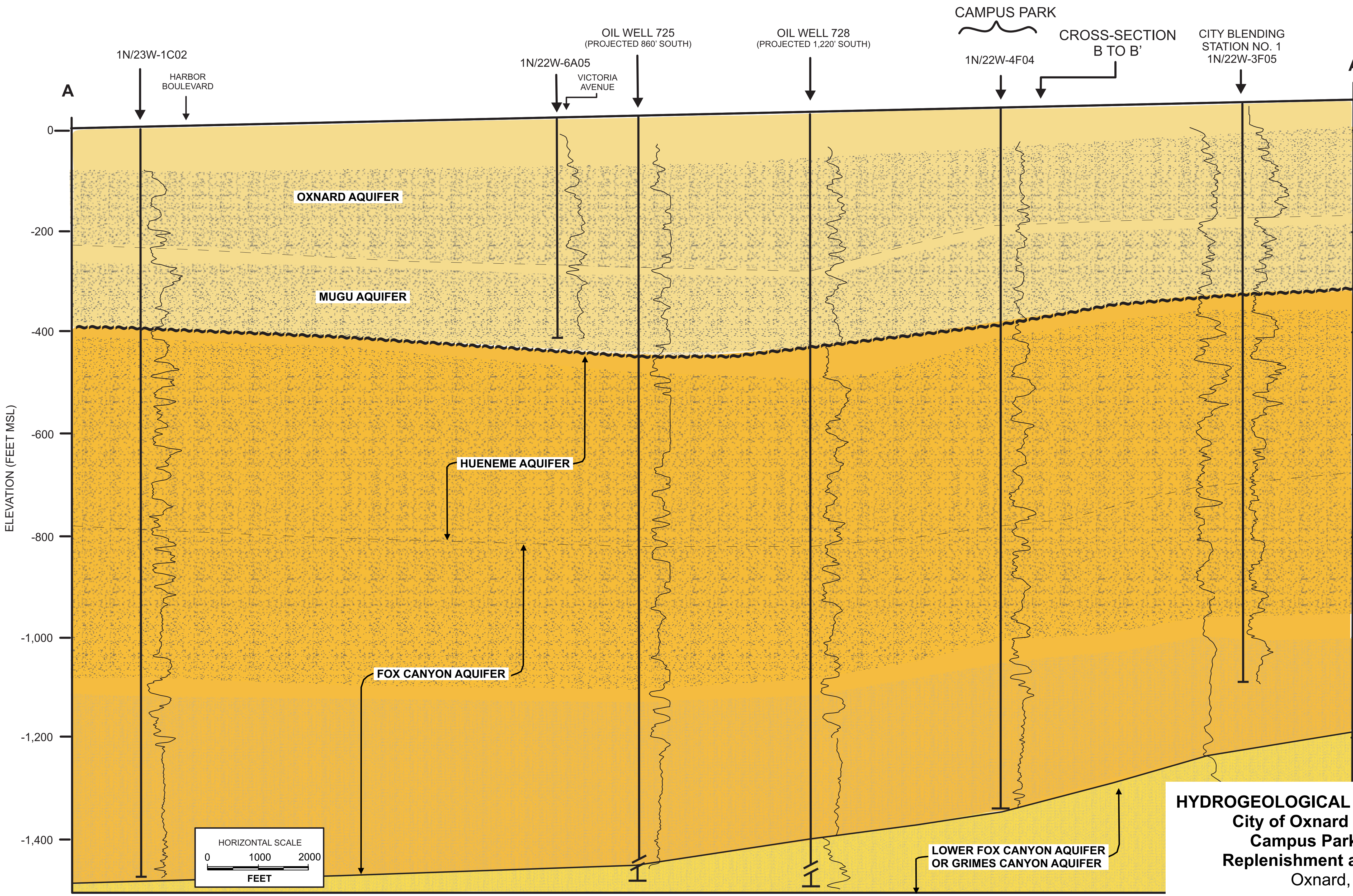


PRELIMINARY ASR WELL NO. 1 DESIGN DRAWING
City of Oxnard GREAT Program
Campus Park Groundwater
Replenishment and Reuse Project
Oxnard, California

PLATE 1

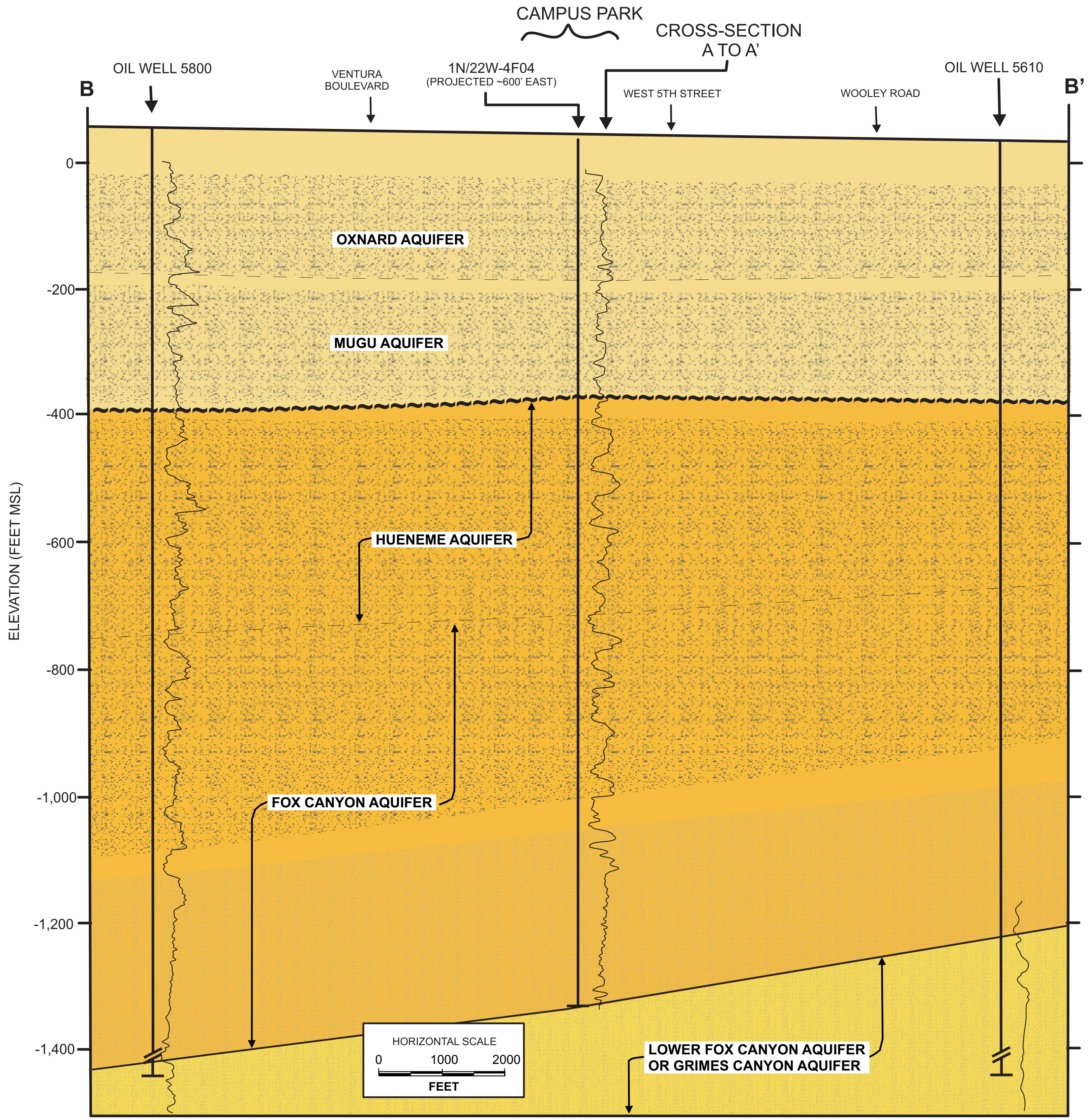


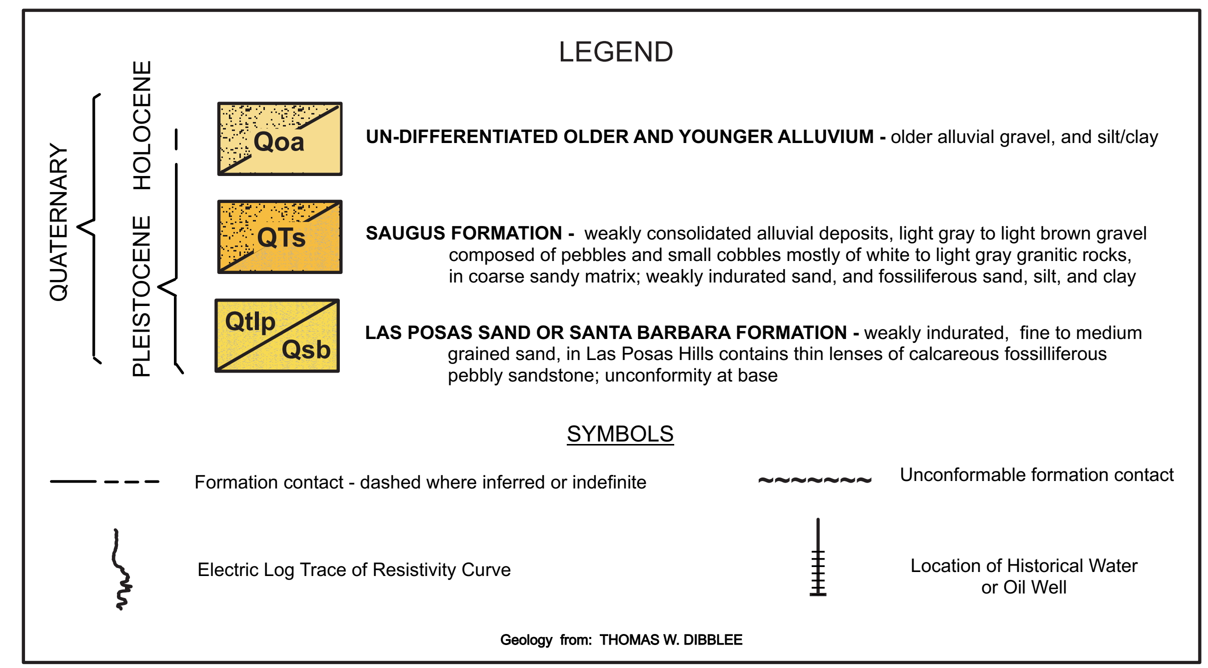
HYDROGEOLOGICAL CROSS-SECTION LOCATION MAP
City of Oxnard GREAT Program
Campus Park Groundwater
Replenishment and Reuse Project
Oxnard, California



HYDROGEOLOGICAL CROSS-SECTION A - A'
City of Oxnard GREAT Program
Campus Park Groundwater
Replenishment and Reuse Project
Oxnard, California

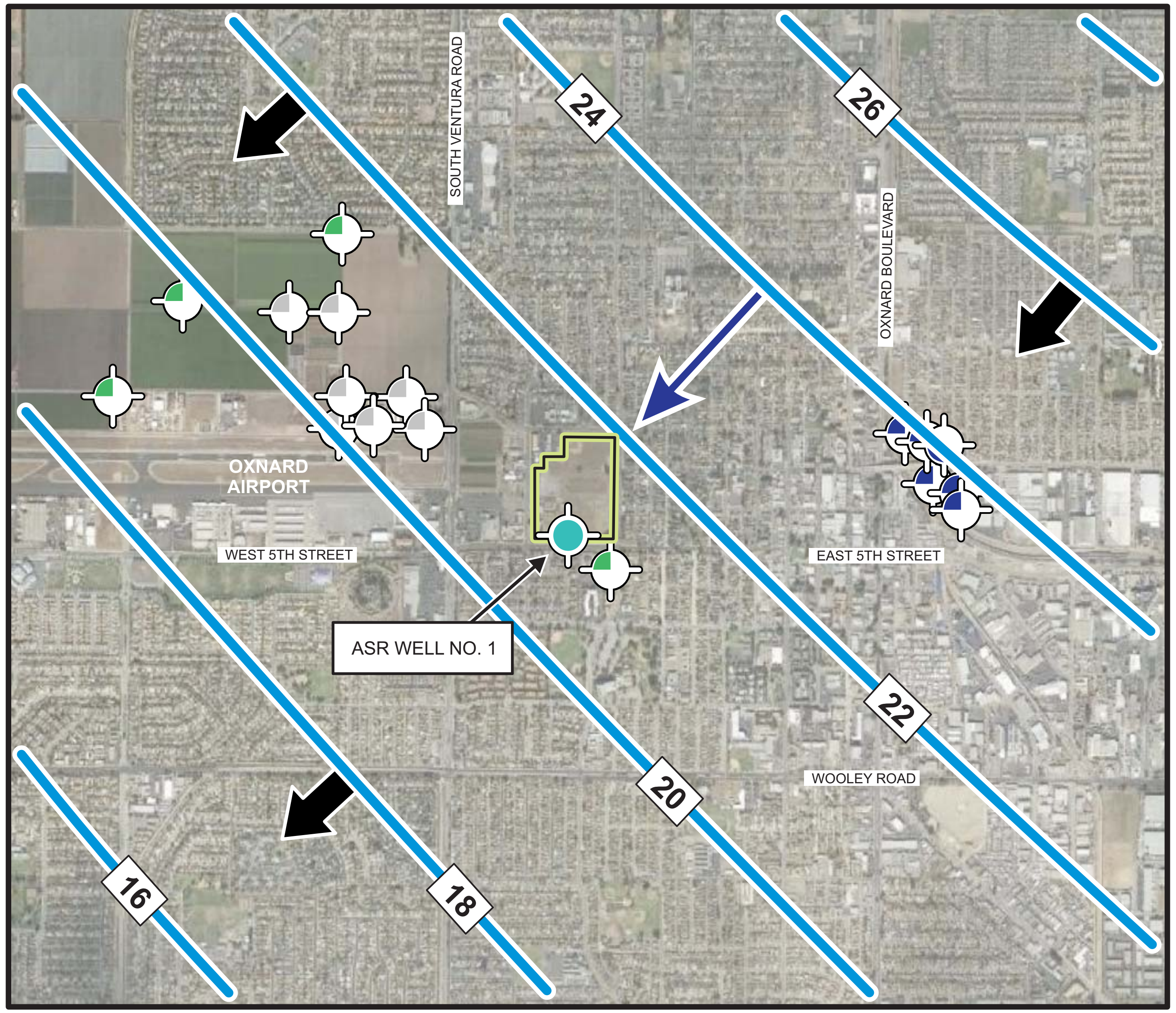
PLATE 3



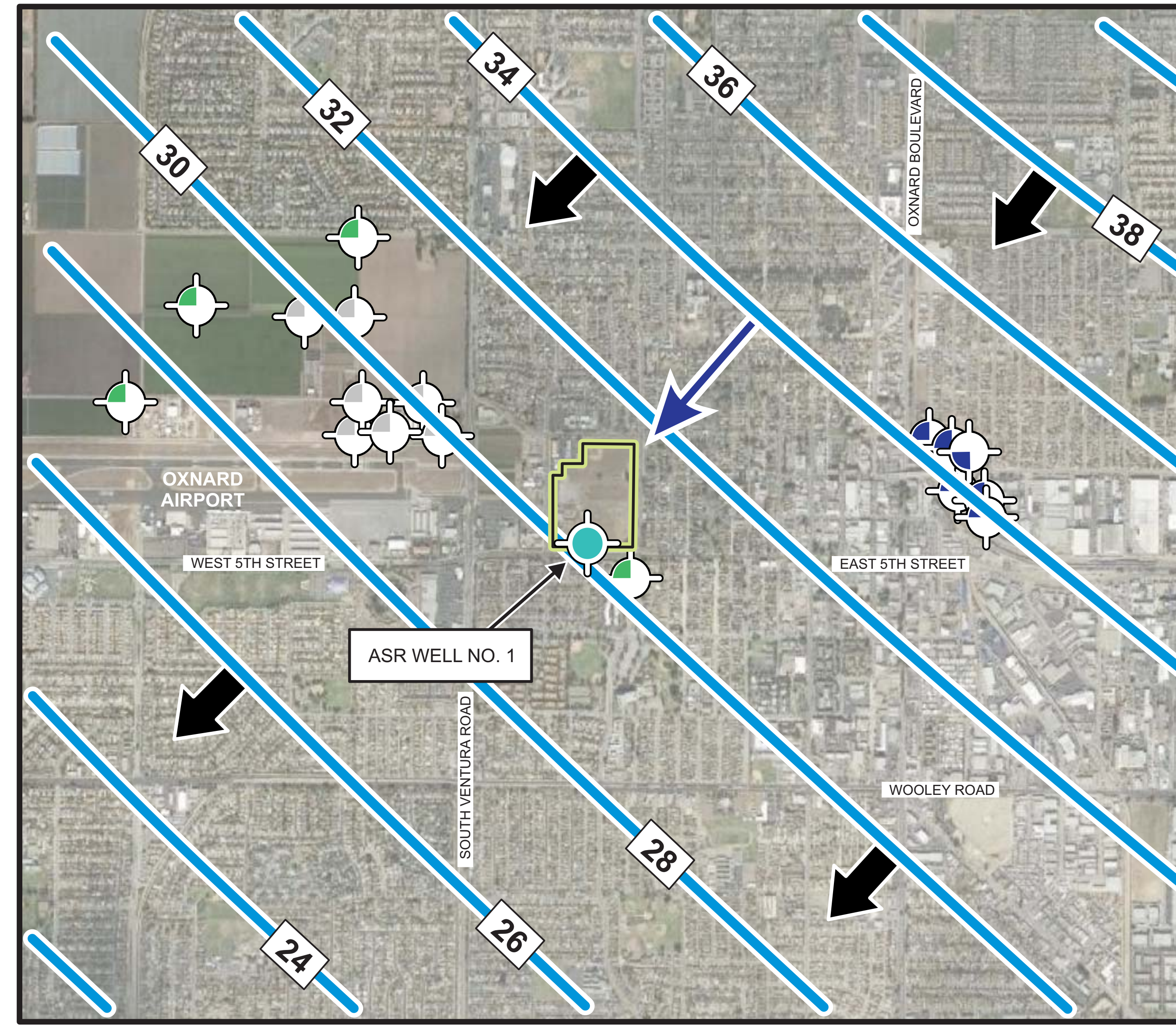


HYDROGEOLOGICAL CROSS-SECTION B - B'
City of Oxnard GREAT Program
Campus Park Groundwater
Replenishment and Reuse Project
Oxnard, California

APPENDIX A
GROUNDWATER ELEVATION
CONTOUR MAPS



JANUARY 2011



APRIL 2011

GROUNDWATER LEGEND

LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0008**

FLOW DIRECTION **S 43° W**

NORTH

0 1000 2000

FEET

WELL LEGEND

MUNICIPAL WELL

DOMESTIC WELL

AGRICULTURAL WELL

SWN 21M1 WELL ID

AQUIFER COMPLETION DESIGNATION

OXNARD AQUIFER
MUGU AQUIFER
HUENEME AQUIFER
FOX CAYNON AQUIFER

UAS
LAS

GROUNDWATER LEGEND

LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

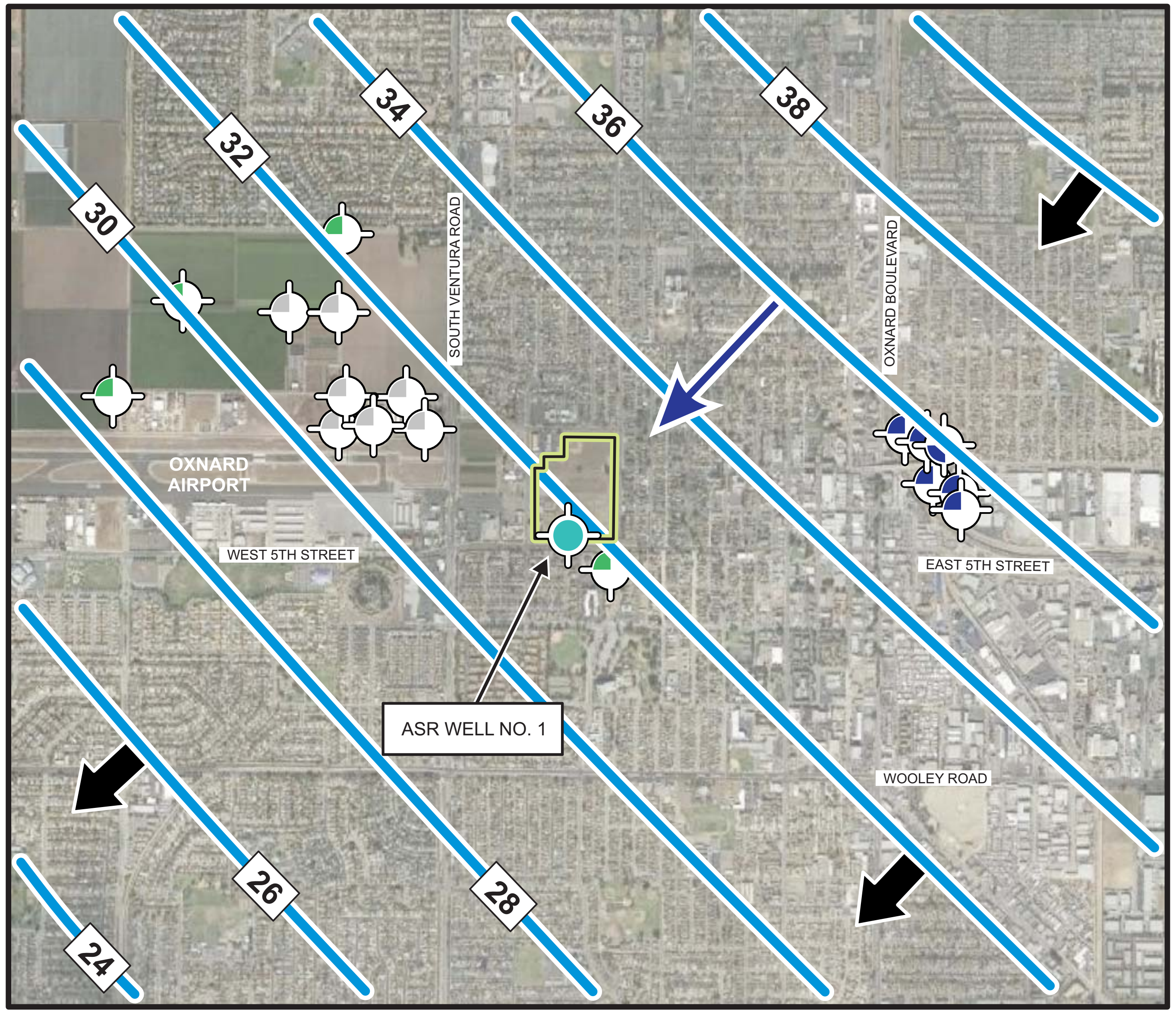
GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0011**

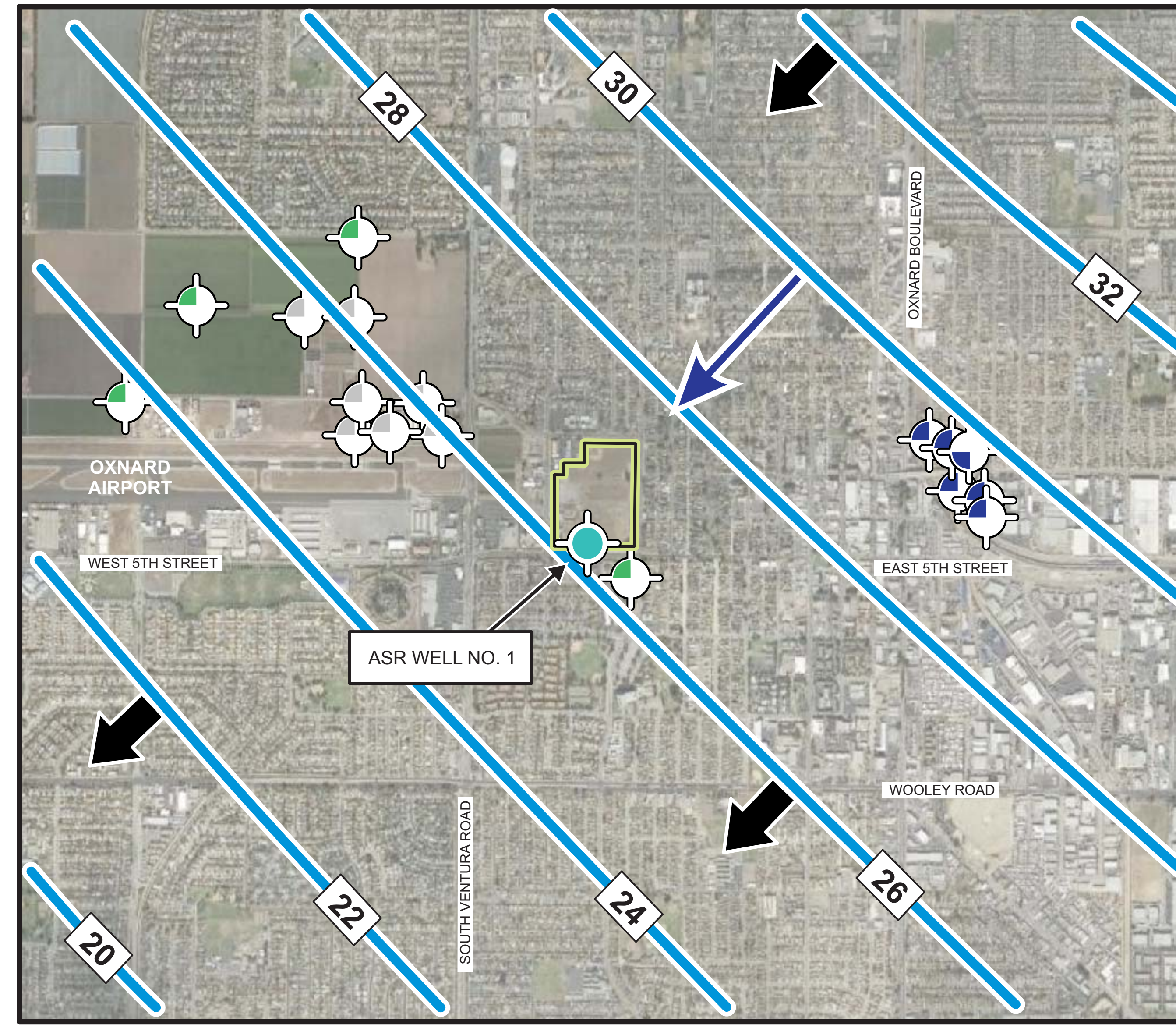
FLOW DIRECTION **S 41° W**

GROUNDWATER ELEVATION CONTOUR MAPS
JANUARY AND APRIL 2011
City of Oxnard GREAT Program
Campus Park Groundwater Replenishment and Reuse Project
Oxnard, California

PLATE A1



JULY 2011



OCTOBER 2011

GROUNDWATER LEGEND

- LINE OF EQUAL GROUNDWATER ELEVATION
- DIRECTION OF GROUNDWATER FLOW
- GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0011**

FLOW DIRECTION **S 44° W**

NORTH

0 1000 2000

FEET

WELL LEGEND

- MUNICIPAL WELL
- DOMESTIC WELL
- AGRICULTURAL WELL
- SWN 21M1 WELL ID

AQUIFER COMPLETION DESIGNATION

OXNARD AQUIFER, MUGU AQUIFER — UAS

HUENEME AQUIFER, FOX CAYNON AQUIFER — LAS

GROUNDWATER LEGEND

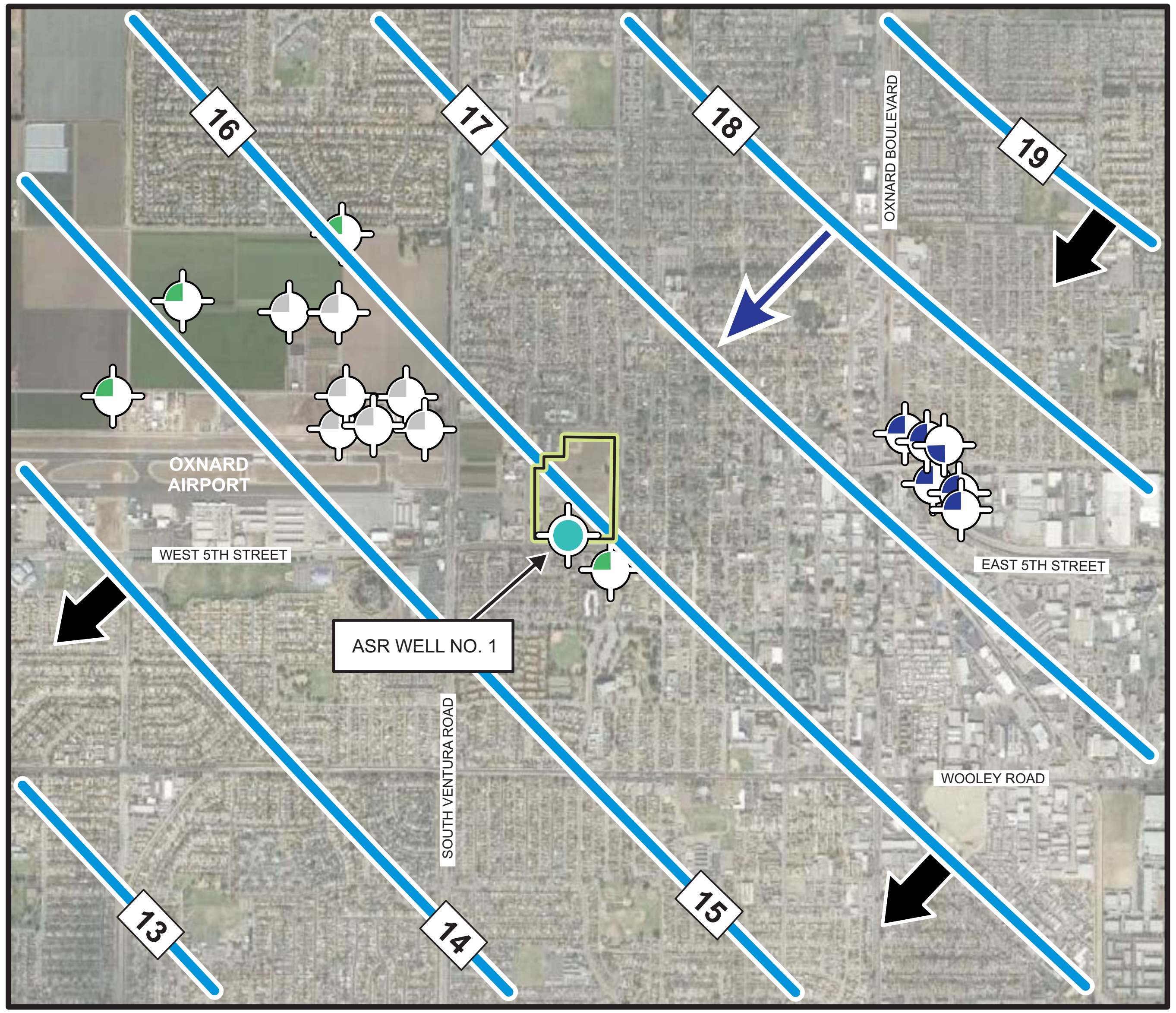
- LINE OF EQUAL GROUNDWATER ELEVATION
- DIRECTION OF GROUNDWATER FLOW
- GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0009**

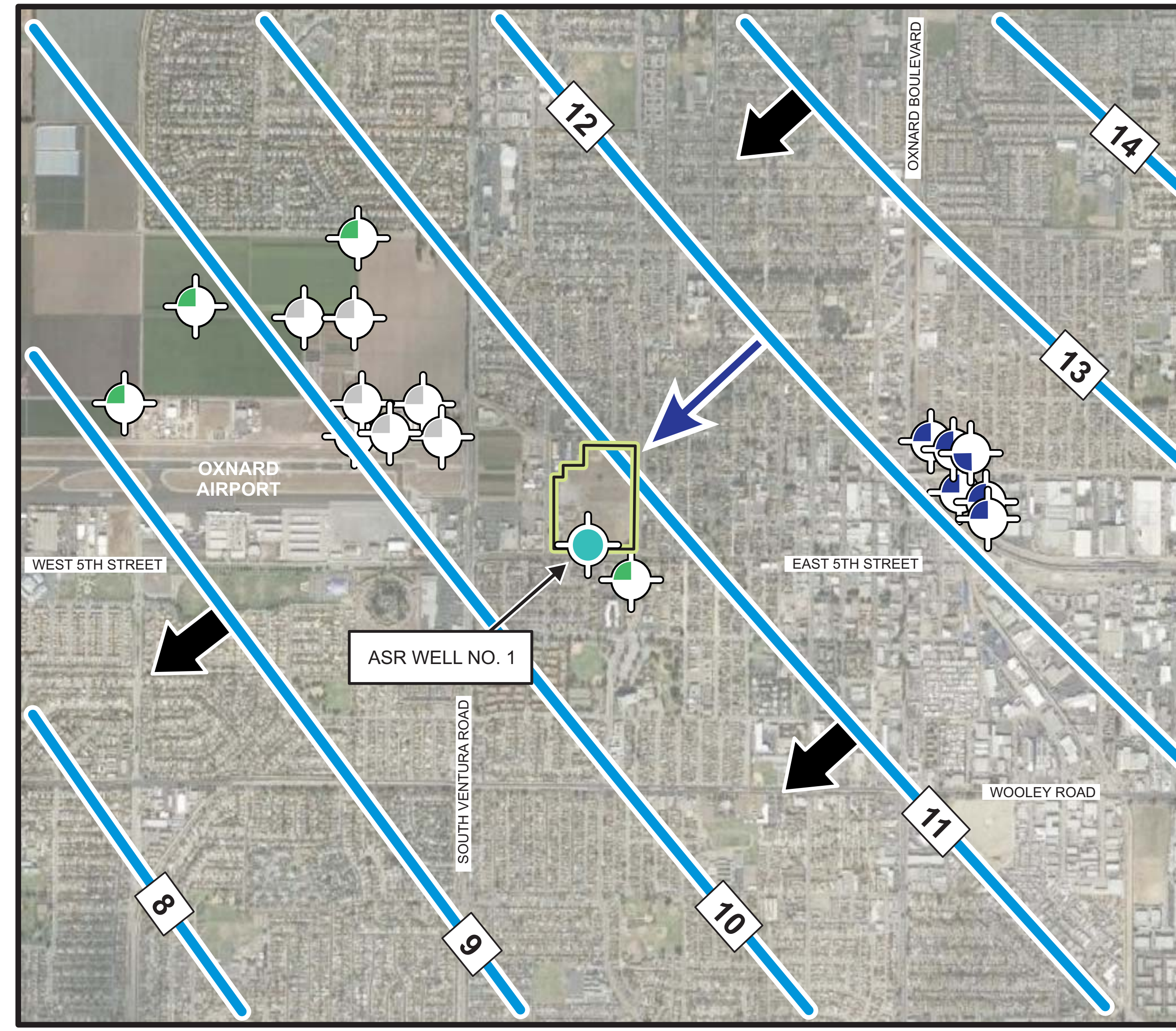
FLOW DIRECTION **S 43° W**

GROUNDWATER ELEVATION CONTOUR MAPS
JULY AND OCTOBER 2011
City of Oxnard GREAT Program
Campus Park Groundwater Replenishment and Reuse Project
Oxnard, California

PLATE A2



JANUARY 2013



APRIL 2013

GROUNDWATER LEGEND

10 LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0004**

FLOW DIRECTION **S 44° W**

NORTH

0 1000 2000

FEET

WELL LEGEND

MUNICIPAL WELL

DOMESTIC WELL

AGRICULTURAL WELL

SWN 21M1 WELL ID

AQUIFER COMPLETION DESIGNATION

OXNARD AQUIFER
MUGU AQUIFER
HUENEME AQUIFER
FOX CAYNON AQUIFER

UAS

LAS

GROUNDWATER LEGEND

10 LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

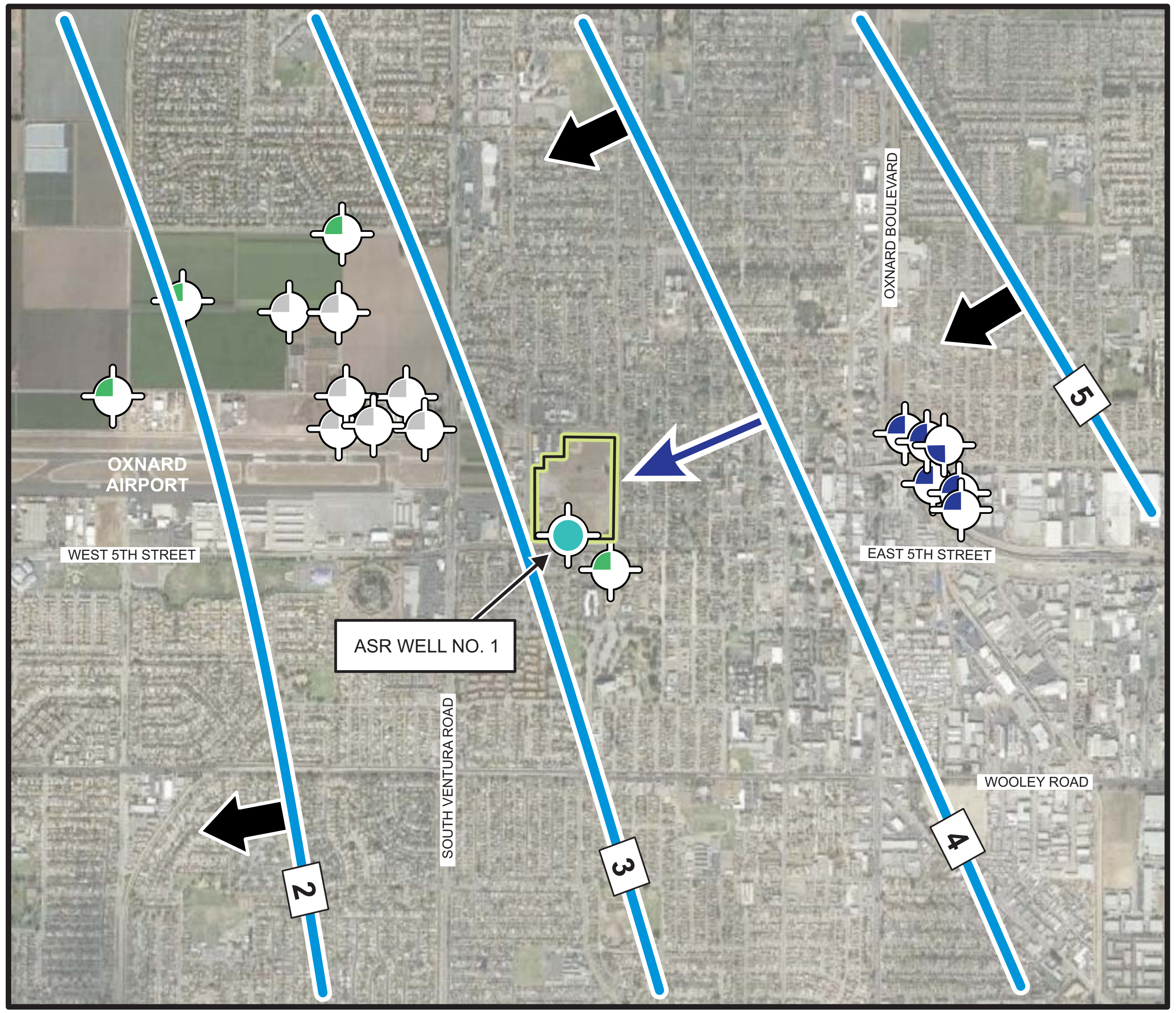
GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0004**

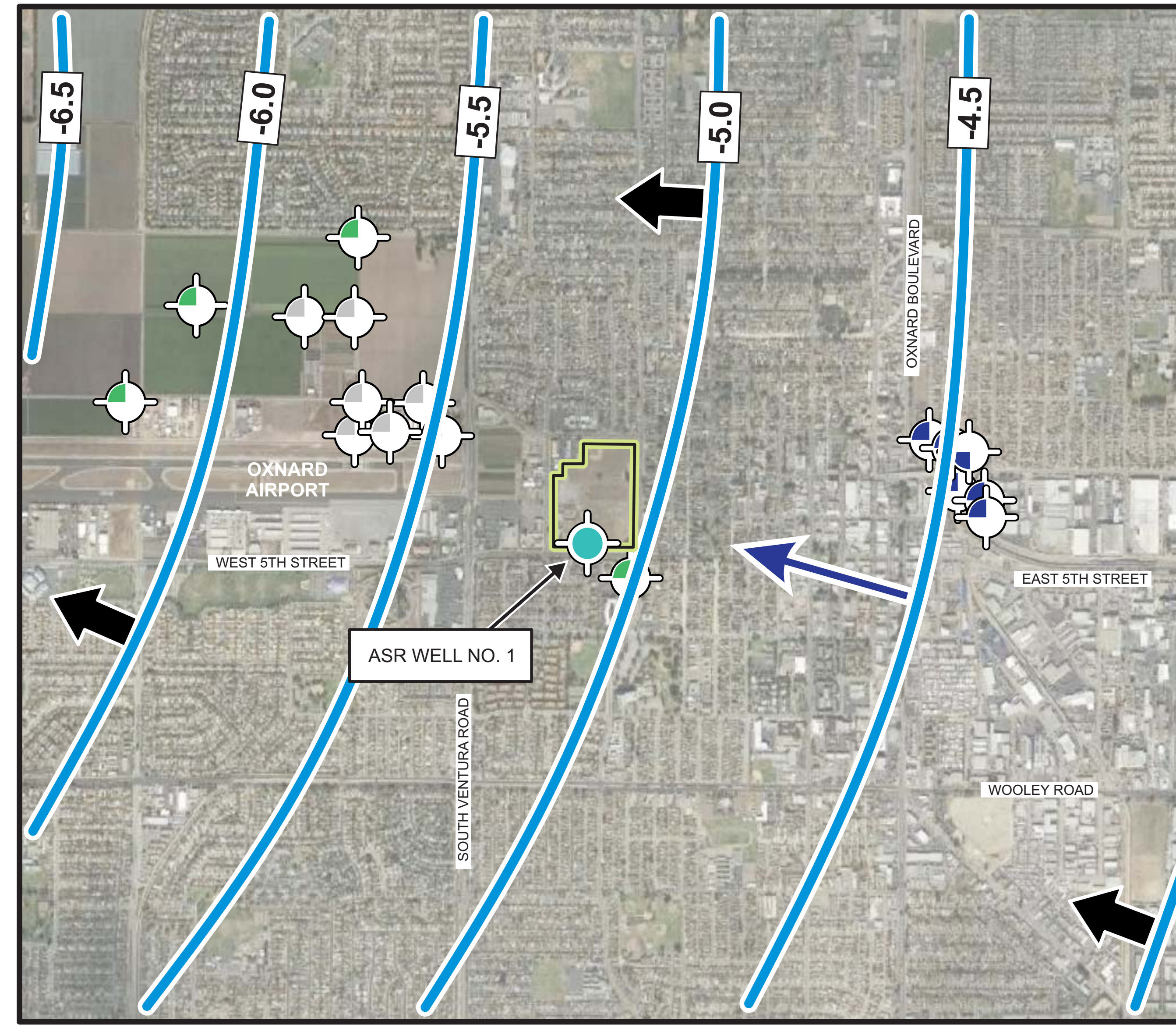
FLOW DIRECTION **S 47° W**

GROUNDWATER ELEVATION
CONTOUR MAPS
JANUARY AND APRIL 2013
City of Oxnard GREAT Program
Campus Park Groundwater
Replenishment and Reuse Project
Oxnard, California

PLATE A3



JULY 2013



OCTOBER 2013

GROUNDWATER LEGEND

10 LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0003**

FLOW DIRECTION **S 67° W**

NORTH

0 1000 2000

FEET

WELL LEGEND

MUNICIPAL WELL

DOMESTIC WELL

AGRICULTURAL WELL

SWN 21M1 WELL ID

AQUIFER COMPLETION DESIGNATION

OXNARD AQUIFER
MUGU AQUIFER
HUENEME AQUIFER
FOX CAYNON AQUIFER

UAS
LAS

GROUNDWATER LEGEND

10 LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

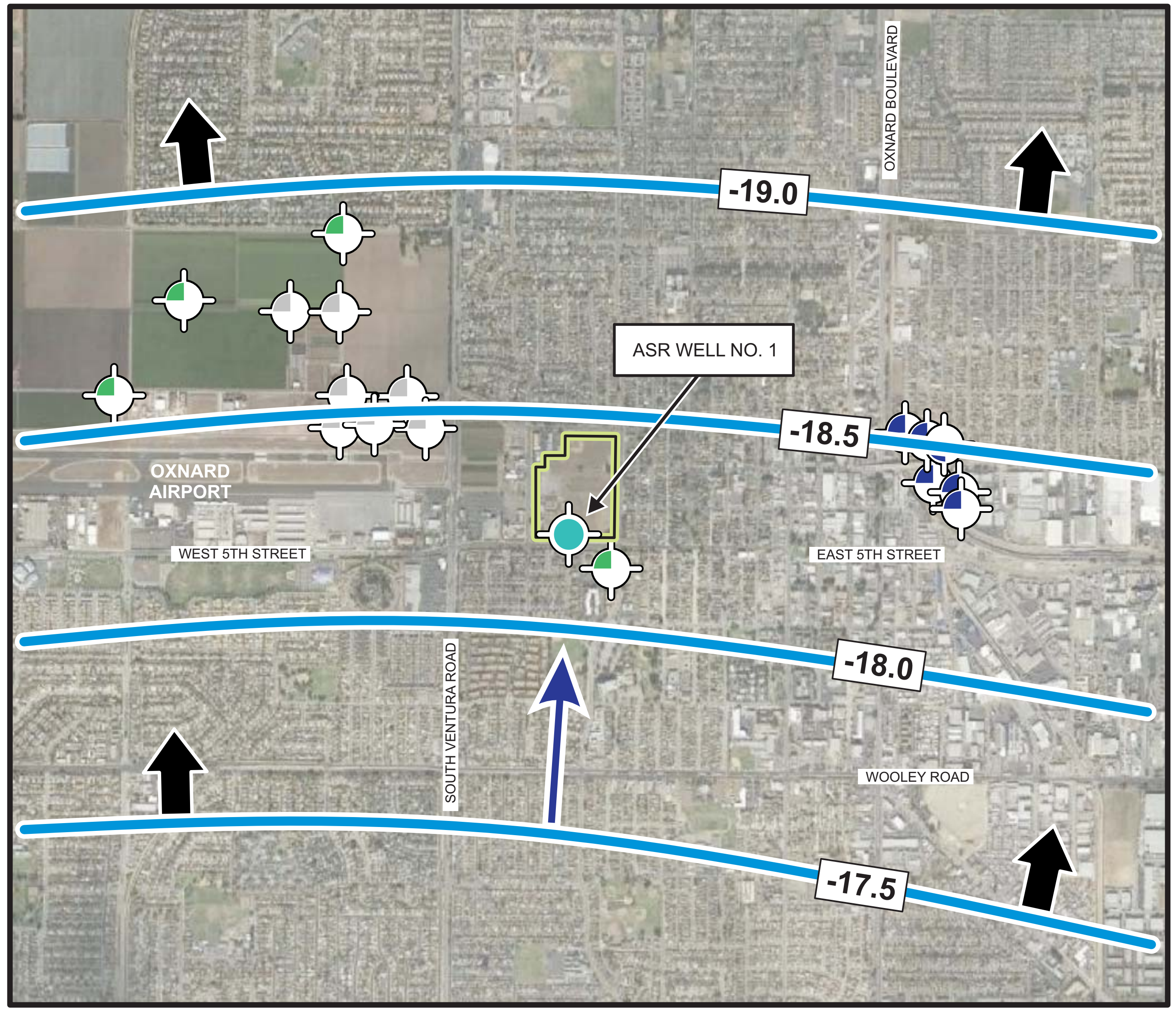
GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0002**

FLOW DIRECTION **N 74° W**

GROUNDWATER ELEVATION CONTOUR MAPS
JULY AND OCTOBER 2013
City of Oxnard GREAT Program
Campus Park Groundwater Replenishment and Reuse Project
Oxnard, California

PLATE A4



AUGUST 2014

GROUNDWATER LEGEND

LINE OF EQUAL GROUNDWATER ELEVATION

DIRECTION OF GROUNDWATER FLOW

GROUNDWATER FLOW DIRECTION BENEATH SITE

GRADIENT **0.0002**

FLOW DIRECTION **N 04° E**

NORTH

0 1000 2000

FEET

WELL LEGEND

MUNICIPAL WELL

DOMESTIC WELL

AGRICULTURAL WELL

SWN 21M1 WELL ID

AQUIFER COMPLETION DESIGNATION

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UAS

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GROUNDWATER ELEVATION CONTOUR MAPS
AUGUST 2014
City of Oxnard GREAT Program
Campus Park Groundwater Replenishment and Reuse Project
Oxnard, California

PLATE A5

APPENDIX G – WRRF-11-10 DPR STUDY, 2013

CITY OF OXNARD

RECYCLED WATER RETROFIT PROGRAM

DIRECT POTABLE REUSE CASE STUDY
For WRRF
EVALUATION OF RISK REDUCTION PRINCIPLES FOR DIRECT POTABLE REUSE
(WRRF-11-10)

DRAFT
July 2013

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CITY OF OXNARD

RECYCLED WATER RETROFIT PROGRAM

DIRECT POTABLE REUSE CASE STUDY

EVALUATION OF RISK REDUCTION PRINCIPLES FOR DIRECT POTABLE REUSE (WRRF-11-10)

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DIRECT POTABLE REUSE CASE STUDY

1.0 INTRODUCTION

The WateReuse Research Foundation is conducting Project #WRRF-11-10: Evaluation of Risk Reduction Principles for Direct Potable Reuse. The primary goal of this project is to develop recommendations for best practices for direct potable reuse (DPR), considering cost and practicality issues without compromising public health protection. The City of Oxnard is a participating utility in developing a case study that would evaluate differing logistical and treatment challenges of DPR, providing a specific example of how different options might be implemented in different municipalities. This case study illustrates some of the inherent trade-offs in logistics, complexity, and cost associated with DPR and will provide an enhanced understanding of what engineering practices could be incorporated into the design and control of advanced treatment systems for DPR.

2.0 BACKGROUND

The City of Oxnard, California (City) is located approximately 60 miles northwest of Los Angeles. The population is approximately 201,499 persons (based on 2010 Census Redistricting Data Summary File) within an area of approximately 27 square miles.

The City's current water supply comes from surface and groundwater sources. Fifty percent of the City's water supply is from northern California rainfall and snowmelt pumped through the Sacramento-San Joaquin Delta and imported to southern California via the State Water Project. This water is delivered by the Calleguas Municipal Water District (CMWD). Twenty-five percent of the City's water is regional groundwater supplied by the United Water Conservation District's (UWCD) spreading and pumping operations on the Santa Clara River and Oxnard Plain. Local, City owned and operated wells account for the remaining twenty-five percent of the City's water.

Based on current estimates, sometime before or by 2015, water demands will exceed water supplies available from CMWD, UWCD, and City groundwater wells. This has led the City to develop new supply alternatives.

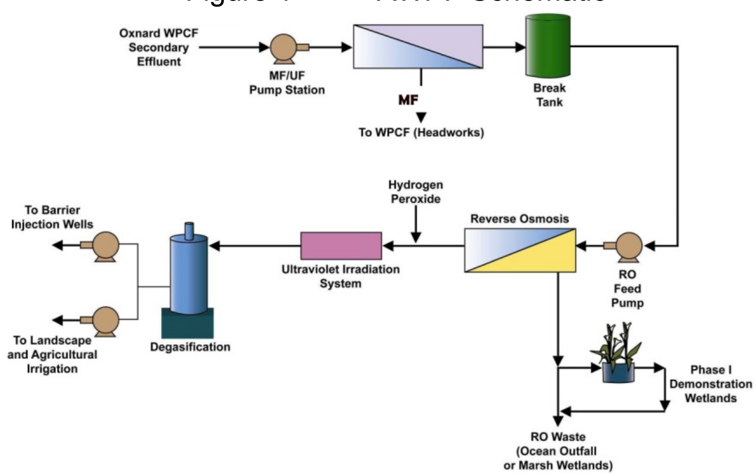
3.0 GREAT PROGRAM

To ensure a future reliable and affordable supply of high quality water, the City has developed the Groundwater Recharge Enhancement and Treatment or GREAT program to be implemented and operated in two phases. Phase 1 (6.25 million gallons per day (mgd), or 7,000 acre-feet per year (AFY)) has been constructed and will be operated in the near term, while Phase 2 would be constructed in the future to 12.5 mgd, with a future final capacity of 25 mgd. The objectives of the GREAT program are as follows:

- Increased reliability of water supply
- Reduced cost of water supply
- Improved dependability of water supply in accommodating existing needs and meeting planned growth and associated water demand
- Enhanced stewardship of local water supply through recycling and reusing a substantial portion of the wastewater of the region.

The GREAT program includes treating wastewater from the Oxnard Wastewater Treatment Plant (OWTP) and providing state-of-the-art microfiltration (MF), reverse osmosis (RO), and advanced oxidation with UV/H_2O_2 at the Advanced Water Purification Facility (AWPF). Figure 1 below provides a schematic of the treatment train.

Figure 1 AWPF Schematic



Feedwater quality from the OWTP is presented in the table below. The effluent is characterized by high levels of total organic carbon (TOC) and dissolved organic carbon (DOC), inorganic ions (sulfate, chloride, sodium, and total dissolved solids [TDS]), and ammonia. Phosphorus levels are only moderate due to the addition of ferric chloride at the headworks of the OWTP for odor control. Ferric addition also aids in the coagulation of colloidal Biological Oxygen Demand (BOD) in the raw wastewater. The high levels of TOC and total nitrogen require a high level of removal of these constituents by the RO process to meet the California Department of Public Health (CDPH) Title 22 Recycled Water Criteria for groundwater recharge (Lozier and Ortega, 2010) (See Table 1).

Table 1 Feedwater Quality (Secondary Effluent)
Recycled Water Retrofit Program
City of Oxnard

Constituent (mg/L. unless otherwise stated)	Mean	Maximum	Minimum
DOC	13.9	15.7	12.8
TOC	16.6	19.6	14.6
Total Suspended Solids	4.5	60	2.4
TDS	1,750	1,850	1,590
Alkalinity (as CaC03)	316	328	298
Turbidity (NTU)	3.30	5.20	2.40
Temperature (°C)	23.0	27.0	21.0
pH (units)	7.83	7.90	7.70
Boron	1.22	1.29	1.18
Total Hardness (as CaC03)	644	716	609
Silica	26.7	28.2	25.2
Sulfate	480	568	422
Ammonia as N	22.2	25.9	19.2
Nitrate as N	1.21	3.20	0.24
Total Nitrogen as N	25.9	31.9	21.5
Total Phosphate as P	1.80	2.50	0.91

Source: Lozier and Ortega 2010

Recycled water that is produced by the AWPF facility, and is not delivered to customers for tertiary recycled water applications, is expected to be used for groundwater injection at location(s) within the City. Elements of the GREAT program are summarized below:

- Recycled Water Delivery System- Distribute recycled water for irrigation to agricultural users.
- Aquifer Storage and Recovery - Intended to help alleviate groundwater overdraft conditions and associated water quality problems, including coastal seawater intrusion. Will allow seasonal storage of potable water supplies to maximize use of the existing potable water distribution system.
- Regional Desalter - Membrane filter systems to remove dissolved minerals from groundwater, in order to reduce the levels of nitrates and TDS in the groundwater basin.
- Blending Station No. 5 - Provide improved water supply infrastructure reliability, water quality, and hydraulic efficiencies. Also, assist in meeting peak-hour and fire-flow water supply demands

- Concentrate collection system from regional brine dischargers - Avoid discharge of high salinity concentrate into City sanitary sewer system and Oxnard wastewater treatment plant
- Permeate Delivery System – Permeate delivery from Regional Desalter to industrial users

All of the end users (agricultural irrigation, landscape irrigation, injection in the aquifer, and industrial) will be served with a common water quality that meets the groundwater recharge criteria. In exchange for the delivery of recycled water, agricultural customers would transfer their groundwater pumping allocation to the City of Oxnard on a one-for-one basis. This will increase the City's ability to pump additional groundwater. The additional groundwater that would be made available to the City from groundwater credits transferred from agricultural users and pumped by City wells from the poor quality Oxnard Aquifer would require additional treatment prior to delivery to the City's distribution system. The GREAT Desalter constructed in 2007/2008 would provide this treatment. It does not increase the total water supply. It does, however, allow full utilization of the City's groundwater resources.

Table 2 from the City's 2010 Urban Water Management Plan (UWMP) provides a summary of projected water demands and supplies for the City from present through 2035 including the GREAT program at full capacity.

4.0 IPR VS DPR POTABLE REUSE BASIC COMPARISONS

For indirect potable reuse (IPR) projects in the State of California (CDPH 2013), a minimum of 10-log Cryptosporidium oocyst reduction, 10-log Giardia cyst reduction, and, 12-log enteric virus reduction are needed through advanced treatment prior to consumption. Per CDPH (2013), the treatment train shall consist of at least three separate treatment processes, and can include a mixture of primary, secondary, and tertiary treatment. For each pathogen (i.e., virus, Giardia cyst, and Cryptosporidium oocyst), a separate treatment process may be credited with no more than 6-log reduction and shall achieve at least 1-log reduction.

The first California Utility to gain CDPH acceptance under the latest regulations (CDPH 2013) is the Water Replenishment District's Leo Vander Lans advanced treatment facility (LVL). Table 3 highlights the pathogen reduction credit provided to LVL, demonstrating the ability of that facility to attain the 12/10/10 credits through a minimum of three treatment processes.

Table 2 Existing Water Supply & Demand (units of Acre-feet/year)
Recycled Water Retrofit Program
City of Oxnard

Water Supply Sources	**2010[(1)]**	**2015**	**2020**	**2025**	**2030**	**2035**
Existing Supplies:						
Imported Water - Calleguas Municipal Water District	11,277	17,379	17,379	17,379	17,379	17,379
Groundwater - United Water Conservation District[(2)]	10,852	9,800	7,800	7,800	7,800	7,800
Groundwater - City-produced[(3)]	7,442	10,782	9,782	9,782	9,782	9,082
Brine Loss[(4)]	(1,254)	(1,490)	(1,641)	(1,700)	(1,755)	(1,810)
Subtotal Existing Supplies	28,317	36,471	33,320	33,261	33,206	32,451
Total Projected Water Use[(5)]		**36,029**	**39,684**	**41,109**	**42,439**	**43,769**
Planned Supplies						
Future City Groundwater[(6)]		527	1,789	2,269	2,269	2,269
Future City Groundwater[(7)]		5,200	11,400	8,500	8,500	8,500
Recycled Water[(8)]		1,800	2,600	5,500	5,500	5,500
Subtotal Planned Supplies		7,527	15,789	16,269	16,269	16,269
Total Estimated Supplies		**43,998**	**49,109**	**49,530**	**49,475**	**48,720**

Notes:
(1) 2010 supplies represent actual consumption, not a limitation in water supply.
(2) City's sub-allocation held by UWCD plus the additional allocation resulting from the M&I Supplemental Water Program.
(3) City's historical and baseline allocation (9,082 AF) plus additional credits resulting from the City's participation in the Ferro Pit Program and credits transferred to the City from PHWA as a result of the Three Party Agreement. The City also has FCGMA credits available as a supply source if needed.
(4) Brine loss is assumed to be 20% of permeate production from desalting operations. Assumes that the City will continue its 2010 blend ratio of groundwater, desalted groundwater, and imported water to maintain product water quality between 600 to 700 TDS.
(5) Based on Table 2-13 UWMP 2010.
(6) Future City groundwater allocations transferred to the City as agricultural lands are developed.
(7) Future City groundwater allocations made available to the City as agricultural users abandon or reduce the use of their wells in exchange for recycled water and/or as a result of groundwater recharge.
(8) GREAT Program recycled water sold to City water customers for municipal and industrial uses, including landscape irrigation.

Table 3 IPR Log Reductions at LVL[1] Recycled Water Retrofit Program City of Oxnard			
Treatment Process	**Cryptosporidium**	**Giardia**	**Virus**
Secondary Treatment (With Sand Filtration[2])	1	2	2
MF	2.7	2.7	0
RO	1.5	1.5	1.5
UV/ H_2O_2	6	6	6
Underground Retention Time	0	0	6
Total	11.2	12.2	15.5
Goal	≥10	≥10	≥12

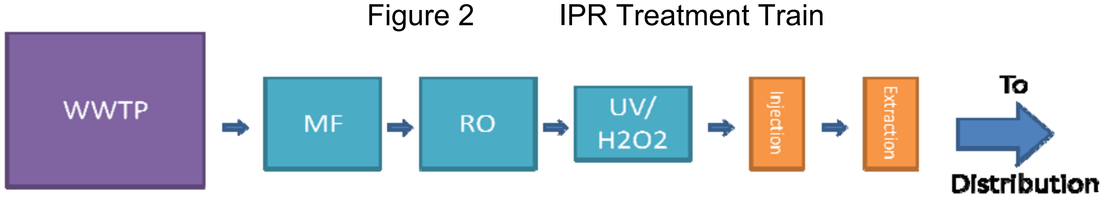
Notes:

(1) Amended Title 22 Engineering Report for the Leo J. Vander Lans Water Treatment Facility Expansion: Alamitos Barrier Recycled Water Project, CDM Smith 2013 for details.

(2) LVL is fed filtered secondary effluent.

For this case study for Oxnard, two alternative treatment scenarios were developed for comparison. The first alternative is the conventional IPR treatment scheme. FAT water produced by the AWPF would be delivered through the existing recycled water distribution system to a proposed injection location. The City of Oxnard's AWPF currently incorporates the "gold standard" of treatment for IPR, also called "fully advanced treatment" or FAT. The AWPF treatment train is MF, RO, and UV/H2O2 as shown in Figure 2. There are notable differences between the LVL facility and the AWPF, as discussed below.

Figure 2 IPR Treatment Train



4.1 Secondary Treatment

The first treatment barrier is the secondary treatment process at the Oxnard Wastewater Treatment Plan (OWTP). Pathogen reduction values for the secondary treatment process were based upon data collected by (Rose et al. 2004) which compared the effectiveness of full-scale biological treatment, filtration, and disinfection for removal and/or inactivation of bacterial and viral indicators, enteric viruses, and protozoan pathogens at six wastewater treatment facilities. The OWTP is most similar to facility "C" analyzed in the report with a secondary treatment process mean cell residence time of 1.6 to 2.7 days. Data presented in (Rose et al. 2004) is summarized in Table 4. The log reduction credits assumed for OWTP are conservatively based upon the lowest value presented for each separate pathogen.

Table 4	Cryptosporidium Log Reductions for Influent through Secondary (Rose et al. 2004) Recycled Water Retrofit Program City of Oxnard		
	Cryptosporidium Oocysts/100 L		
Sample	**Influent**	**Secondary Effluent**	**Log Reduction**
C-1	4.35E+02	1.00E+01	1.64E+00
C-2	8.16E+02	1.00E+01	1.91E+00
C-3	5.60E+03	1.37E+01	2.61E+00
C-4	1.10E+04	6.15E+02	1.25E+00
C-5	4.40E+02	1.28E+01	1.54E+00

Table 5	Giardia Log Reductions for Influent through Secondary (Rose et al. 2004) Recycled Water Retrofit Program City of Oxnard		
Sample	**Influent**	**Secondary Effluent**	**Log Reduction**
C-1	2.00E+04	9.17E+01	2.34E+00
C-2	-	-	-
C-3	2.20E+04	1.00E+01	3.34E+00
C-4	5.90E+05	1.37E+02	3.63E+00
C-5	3.40E+05	9.35E+03	1.56E+00
C-6	3.57E+04	1.01E+03	1.55E+00

Table 6	Virus Log Reductions for Influent through Secondary (Rose et al. 2004) Recycled Water Retrofit Program City of Oxnard		
	Enteric Virus Mpn/100 L		
Sample	**Influent**	**Secondary Effluent**	**Log Reduction**
C1	2.30E+04	3.50E+01	2.82E+00
C2	-	-	-
C3	4.00E+03	2.70E+02	1.17E+00
C4	6.30E+04	9.60E+01	2.82E+00
C5	2.20E+04	2.30E+02	1.98E+00
C6	6.30E+03	2.00E+02	1.50E+00

Thus based on the data presented above the following credits are assumed for secondary treatment at the OWTP: 1.3-log for Cryptosporidium oocysts; 1.6-log removal for Giardia; and 1.2-log removal for virus. Virus removal could potentially be as high as 2-log according to EPA 1986 and Francy et al., 2012. 2-log virus removal was credited for LVL based upon an existing filtration system and based upon turbidity not exceeding an average of 2 NTU within a 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU any time. As the OWTP has no sand filtration, a lower value for virus reduction is appropriate.

4.2 Microfiltration Treatment Credit

The second level of removal would be at the AWPF within the microfiltration membranes. The AWPF currently employs Pall membranes which according to the California Surface Water Treatment Alternative Filtration Technology Summary (2011) would receive 4 log removal for Giardia 4-log removal for Cryptosporidium, and 0.5-log for virus. As mentioned CDPH does not provide log removal credit for reductions less than one. Thus, no virus credit is expected, similar to the LVL permit approval. However, there has been much research into removal of viruses by microfiltration membrane processes which have shown log removal values ranging from zero to 4-log removal (Reardon et al., 2005; Lovins et al., 2002). Additional credits could possibly be credited if a rigorous validation were undertaken.

4.3 Reverse Osmosis Treatment Credit

The third level of reduction is within the RO membranes. There is currently no recognized "direct integrity test" that can be conducted on a daily basis which can demonstrate more than 2-log removal of the target pathogens (electrical conductivity (EC) can detect ~99% removal of pathogens). As such, only 2-log removal is currently credited by CDPH. For the LVL facility, because of increased salt loading due to a third stage RO process, less than 99% removal of EC was anticipated and thus only 1.5 log reduction credit for RO was requested. Research suggests that RO can provide up to 6-log reduction of all pathogens. The missing item for 6-log credit is a reliable method to monitor such a high level of performance. One likely method for such accurate monitoring is the use of a doped anti-scalant (dosed continuously ahead of RO). Such a chemical, as documented by Nalco for their Trasar product, appears sufficiently accurate to attain 4 to 6-log credit from CDPH, once more detailed testing is performed.

4.4 UV/H_2O_2 Treatment Credit

For the existing AWTF UV system, the UV system is sized to remove 1.2-logs of NDMA. The UV dose required to provide this level of photo-oxidation likely exceeds 750 mJ/cm_2 (some literature suggest the dose is ~500 mJ/cm_2). Under the EPA's UV Disinfection Guidance Manual (UVDGM 2006), a UV dose of 186 and 22 mJ/cm_2 is sufficient to attain 4-log disinfection of virus and protozoa, respectively, with the proper inclusion of a validation factor per UVDGM (2006). Thus, a UV dose of >500 mJ/cm_2 is more than sufficient to provide 6-log reduction of all target pathogens.

4.5 Groundwater Treatment Credit

For typical IPR applications implementing injection and extraction from separate locations, a disinfection credit is afforded by CDPH for underground travel time. According to the Draft Regulation for Groundwater Replenishment Reuse (CDPH 2013), for each month of underground retention, the recycled municipal wastewater or recharge water will be credited with 1-log virus reduction. No credit is given for Cryptosporidium or Giardia.

Because these reductions are based on the assumption of underground travel, which is not the case for an Aquifer Storage and Recovery (ASR) type of project, no log reduction credits are assumed for underground retention time as part of the ASR approach to IPR. If the city decides to use percolation ponds or utilize underground travel time, between 2-log to 6-log virus reduction could be credited depending on retention time.

4.5.1 Summary of Treatment Credit

The log reduction credits that can reasonably be approved for Oxnard by CDPH are summarized in Table 7. The existing credits for treatment performance of the Oxnard AWPF are sufficient to meet protozoan targets (Cryptosporidium and Giardia), but insufficient to meet virus criteria. Either additional treatment is required or obtaining increased treatment credit is required to demonstrate an additional 3-logs (2.8-logs to be exact) of virus removal. Four approaches to obtaining additional treatment credit are highlighted in Table 8.

Table 7 IPR Log Reductions
Recycled Water Retrofit Program
City of Oxnard

Treatment Process	Cryptosporidium	Giardia	Virus
Secondary Treatment	1.3[(1)]	1.6[(1)]	1.2[(1,2,3)]
MF	4.0[(4,5)]	4.0[(4,5)]	0[(4,5)]
RO	2.0[(6)]	2.0[(7)]	2.0[(7)]
UV/ H_2O_2	6.0[(8,9)]	6.0[(9)]	6[(10)]
Underground Retention Time	0[(11)]	0[(11)]	0[(11)]
Total	13.3	13.6	9.2
Goal	≥10	≥10	≥12

Notes:
(1) Rose et al, 2004
(2) EPA, 1986 (see Table 2-3).
(3) Francy et al, 2012 (see Table 2)
(4) Reardon et al., 2005
(5) CDPH 2011, based on Pall membranes. Various sources have shown up to 4-log removal may be achievable.
(6) Schäfer et al., 2005; limited by online monitoring of conductivity.
(7) Reardon et al., 2005; limited by online monitoring of conductivity.
(8) Rochelle et al., 2005
(9) EPA 2006[1]
(10) Hijnen et al., 2006
(11) CDPH, 2013

[1] Under the EPA's UV Disinfection Guidance Manual (2006), a UV dose of 186 and 22 mJ/cm^2 is sufficient to attain 4-log disinfection of virus and protozoa, respectively, with the proper inclusion of a validation factor. Thus, a UV dose of >500 mJ/cm^2 is more than sufficient to provide 6-log reduction of all target pathogens.

Table 8 Increased Virus Reduction Measures
Recycled Water Retrofit Program
City of Oxnard

Approach	Potential Increased Virus Reduction Credit	Methods/Costs	Likelihood Of Success
Demonstration Testing of Microfiltration System	1	Virus challenge studies on existing MF membranes, both when new and after extended operation. Cost of testing and reporting to CDPH is ~$75,000.	Low, as virus testing on older membranes often results in low reduction performance.
Demonstration Testing of RO System	4	Use of doped anti-scalants has been shown to prove up to 6-log virus reduction. The Nalco Trasar system would be used to evaluate the performance of the existing RO system. One time cost of testing and reporting to CDPH is ~$60,000.	High, as recent testing at other locations (MWH 2007) has demonstrated that 6-log is attainable.
Chlorination of UV/ H_2O_2 Product Water	4	Batch testing of free chlorination of UV product water, under the assumption that all product water will be stored and chlorinated for a set period of time. One time cost for testing and reporting to CDPH is $40,000	High, as free chlorination is well proven for virus kill.
Conventional Groundwater percolation/ Injection, monitoring, and extraction	2 to 6	Initial thinking on IPR for Oxnard is to utilize an ASR approach to groundwater storage and extraction, which would result in zero disinfection credit. However, use of a conventional surface spreading or injection and subsequent extraction program would receive from 2 to 6 log credit depending upon the underground retention time. Costs for such a program could be extensive, as the infrastructure for spreading/injection, monitoring, and extraction are much more than the ASR approach.	Nearly guaranteed.

4.6 DPR Alternative

The second alternative for potable reuse is the DPR alternative. The existing AWPF FAT process is also used and additional treatment (chlorination) and monitoring is substituted for the environmental buffer (Underground Travel Time). Treatment would be similar to the IPR scheme with an additional storage (decoupling) and monitoring step added in; storage would be such that treated "potable" water would be diverted for 12 hours at a time to one of three tanks. This process would function as follows:

- OWTP effluent is treated by MF and RO (which includes a permeate recarbonation step for corrosion prevention) and UV/H_2O_2. Additional innovative monitoring techniques would be employed for the RO process to further bolster performance confidence (e.g., a tracer chemical that can be measured to a resolution higher than 2-log removal, potentially up to 6-log removal).

- Water flows into one of three storage tanks. The storage tanks are placed after the advanced oxidation process in this case study because the AWPF is already constructed and placing the tanks elsewhere in the treatment train would require large scale hydraulic modifications. The three tanks are (one) each in the following modes. Figure 3 illustrates this process.
  - Filling
    - The influent to the storage tank would be dosed with free chlorine to provide for an additional measure of disinfection and destruction of trace pollutants.
    - The influent water would also be tested using one or more advanced biological monitoring methods.
    - After 12 hours of flow to the filling tank, it would be sealed (it would become the "Holding" tank). The disinfected RO permeate would now be diverted to start filling the previously "Emptying", tank, which is at this point empty.
  - Holding
    - The disinfected RO permeate is then stored for a set period of time to allow results from the last sample taken during filling to be processed; 12 hours is proposed here based on information provided by biological monitoring companies on analysis time.
    - Upon successful completion of the advanced monitoring, water would be released from the full tank (it would become the "Emptying" tank).
  - Emptying
    - While one tank is filling and another tank is testing, a third tank is emptying to the distribution system. This is predicated on the assumption that the monitoring results on the tank were favorable.
    - The AOP purified water exits and would be conveyed to the Oxnard Hueneme potable water transmission main for distribution and use.

Figure 3 DPR Treatment Train

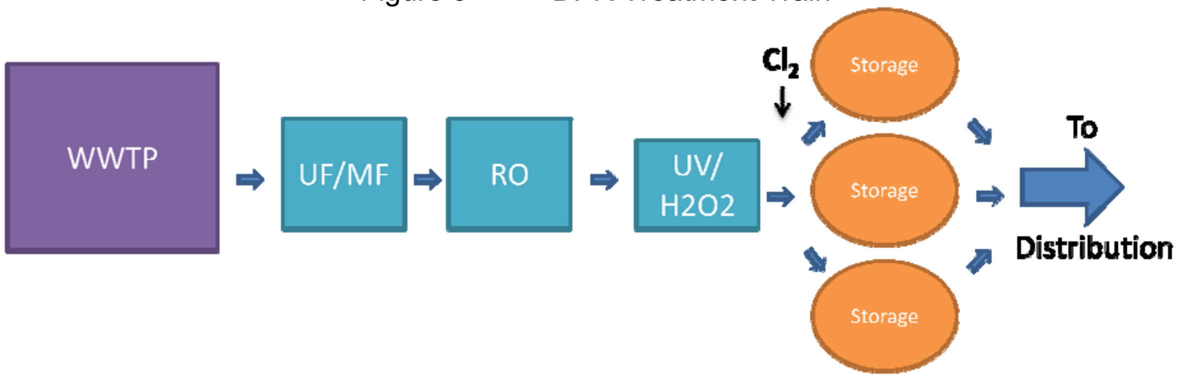
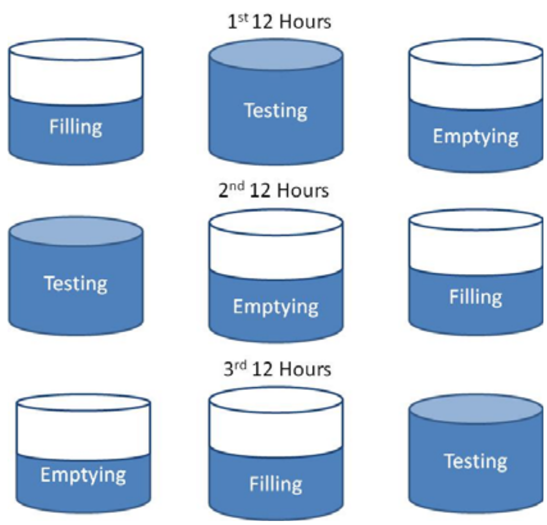


Figure 4 Engineered Storage Process



As discussed in Section 6.0 of this report, additional innovative monitoring techniques are proposed for the RO process to further verify process performance. The associated pathogen log reductions for the DPR alternative are summarized in Table 9.

5.0 POTENTIAL FOR DPR AS PART OF GREAT PROGRAM (APPROACH AND LAYOUT)

According to discussions with the City it is anticipated that most of the 7,000 AFY produced by the AWPF would be used for tertiary use and any remaining purified water would be available for either DPR or IPR. Additional water would be available for DPR if the AWPF is expanded to 14,000 AFY capacity. This alternative is analyzed in Section 9.0.

Irrigation demands vary throughout the year with substantially lower demand during the winter months. During the winter months, the AWPF would continue to operate at full capacity creating the potential for additional available supplies for the City's potable water supply. The final distribution of GREAT water for agricultural and direct potable reuse would be dependent upon agricultural demand and agreements with current providers of potable water including UWCD and CMWD.

Table 9 DPR Log Reductions
Recycled Water Retrofit Program
City of Oxnard

Treatment Process	*Cryptosporidium*	*Giardia*	Virus
Secondary	1.3(1)	1.6(1)	1.2(1,2,3)
MF	4.0(4,5)	4.0(4,5)	0(4,5)
RO	2.0(6)	2.0(7)	2.0(7)
UV/ H_2O_2	6.0(8,9)	6.0(9)	6(9,10)
Chlorination	0	1.0(11)	4.0(11)
Total	13.3	15.0	13.2
Goal	≥10	≥10	≥12

Notes:
(1) Rose et al, 2004
(2) EPA, 1986 (see Table 2-3).
(3) Francy et al, 2012 (see Table 2).
(4) Reardon et al., 2005
(5) CDPH 2011, based on Pall membranes. Various sources have shown up to 4-log removal may be achievable.
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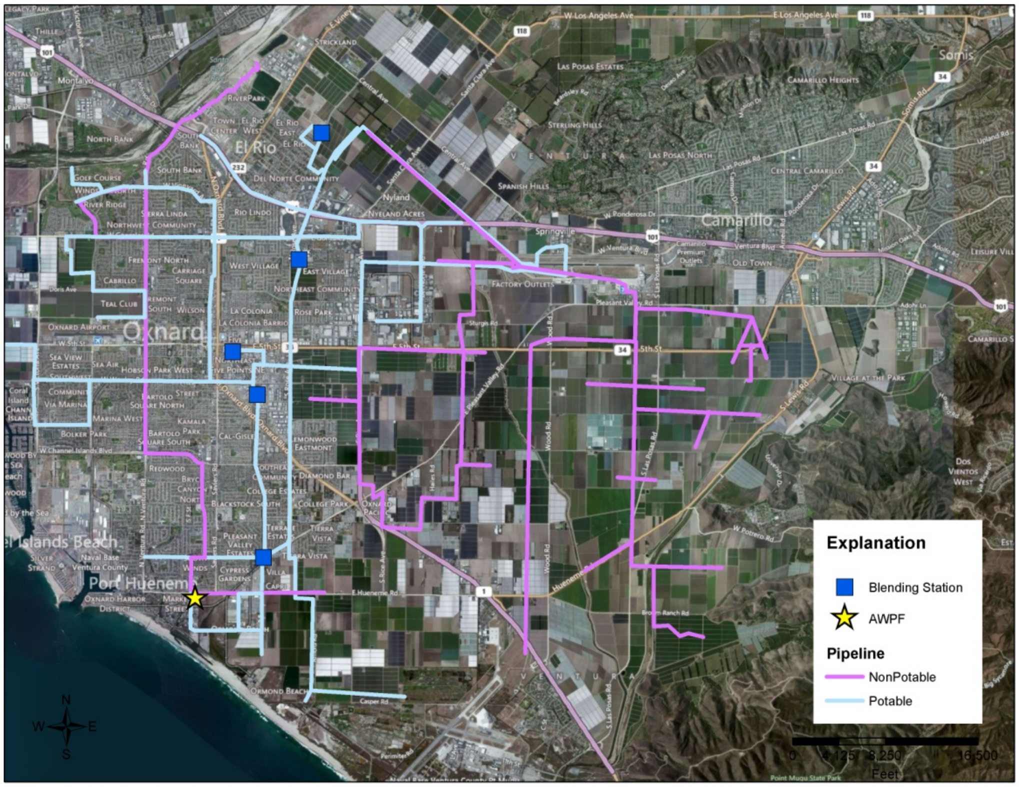
(8) Rochelle et al., 2005
(9) EPA 2006[2]
(10) Hijnen et al., 2006.
(11) EPA 1989

DPR water from the AWPF could potentially be distributed by the Oxnard-Hueneme (O-H) pipeline system which is used to convey groundwater extracted from the Oxnard Forebay to the City, the Port Hueneme Water Agency, and other small users. The existing infrastructure consists of wells at the El Rio Spreading Grounds, a groundwater collection and treatment system, a booster pump station, and transmission pipelines. A figure of the existing distribution system is provided below (Figure 5). Existing distribution lines have been categorized as potable or non-potable. The non-potable distribution lines include phase 1 of the Oxnard recycled water pipeline as well as the Pumping-Trough Pipeline (PTP) and Pleasant Valley Pipeline all of which could potentially distribute water from the GREAT program in the future. Phase 2 and Phase 3 of the Oxnard recycled water pipeline

[2] Under the EPA's UV Disinfection Guidance Manual (2006), a UV dose of 186 and 22 mJ/cm^2 is sufficient to attain 4-log disinfection of virus and protozoa, respectively, with the proper inclusion of a validation factor. Thus, a UV dose of >500 mJ/cm^2 is more than sufficient to provide 6-log reduction of all target pathogens.

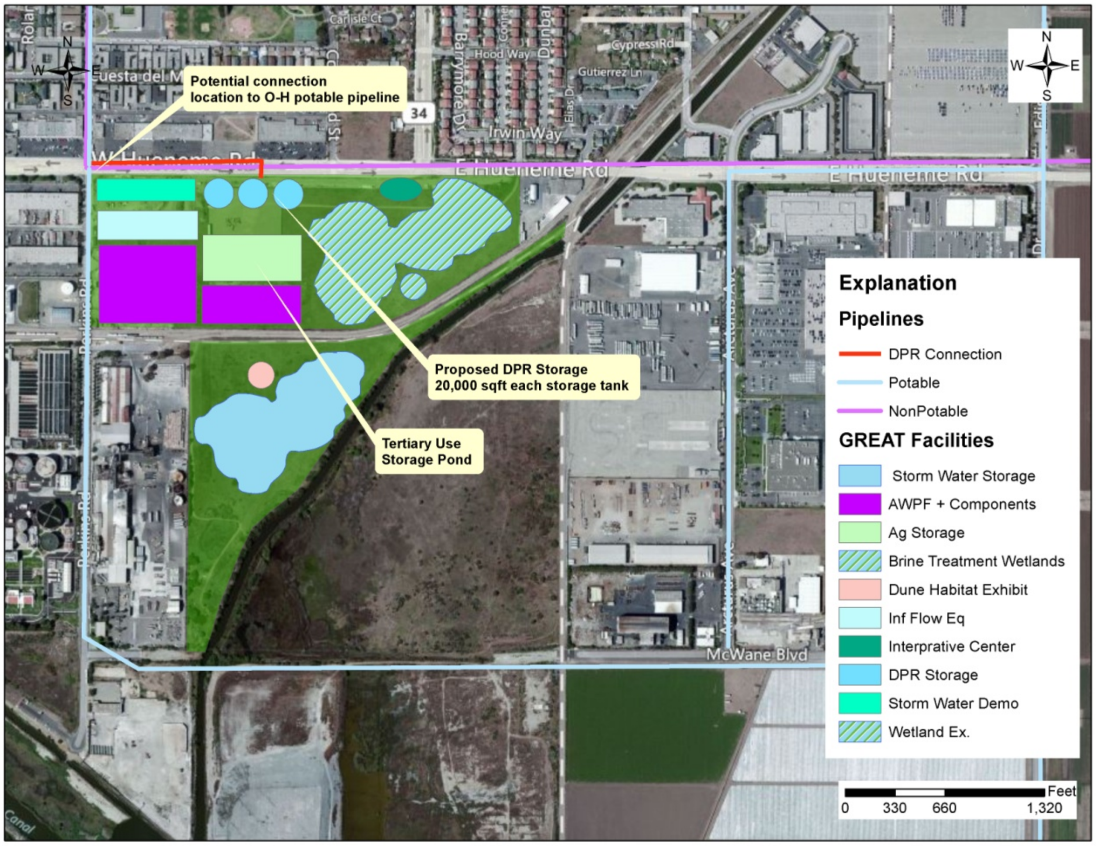
have not been added, as future IPR or DPR could possibly limit the expansion of the tertiary recycled water program.

Figure 5 Existing Potable Recycled Water Distribution



Assuming the transmission line at the anticipated point of connection (adjacent to the AWPF) is at least 16 inches in diameter and existing potable distribution system would be able to handle the maximum flows (6.25 mgd) from the AWPF meeting the City's requirements for maximum velocity and maximum allowable headloss for potable water (15 ft/sec and 15 ft/1,000 ft respectively).This would allow the City flexibility in distributing varying flows depending on availability. An alternative point of connection would be at the intersection of Rose Avenue and Hueneme Road where the transmission main diameter is at least 18 inches in diameter. Further hydraulic modeling would be needed to verify and optimize the use of existing infrastructure to distribute a maximum of 6.25 mgd of treated water depending on the City's desired adjustment of existing supply sources. Figure 6 illustrates an approximate footprint for the DPR scenario as part of the existing and planned GREAT infrastructure including the AWPF, associated educational components, brine treatment wetlands and storm water storage. As described above an additional three storage tanks will need to be added in order to allow for additional time for monitoring between the RO phase and UV/H_2O_2 before the water enters the distribution system. Storage tank sizing will ultimately depend upon final flows diverted from the AWPF for DPR. Assuming a maximum flow of 6.25 mgd it is anticipated that each storage tank would have a 3.125 million gallons (MG) capacity and would each occupy approximately 20,000 ft^2 . Assuming a minimum flow of 500 AFY for DPR, storage tank capacity would equal 0.2 MG per tank occupying approximately 1,500 ft^2 each. If sizing for build-out, tanks would be sized for 6.25 MG capacity.

Figure 6 Footprint of Existing GREAT Facilities with DPR



An additional storage basin is needed for agricultural use, taking into account peak demand, enabling farmers' access to water at various times of day depending on irrigation demands. The size of a storage basin for recycled water would depend upon these demands. According to the 2010 RWMP peak hour demand for recycled water would occur between 10 pm and 6 am and could exceed 4963 gpm (7 mgd). At this rate for 8 hours a total of 2.4 MG would need to be supplied. Assuming that at times of peak demand all water produced by the AWPF could go to agricultural use, approximately 2.5 MG of storage would provide approximately one day's worth of storage to supply this peak demand. An additional 45,000 ft^2 storage basin (8 ft depth) would be needed for the 2.5 MG pond. Increased peak tertiary flows would necessitate additional storage.

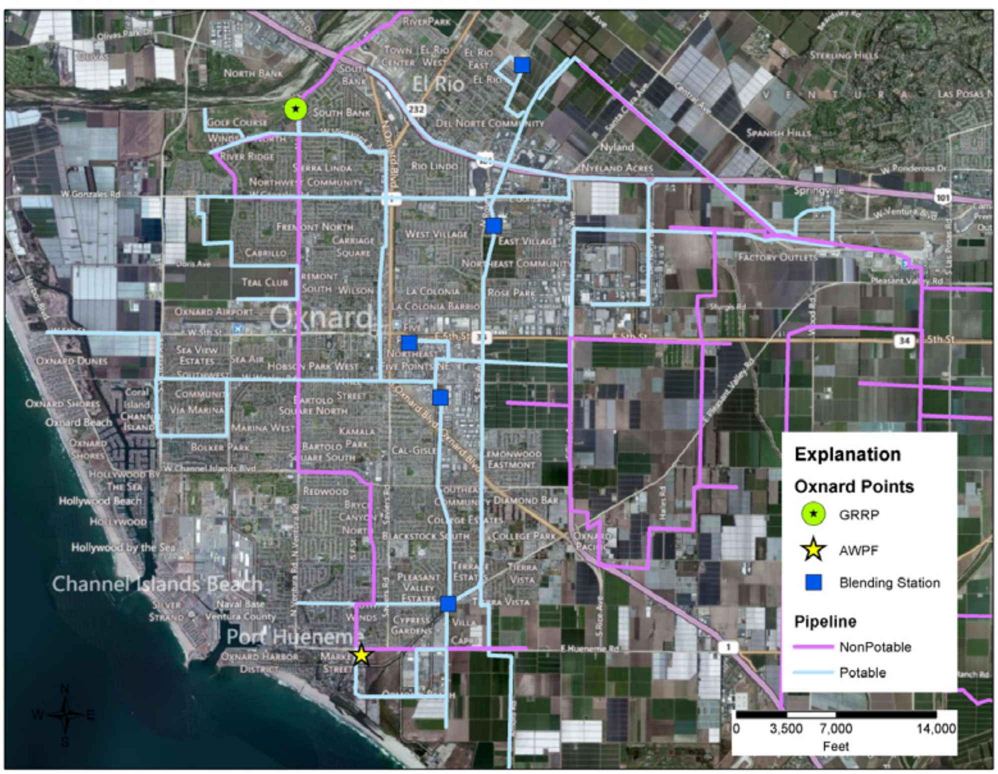
5.1 Conventional Indirect Potable Reuse

A preliminary hydrogeological study was completed by Hopkins Groundwater Consultants, Inc. (Hopkins) in June 2013 to evaluate the feasibility of a Groundwater Replenishment Reuse Project (GRRP) using highly treated (purified) recycled water. The following information is based on the March 2013 draft report.

The current thinking on IPR is to utilize the groundwater basin for Aquifer Storage and Recovery (ASR), which is different than the other ongoing groundwater recharge IPR projects in California. Under this alternative FAT water produced by the GREAT program would flow through the existing recycled water pipeline and would be injected into the Lower Aquifer System (LAS) of the Oxnard Plain Basin. The aquifer is such that one aquifer zone can be filled without affecting wells that tap other aquifer zones. The significance of the confined conditions that result from this discretely layered aquifer system (LAS) is that wells located in close proximity (50 feet apart) but producing from different aquifer layers, do not have hydraulic connectivity to each other. The benefit of this natural condition to the GRRP is that multiple wells can be operated on the same site with a rotating schedule which allows discrete recharge, storage (retention time), and recovery from separate aquifer zones.

The GRRP ASR well location identified for recharge is identified in Figure 7 below. This location serves to distribute City groundwater facilities around the periphery of the Oxnard Forebay Basin. The area selected for installation and operation of the GRRP ASR wells is owned by the City and has an existing well constructed in the UAS (City Well No. 18) which was historically utilized for golf course irrigation. Blending stations shown are used to mix (blend) lower quality groundwater pumped from adjacent wells with imported water or desalted water.

Figure 7 GRRP Program



Injection into the LAS in the Oxnard Plain Basin would require one well initially that would likely be capable of a sustained injection rate of approximately 1,600 AFY (2000 gpm) based on aquifer properties. For initial GRRP operations, the City proposes to recharge each well for approximately 3 to 6 months with FATW followed by approximately 5 days of potable water injection to push the recycled water a radial distance of approximately 100 to 200 feet away from the ASR well. Upon completion of the recharge cycle, the City will initially allow a 5 to 12-month response time where the FATW will continue to move through the aquifer under the influence of the regional groundwater gradient (which ever direction that may be) and receive soil aquifer treatment throughout the retention time. This will enable the City to achieve the required 3-log reduction credit for virus that is not achieved through FAT treatment at the AWPF. The stored water will be recovered over an approximate 2 to 4- month recovery period. While the City continues to work on increasing the virus log reduction, response time is expected to decrease over time and match the minimum CDPH required response time. Additional wells can be added to accommodate greater recharge and storage volumes or achieve higher retention time, as required. Under the proposed ASR program, injection and extraction would occur from the same well. Injection and extraction would alternate between wells throughout the year in such a way that would enable storage and extraction throughout the year. Figure 8 below provides a schematic of the proposed delineation of wells in isolated aquifer zones.

Figure 8 Discrete Aquifer Zone Delineation

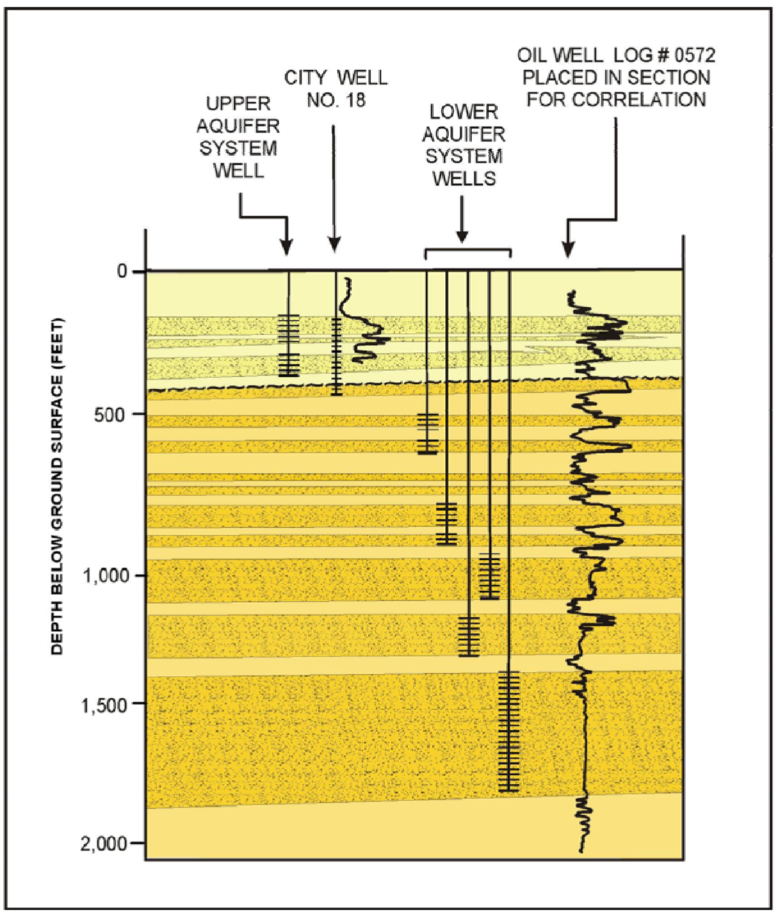


Figure from Hopkins, 2013.

The City proposes to recharge each well for approximately 3 to 4 months, allow 2 to 4 months retention time, and a 2 to 4-month recovery period. Additional wells can be added to accommodate greater recharge and storage volumes or achieve higher retention time as required.

The LAS is generally a calcium sulfate chemical character of fair to poor quality with total dissolved solids (TDS) concentrations in the range of 900 to 1,300 milligrams per liter (mg/l) and sulfate concentrations that range from 400 to 650 mg/l. According to the Hopkins 2013 draft report, these historical data indicate that the storage of the proposed recycled water will improve the quality of groundwater in LAS (a beneficial impact) and that injection water chemistry can likely be controlled (buffered) to be compatible with native groundwater and avoid significant degradation. After extraction the potable water would be distributed through existing infrastructure available in the vicinity of the proposed well field.

5.2 Failure Scenario

In the event of a treatment system malfunction (spike in water quality, reduced level of tracer removal, etc.) that triggers the advanced monitoring system alarm, the treated water would have to be diverted from entering the potable water system. A number of alternatives exist:

- Recirculation of water back to the OWTP
- Release of water through the existing outfall at OWTP
- Diversion of water from DPR storage tanks to tertiary uses or storage pond

At this stage of treatment, log-reduction rates would still be extensive and this water is of adequate quality for use as a raw water source or as a recycled water source. Filtered water turbidity is typically well below 1.0 NTU and is often below 0.1 NTU. Reverse osmosis, can achieve turbidity values that approach those of pure water, in the range of 0.010–0.015 NTU. Water could then be either directly delivered into the recycled water system from the storage tanks.

For the IPR scenario, as mentioned previously, water would be distributed through an existing recycled water pipeline and would meet tertiary requirements set by CDPH as described above. In the event of failure, water could be continued to be used for agriculture but would not be injected for storage until the failure was remedied. A minimum response time would have to be set for “approved” water to flow in the pipeline before resumption of injection.

6.0 MONITORING

Facilities that utilize advanced treatment for IPR have detailed water quality monitoring plans, including testing and analysis of the treatment process and of the water as it migrates from the point of application to the point of use. This discussion relates to the additional monitoring recommended for DPR projects. These proposed monitoring tools are intended to provide a higher degree of confidence in process performance.

7.0 MEMBRANE INTEGRITY

The membranes that are typically used in advanced treatment provide for a large amount of the total performance of the advanced treatment system. Accordingly, the ability to continuously and accurately track the membrane performance is desired.

In 2005, EPA published the Membrane Filtration Guidance Manual (MFGM) (EPA 2005) which put forth the following requirements to verify integrity for an RO and Nano Filtration (NF) Membrane System (as per Section 1.3 of the MFGM):

1. Removal efficiency must be established through product-specific challenge test and direct integrity testing.
2. Continuous indirect integrity testing. The MFGM states that turbidity and particle counting are acceptable continuous integrity tests for MF/UF membranes (Sections 5.2 and 5.3) and conductivity is acceptable for RO/NF membranes (Section 5.4).
3. Daily direct integrity testing using a method sensitive to the log removal rating that the system is credited for.

Regarding MF/UF, methods for direct integrity testing include, air pressure decay or hold tests, diffusive airflow monitoring, sonic testing, and bubble point tests. The most commonly applied direct integrity test method is the pressure decay test, which is a variation of the diffusion test, in which the leakage of air from a closed volume at known pressure through a wetted membrane is measured and converted to an equivalent water leakage rate. The air leaks only through pathways representing large pore sizes, since the smaller pores remain wetted due to capillary forces. By selecting the appropriate test pressure, typically between 10–20 psig, it is possible to measure the leak rate through only those pathways large enough to cause transmission of pathogenic protozoa.

One disadvantage of the direct integrity monitoring is the need to perform the tests offline and the consequent interruption of normal operation. Another limitation of the pressure-driven integrity monitoring tests is the minimal detectable pore size that can be detected within the operating range of the membranes being tested. Typical pressure for conducting pressure decay or diffusive airflow tests is in the range of 10-20 psi, which would be able to detect defects on the order of 2-3 μm, approximately the size of protozoan cysts (Lozier et al., 2003). The required test pressure for a virus-sized resolution of 0.01 μm is over 4,000 psi, a value far in excess of what any current, commercially available water treatment membrane could withstand without rupturing (USEPA, 2005).

Regarding RO and NF, there is currently no recognized “direct integrity test” that can be conducted on a daily basis which can demonstrate more than 2-log removal of the target pathogens (electrical conductivity (EC) can detect a 99% removal of pathogens). Improved monitoring techniques are needed and should be sensitive enough to pick up small but significant changes and trends in treatment performance that could have a significant impact on the safety of the finished water. An ideal monitoring system would be able to continuously detect up to 6-log reduction of a trace particle that is equal or smaller than the approximate virus size of 0.01 µm. This method could be used to test RO and NF as well as MF/UF systems.

There are a number of products on the market that could provide useful assurances for membrane integrity. Two possible examples of technologies that could provide membrane integrity verification would be the 3D Trasar® Technology by Nalco and Mem Shield by MINT. Trasar is an inert molecular tracer that can be detected down to concentrations of parts per trillion by fluorescence. It is currently used as part of a continuous online monitoring method for antiscalant used in RO facilities. The Trasar molecule is approximately 610 Da, which is approximately 4 orders of magnitude smaller than the average virus. The Trasar molecule alone (or blended in with Antiscalants) has NSF Std 60 approval for use in potable water in front of an RO system. Trasar was tested in 2007 as part of the City of Sand Diego Advanced Water Treatment Research Studies (MWH, 2007), where results showed a log removal value of greater than 6 log. Further testing would be required to gain CDPH confidence in this technology. The figure below illustrates the potential value of the Trasar or similar type of product.

MEM-SHIELD (http://www.mintmembranes.com/the-technology/) is an indirect integrity testing method for low-pressure membrane systems such as MF/UF, which can then be used to trigger a direct integrity test. The direct integrity test is based on correlation to the MFGM log removal values (LRV) calculations. Direct integrity testing based on correlation has not been accepted yet by regulators in the US. The principle of operation is based on measuring the differential pressure across a membrane that intercepts a portion of the filtrate from the MF/UF modules relative to the differential pressure across a valve. The system is able to detect breaches of up to 0.001% broken fibers with a resolution of 3 µm. MEM-SHIELD claims to be able to reliably differentiate between 3 log removal and 4 log removal of protozoa sized pathogens (> 3 µm) with further work being done to differentiate between log 4 removal and log 5 removal. The product is currently being tested at the Bedok Newater Factory in Singapore. Existing monitoring methods that have been found or inferred to be the most sensitive and reliable include methods such as the pressure decay test, microbial challenge test and high-sensitivity (0.5 µm or 0.05 µm) particle counters have been found capable of detecting as low as 1 cut fiber in a full-scale rack. A 2-µm particle counter has been shown able to detect between 1 to 0.001% cut fibers in a full-scale UF rack, depending on the feed water turbidity (Sethi et al, 2004).

8.0 PATHOGEN MONITORING

Continuous and accurate online monitoring of membrane performance should be complimented with rapid response water quality analysis. Ideally, an online monitor would be able to continuously monitor for bacteria, protozoa, and virus. There are a number of products currently on the market that can continuously monitor for bacteria sized pathogens: ZAPS http://www.zapstechnologies.com/ is an optical, online instrument for real time multi-parameter water quality monitoring which can detect E. coli among other water quality parameters. Biosentry http://www.jmar.com/wordpress/ uses optical spectroscopy to identify pathogens between 0.5 µm to 15 µm. The approximate size of Giardia (6-10 µm) and Cryptosporidium (3-7 µm) would fall in under this range. Viruses are much smaller and range between 0.01 µm to 0.1 µm. Biosentry is based on light scatter from specific pathogens. RMS--W™ from Instant Bioscan http://www.ibioscan.com/ utilizes auto-fluorescence from certain metabolites and other proteins in the microbial cells and uses this fluorescence as biological marker for differentiating microbes from inert particles., but can only detect presence/absence of bacteria sized pathogens greater than 0.3 µm.

Current online detection methods are unable to detect virus-sized pathogens at levels of less than 1 CFU/1 ml without DNA enrichment or concentration, which takes time Other Presence/Absence tests could provide a “red flag” however, results could be skewed due non-pathogenic microbial growth on membranes. The ZAPS Technologies product LiquID Station is currently being piloted in San Diego, CA and could possibly be sensitive enough to detect virus though this has not been demonstrated yet.

It is important to note that the time for testing and reporting of results is critical. Large engineered storage systems are costly and have a significant footprint. As methods are developed that can produce results in shorter amounts of time, costs will decrease accordingly. The currently proposed scheme is to utilize 12 hours of storage to allow for rapid response water quality monitoring. One method that could possibly achieve the sensitivities needed in under 12 hours is real time quantitative polymerase chain reaction (qPCR). This method has been widely used to detect viruses in environmental waters. A number of these uses are referenced in EPA Method 1615, 2010. This molecular procedure has the ability to obtain results in a very short time and is more rapid than cell culture but cannot distinguish between infectious and inactivated viruses. Research is ongoing on several promising approaches to detect infectious viruses (Reynolds, et al. 1996, Parshionikar, et al. 2010). However, qPCR is still a useful public health tool in spite of these problems. Because there is a strong relationship between indicator measurements by qPCR and health effects in recreational waters (Wade, et al. 2010), the EPA is considering using qPCR to set new criteria for monitoring recreational beaches (EPA Method 1615, 2010).

In theory, no virus would be able to penetrate the RO membrane. The advanced monitoring methods proposed above are proposed as an additional level of safety and would be employed before the UV and advanced oxidation process, which would provide an additional level of safety. As such, even in the event of a membrane malfunction, anticipated virus concentrations would be extremely small (on the order of 1 Colony Forming Unit (CFU)/ 100 mL). Under these conditions, purified water samples would have to be concentrated or enriched in order for there to be enough DNA to run a qPCR analysis. Concentration steps would possibly involve a bench scale RO system, running continuously with the RO brine being tested periodically by qPCR for virus and bacteria. The obvious drawback to this concentration method is the possibility of membrane performance problems with the concentration system, which would reduce the ability to capture and subsequently detect pathogens in the main treatment stream. Additional research is needed to identify the current operational constraints of existing methods and to develop a protocol for a method using qPCR or other molecular techniques and perhaps combine these molecular techniques with one of the online monitoring techniques mentioned above.

With regard to trace organic contaminant monitoring, an accurate method has been developed for the trace analysis of 15 pharmaceuticals, four metabolites of pharmaceuticals, three potential endocrine disruptors, and one personal care product in various waters (Vanderford and Snyder, 2006). The method reporting limits for all compounds were between 0.25 and 1.0 ng/L, based on 500 mL of sample extracted and a final extract volume of 500 µL. The method is based on solid phase extraction (SPE) and liquid chromatography/tandem mass spectrometry (LC-MS/MS), using electrospray ionization (ESI) in both positive and negative modes. This method would be able to provide results in approximately 24 hours. Daily monitoring of trace pollutants (or surrogates) would provide further confidence in advanced treatment performance.

Table 10 summarizes a number of pathogen testing techniques currently available or under development:

Table 10 Pathogen Monitoring Methods
Recycled Water Retrofit Program
City of Oxnard

Product	Company/Research	Description	Sensitivity	Pathogens Detected	Analysis Time	Cost	Ease of Use	Market Readiness
MassCode PCR	Widely used in research	Endpoint amplification of a suite of indicators or pathogens. This method is good if for high throughput applications or for more than 10 types of pathogens and high level of sampling.	100-500 DNA copies (would require an enrichment step)	Can be used for Bacteria, Protozoa, and Virus. Specific probe for each different pathogen.	Could potentially have results in under 6 hours	NA	Manual, but could possibly automate	On Market. Need to develop protocol specific to low concentrations.
QPCR	Widely used in research	Amplified DNA is detected as the reaction progresses in real time. Cannot distinguish between infectious and inactivated viruses QPCR is much more sensitive than PCR, and more affordable.	Can detect down to 1 copy of DNA but would need a concentration or enrichment step.	Can be used for Bacteria, Protozoa, and Virus. Specific probe for each different pathogen.	Could potentially have results in under 6 hours	NA	Manual, but could possibly automate	On Market. Need to develop protocol specific to low concentrations.
Biosentry	Jmar	Microbial activity detection using light scatter. The concept is that specific pathogens (or microorganisms) scatter light in repeatable ways. Key here is that the organisms must be dispersed and wastewater particulates do not interfere. Should be acceptable for RO permeate. 3 channels of size and shape to determine biologicals plus unknown channel.	All Microorganisms and Particles are Detected from 0.5 microns to 15 microns in size. Previous calibration of the BioSentry showed a sensitivity of 1 CPM per 1.2 CFU per mL	Rod shaped bacteria (*E.coli*), endospores, protozoan cysts	Measurement each minute	NA	Continuous real time monitoring.	On market
Endetect -TECTA- B16	Tecta Automated Rapid Microbial Detection Systems	Based on enzymatic reaction of *E.coli* growth in water. Technology assesses growth through continuous monitoring using an enzyme detection algorithm. This increases the sensitivity of the instrument and it is now quicker to detect low enzyme concentrations over the general background noise. This is particularly helpful when there are low levels of bacteria concentrations or where the bacteria are stressed and slow at producing the required detection enzymes. Similar to IDEXX.	Dynamic range of <1 to >10 CFU in 100 ml without requirement for sample dilution. Needs an additional step for enrichment, makes it 18 hrs.	E.Coli and Coliform	18 hrs	$20,000 + $525/box of 48 tests	Grab sample. Don't need lab	On market
Anti-Body Based Bio Sensor	Dr. Alocilja, University of Michigan	Antibody based bio-sensor. Can change the antibody to any specific target	1 CFU /1 ML. Would need an additional enrichment step to get down to 1 CFU /100 ML	Specific antibody can be developed for target pathogen	18 hrs w/enrichment. 50 min for concentrations of 5-10CFU/1ML	NA	Manual. Could be automated	Bench scale currently
DNA Based Bio Sensor	Dr. Alocilja, University of Michigan	DNA based biosensor. Targets pathogen specific DNA target. Detection achieved electrochemically by measuring the Redox potential of attached electrically active magnetic nanoparticles	Has been able to detect redox signal of the nanoparticles as low as 0.01 ng/ul	In development. So far for *Bacillus anthracis* and *Salmonella enteritidis*	Under development	NA	Manual. Could be automated	Bench scale currently
RMS-W™	Instant BioScan	Continuous presence/non-presence monitoring. Monitors for certain particle sizes. Cannot speciate for different microbes. Works on a Mie Scatter for particle sizing using photodiode and fluorescence emission for bio detection using PMT. Flow rate of 100 mL/min.	Can detect down to 0.3um. Min resolution needed is 1 bio count	Not pathogen specific	Online/instant	$39,900 or Lease $2,500/month	Constant Online monitoring	On Market
LiquID Station (Multi-Frequency optical measurement)	Zaps Technologies	An optical, online instrument for real time multi-parameter water quality monitoring. Can detect multiple parameters using "hyperspectral" detection methodology. Also uses a hybrid spectrometer, which allows the system to monitor absorbance, fluorescence, and reflectance on the same optical platform.	BOD, cBOD, COD 1 to 10,000 mg/l, *Ecoli* ~1 CFU/100ml TOX 10mg/l NO3 0.05 – 500 mg-N/l	*E.coli*, BOD, cBOD, COD, NO3, TOC, TSS, TOX (disinfection byproducts)	Online/instant	$65,000 + minimal O&M	Constant Online monitoring	On Market.
Bactiquant	Mycometer	BactiQuant®water is based on detection of a hydrolytic enzyme activity by use of fluorescence technology. Presence/Non presence only.	Sensitivity can be adjusted. Can detect down to 1 CFU/100ml but would need large sample volume (2 L).	Multiple Bacteria: E.Coli, Athrobacter, Bacillus cereus, Pseudomonas, Rhodobacter. Both gram positive and gram negative	2 hours	$7500 + $18 per test	Manual. Minimal human intervention needed	On Market.

* NA – Not Available. Costs were either not available or more information is needed costs of developing technology.

9.0 COSTS

A summary of preliminary costs estimated for the two supply alternatives presented above is presented in Table 11. To compare the DPR and IPR alternatives directly, the DPR cost estimate has been developed using the cost estimates and methods of calculation provided in the *Ground Water Recovery Enhancement (GREAT) Program Update* (June 21, 2012).

Table 11 Cost Summary
Recycled Water Retrofit Program
City of Oxnard

	Yield	Total Capital Cost	Annual O&M(1)	Annual Cost ($/AFY)	Annual Cost ($/1000 gal)
	7,000 AFY Scenario				
DPR	7,000	$130.7M	$3.8M	$1,700	$5.20
IPR	7,000	$133.7M	$3.7M	$1,700	$5.50
	14,000 AFY Scenario				
DPR	14,000	$173.9M	$7.0M	$1,300	$4.00
IPR	14,000	$171.5M	$7.2M	$1,300	$4.00

Notes:
(1) Value represents adjustment for LRP program and grant funds.
(2) Costs do no include wetlands for concentrate treatment.
(3) Costs include sunk costs for Phase 1 of AWPF capital investment ($109M) and additional RW piping.

In addition to a comparison of potential IPR versus DPR costs, two different levels of yield have been compared, 7,000 AFY and 14,000 AFY. The 14,000 AFY option would build upon infrastructure constructed for Phase 1. As such, storage tanks and conveyance piping is sized for a build-out capacity of 14,000 AFY. The cost associated with increased yield to 14,000 AFY is based upon the following:

- Addition of two additional RO skids of 3.125 mgd to the AWPF
- Flow equalization basin prior to the MF membranes
- Additional chlorination facility
- Additional wells for IPR
- Additional Storage for DPR

For the 7,000 AFY scenario it is assumed that the majority of purified water will go to tertiary use with a minimum amount going to either DPR or IPR (approximately 500 AF). The 14,000 AFY scenario assumes larger volumes going to either IPR or DPR (7,000 AFY) scenarios increasing associated storage cost and well costs for the separate approaches.

The costs for both yield scenarios take in to account all costs associated with completion of Phase 1 of the GREAT program as well as previous expenditures. Additional expansion of the Regional Desalter system and associated components have not been applied to either the DPR or IPR scenarios under comparison. It is assumed that in the 14,000 AFY scenario the amount of purified water available through either DPR or IPR would be sufficient to replace additional groundwater credits provided by the use of recycled water by agricultural users. Concentrate treatment and disposal as well as storm water storage have not been addressed as part of this case study and as such have not been included in the cost estimate.

Costs include infrastructure costs (AWPF, conveyance pipelines, wells, storage) as well as operation and maintenance (O&M) costs, including that for advanced monitoring. The total implementation cost for both alternatives includes all capital costs, construction and engineering contingencies, however do not include costs associated with environmental documentation. All costs are in 2012 dollars.

The total annual cost is determined by calculating the annual amortization of the capital cost for the treatment plant at 5 percent interest over 30 years and adding it to the annual O&M cost. The total annual cost is then divided by the annual production in acre-feet (7,000 AF and 14,000 AF) to determine a cost per acre-foot.

The costs presented above are for the general information of the City, for comparison of alternatives. Detailed cost estimates for the above options are presented in the Appendix of this report. Before developing a final budget and financing for the preferred alternative, it is recommended that a preliminary engineering report be prepared, investigating in greater detail site-specific conditions that may affect costs.

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APPENDIX – DETAILED COST ESTIMATES

DPR Treatment Options Oxnard 6.25 mgd DPR option City of Oxnard		
Project Element		**Cost Estimate**
Completed or funded FAT related costs		$109,009,379
RW Pipeline		$15,296,000
Backup Power		$2,000,000
Ag Storage		$280,000
DPR Storage (3 x 0.2 mgd)		$510,000
Pipeline for Connnection		$450,000
Subtotal (New Components Only)		**$3,240,000**
Total		**$127,550,000**
Construction Contingency	30.00%	$972,000
Subtotal		$4,212,000
General Contractor Overhead+Profit	10.00%	$421,200
Subtotal		$4,633,200
Sales Tax (7.25% of 50% of Total Cost)	7%	$305,370
Total Capital Cost + (30% Contingency)		**$4,940,000**
Engineering	30%	$1,482,000
Land Acquisition	0	$0
Total Estimated Project Capital Cost (New)		**$6,430,000**
Total Estimated Project Capital Cost (New + Existing)		**$130,735,379**
Annualized Capital Cost		**$8,504,524**
O & M Pump Station + Pipeline	2.50%	$443,650
O & M Treatment (FAT)		$3,816,197
O&M Storage	2.00%	$15,800
Advanced Monitoring		$100,000
LRP Credit (2,310 AF)		-$577,500
Total O&M		**$3,800,000**
Total Annualized Cost		**$12,310,000**
Annual Yield AF		**7000**
Unit Cost ($/1000gal)		**$5.50**
Unit Cost ($/AF)		**$1,800**

Notes:

Rate of 5% assumed over 30 year life

DPR Treatment Options Oxnard 6.25 mgd IPR option City of Oxnard		
Project Element		**Cost Estimate**
Completed or funded FAT related costs		$109,009,379
RW Pipeline		$15,296,000
Backup Power		$2,000,000
Ag Storage		$280,000
GRRP ASR Wells + Monitoring Wells		$2,000,000
Pipeline for Connnection		$450,000
Subtotal (New Components Only)		**$4,730,000**
Total		**$129,035,379**
Construction Contingency	30.00%	$1,419,000
Subtotal		$6,149,000
General Contractor Overhead+Profit	10.00%	$614,900
Subtotal		$6,763,900
Sales Tax (7.25% of 50% of Total Cost)	7%	$445,803
Total Capital Cost + (30% Contingency) (New Only)		**$7,210,000**
Engineering	30%	$2,163,000
Land Acquisition	0	$0
Total Estimated Project Capital Cost (New)		**$9,380,000**
Total Estimated Project Capital Cost (New + Existing)		**$133,685,379**
Annualized Capital Cost		**$8,696,426**
O & M Pump Station + Pipeline+ Wells	2.50%	$493,650
O & M Treatment (FAT)		$3,816,197
O&M Storage	2.00%	$5,600
LRP Credit (2,310 AF)		-$577,500
Total O&M		**$3,740,000**
Total Annualized Cost		**$12,440,000**
Annual Yield AF		**7000**
Unit Cost ($/1000gal)		**$5.50**
Unit Cost ($/AF)		**$1,800**
Notes: Rate of 5% assumed over 30 year life		

DPR Treatment Options Oxnard 12.5 mgd DPR option City of Oxnard		
Project Element		**Cost Estimate**
Backup Power		$0
Ag Storage		$0
AWPF Expansion		$19,162,152
DPR Storage (3 x 4.5 mgd)		$8,400,000
Pipeline for Connnection		$0
Total		**$27,570,000**
Construction Contingency	0.00%	$0
Subtotal		$27,570,000
General Contractor Overhead+Profit	0.00%	$0
Subtotal		$27,570,000
Sales Tax (7.25% of 50% of Total Cost)	0%	$0
Total Capital Cost + (30% Contingency)		**$27,570,000**
Engineering	0%	$0
Land Acquisition	0	$0
Phase 1 Total Capital Cost		**$146,375,379**
Total Estimated Project Capital Cost (Includes Phase 1)		**$173,945,379**
Annualized Capital Cost		**$11,315,397**
O & M Pump Station + Pipeline	2.50%	$443,650
O & M Treatment (FAT)		$7,127,737
O&M Storage	2.00%	$178,200
Advanced Monitoring		$200,000
LRP Credit (2,310 AF)		-$577,500
Total O&M		**$7,380,000**
Total Annualized Cost		**$18,700,000**
Annual Yield AF		**14000**
Unit Cost ($/1000gal)		**$4.00**
Unit Cost ($/AF)		**$1,300**

Notes:

Rate of 5% assumed over 30 year life

Contingencies are assumed to be included in expansion and storage costs

DPR Treatment Options Oxnard 12.5 mgd IPR option City of Oxnard		
Project Element		**Cost Estimate**
Backup Power		$0
Ag Storage		$0
AWPF Expansion		$19,162,152
GRRP ASR Wells + Monitoring Wells		$6,000,000
Pipeline for Connnection		$0
Total		**$25,170,000**
Construction Contingency	0.00%	$0
Subtotal		$25,170,000
General Contractor Overhead+Profit	0.00%	$0
Subtotal		$25,170,000
Sales Tax (7.25% of 50% of Total Cost)	0%	$0
Total Capital Cost + (30% Contingency)		**$25,170,000**
Engineering	0%	$0
Land Acquisition	0	$0
Phase 1 Total Capital Cost		**$146,375,379**
Total Estimated Project Capital Cost (Includes Phase 1)		**$171,545,379**
Annualized Capital Cost		**$11,159,273**
O & M Pump Station + Pipeline+ Wells	2.50%	$643,650
O & M Treatment (FAT)		$7,127,737
O&M Storage	2.00%	$5,600
LRP Credit (2,310 AF)		-$577,500
Total O&M		**$7,200,000**
Total Annualized Cost		**$18,360,000**
Annual Yield AF		**14000**
Unit Cost ($/1000gal)		**$4.00**
Unit Cost ($/AF)		**$1,300**
Notes: Rate of 5% assumed over 30 year life Contingencies are assumed to be included in expansion and well costs		

APPENDIX H – SEAWATER DESALINATION PROJECT OVERVIEW

CITY OF OXNARD

RECYCLED WATER RETROFIT PROGRAM

TECHNICAL MEMORANDUM NO. ##

SEAWATER DESALINATION PROJECT OVERVIEW

WORKING DRAFT
April 2012

CITY OF OXNARD

RECYCLED WATER RETROFIT PROGRAM

TECHNICAL MEMORANDUM
NO. 1
SEAWATER DESALINATION PROJECT OVERVIEW

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1.0 PURPOSE AND OVERVIEW

Two simple facts make seawater desalination a potentially attractive alternative for water supply in the United States (US). First, the overwhelming majority of this planet's water, about 97.5%, is saline. Most of the remaining water, about 2.5% of the total, is freshwater that is locked away in deep groundwater and polar icecaps. Less than 0.3% of the world's water is freshwater available for human and ecological use. Secondly, more than half the population of the US lives within 50 miles of a coast, making seawater reasonably accessible to those people (AWWA, 2011).

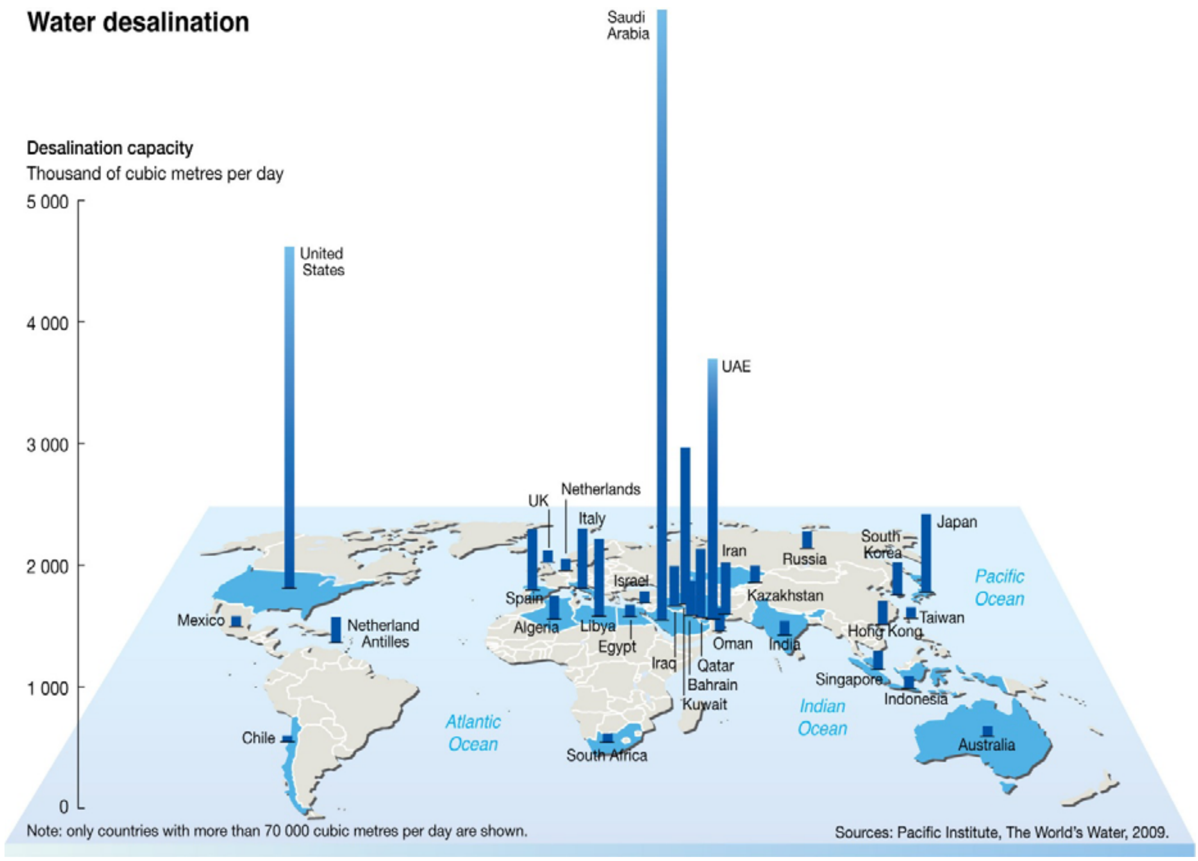

Figure xx. Desalination capacity by country, in 2009.
(Image Source: UNEP/GRID-Arendal http://www.grida.no/graphicslib/detail/water-desalination_11e4)

In the past, the high cost of desalinated water has restricted its use to locations where freshwater is most scarce and an abundance of cheap energy makes desalination less costly (i.e., Persian Gulf states). However, the cost of membrane desalination has been falling over the last several decades, and in many places, including parts of Southern California, the cost of dwindling freshwater supplies has risen to approach the cost of desalination. Figure xx shows the installed desalination capacity, by country, as of 2009.

1.1 Purpose and extent of TM and Desalination in Oxnard

The purpose of this desalination project technical memorandum (TM) is to discuss, in general terms, the possibility of a seawater desalination project in Oxnard. This TM lists the major technical, social, financial, and environmental issues or concerns with seawater desalination.

[maybe add more…]

1.2 Brief overview of existing desalination projects (ESA)

1.3 Brief overview of proposed California desalination projects (ESA)

1.4 Desalination as a component of the GREAT program

As described by the City of Oxnard's web site, "[t]he Groundwater Recovery Enhancement and Treatment (GREAT) Program is the City of Oxnard's adopted and active long-range water supply strategy to combine wastewater recycling, groundwater injection, and groundwater desalination to make more efficient use of existing local water resources to meet projected water supply needs of the City through year 2020" (Oxnard, 2012).

Desalination is one of many potential new sources of water considered as part of the GREAT Program; however, seawater desalination is not explicitly included in the GREAT Program Water Resources Technical Report, which lists "wastewater recycling and reuse; groundwater injection, storage, and recovery; and groundwater desalination" as potential means to provide regional water supply solutions to water users within the Oxnard Plain and Pleasant Valley areas (CH2M Hill, 2004).

This TM augments the water resources analysis already performed by providing an overview of the key technical, social, environmental, permitting, and cost aspects of implementing seawater desalination in California.

2.0 KEY TECHNICAL ISSUES OF CONCERN FOR DESALINATION PROJECTS

A successful desalination project requires overcoming many technical challenges, not only related to the actual desalination process, but also to identifying a source water and a means of conveying it to the plant, disposing of the treatment residuals, and conveyance of the finished water. This section describes the key technical issues generally associated with desalination projects.

2.1 Intake Considerations

Desalination plant intakes collect source seawater for the desalination process. If properly designed, they provide raw water of adequate quantity and quality in a reliable and sustainable fashion, with minimal impact on the environment. Unless otherwise noted, most of the information in this section was obtained from recent WateReuse Association White Papers (WateReuse 2011a; 2011c)

2.1.1 Intake Types

There are two general types of desalination plant intakes, open and subsurface. Open intakes collect seawater directly from the ocean using an inlet structure and piping to convey the water to the desalination facility. Subsurface intakes withdraw water from beneath the ocean floor, tapping either into saline or brackish coastal aquifers, or into offshore aquifers.

Subsurface intakes are often preferred by the environmental community because of their perceived lower impingement and entrainment impacts on aquatic life (see Section __). However, they are limited in their applicability and are rarely employed for medium- and large-scale desalination projects.

2.1.1.1 Open Ocean Intakes

Open ocean intakes are the most prevalent form of intake for desalination plants. In the US, open ocean intakes are also often used by coastal power plants that use large quantities of ocean water for cooling.

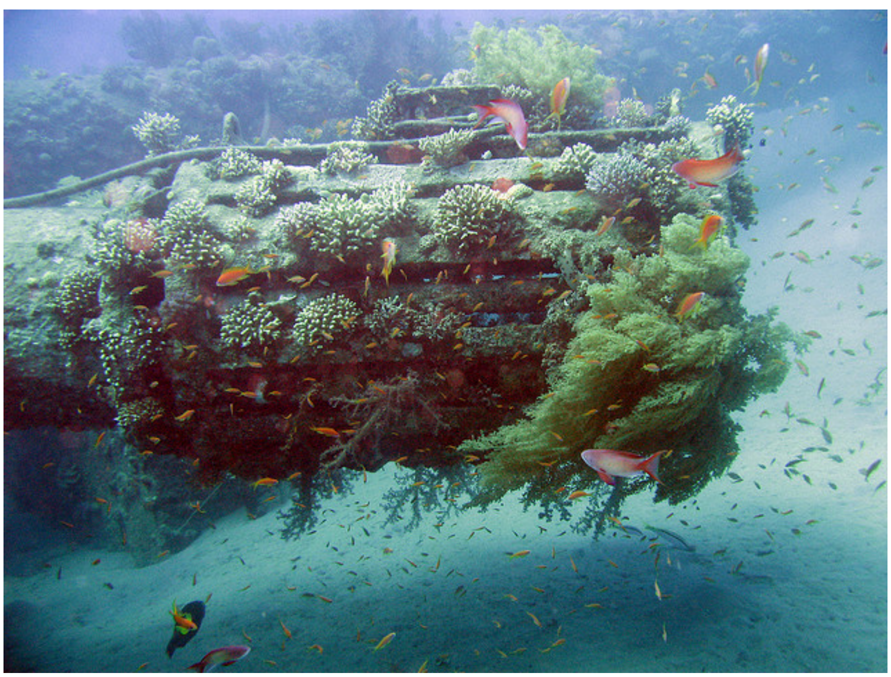

Figure XX. Open Ocean Desalination Intake at Nuweiba, Egypt.
(Credit: http://www.flickr.com/photos/silkebaron/3005399828/)

Open ocean intakes typically include the following key components: inlet structure with coarse bar screens, source water conveyance pipeline or channel connecting the inlet structure to an onshore concrete screen chamber, and mechanical fine screens in the chamber. A popular alternative to this typical setup are intakes that include passive wedge-wire screens, which eliminate the need for screens in onshore facilities. Wedge-wire screens are cylindrical metal screens with trapezoidal-shaped “wedgewire” slits with openings of 0.5 to 10 mm (WateReuse, 2011c). These screens minimize impingement and entrainment (see Sections 2.1.2 and) with very low flow-through velocities, small slot size, and naturally occurring high screen surface sweeping.

Figure XX. Wegewire Screen Intake
(Credit: http://cfeceny.blogspot.com/2010/07/wedgewire-screens-best-available.html)

Currently, open ocean intakes are the most prevalent intake type because they can be installed in most locations and built in a range of sizes. The cost effectiveness of open intakes depends on a number of factors, including plant size, depth to and type of ocean bottom, and the extent to which ocean water quality near the proposed intake site is impacted by pollutant sources.

2.1.1.2 Subsurface Intakes

Several different types of subsurface intakes exist, including vertical beach wells, radial wells, horizontal directionally drilled (HDD) wells, slant wells, and infiltration galleries. These intakes have in common that the seawater collected in them is naturally pretreated via slow filtration through the ocean floor. If the water collected by the subsurface intakes originates in part from a coastal aquifer, its salinity may also be lower. Subsurface intakes are generally considered low-impact technology with respect to impingement and entrainment.

Vertical beach wells are generally only suitable for smaller applications (i.e., less than 1 mgd), but horizontal wells, configured in radial patterns below an on-shore pump-house (“Ranney-type”) or directionally drilled out towards the sea (“HDD”) can and have been used for larger desalination facilities. Slant wells are similar; inclined source water collectors are installed below the sea floor using vertical well drilling technology.

Infiltration galleries are a separate type of subsurface intake. For this type of intake, the slow sand filtration media through which the water is filtered is put in place during construction, instead of taking advantage of naturally occurring sandy alluvial sediments. These seabed filtration beds are constructed in the near-shore surf zone.

The feasibility of using subsurface intakes is very dependent on the availability of suitable surface and hydrogeological site conditions, ideally including a geologic formation with a hydraulic conductivity of 1000 gallons/day/ft^2 and a depth of at least 45 feet (AWWA, 2011). Additional considerations include (WateReuse, 2011a).:

- Connectivity of the coastal aquifer targeted as the desalination supply water to another on-shore aquifer that would be negatively impacted by extraction of water for desalination;

- Beach erosion patterns, which may affect the subsurface intake structure, whether by erosion around beach wells that compromises their structural integrity, or erosion of the man-made filtration beds in infiltration galleries, which may have to be replaced several times over the lifetime of the desalination plant at potentially great cost;

- Deposition of sediments on the sea floor near the subsurface intakes, which may result in decreased well or infiltration gallery productivity that might require dredging of the sea floor to restore original flow rates; and

- The environmental impacts associated with the construction of an infiltration gallery, which involve the disturbance of large areas of near-shore sea floor and the associated aquatic and benthic ecosystems.

It is rare to find optimal conditions for subsurface intakes, which has limited their application to date to plants of relatively small capacity. This is in part because the same factors that generally give rise to the need for desalination plants, e.g., population density with increasing water demands, are the same that make large-scale installation of infrastructure such as beach wells more difficult (WateReuse, 2011a).

2.1.2 Impingement/Entrainment

Seawater contains both large and small aquatic organisms such as algae, plankton, fish, bacteria, etc., that constitute an important part of the marine ecosystem. Impingement occurs when larger organisms such as fish are trapped against intake screens by the force of the water flowing into the intake. Entrainment occurs when smaller organisms, such as fish larvae, are pulled into the intake structure along with the source water.

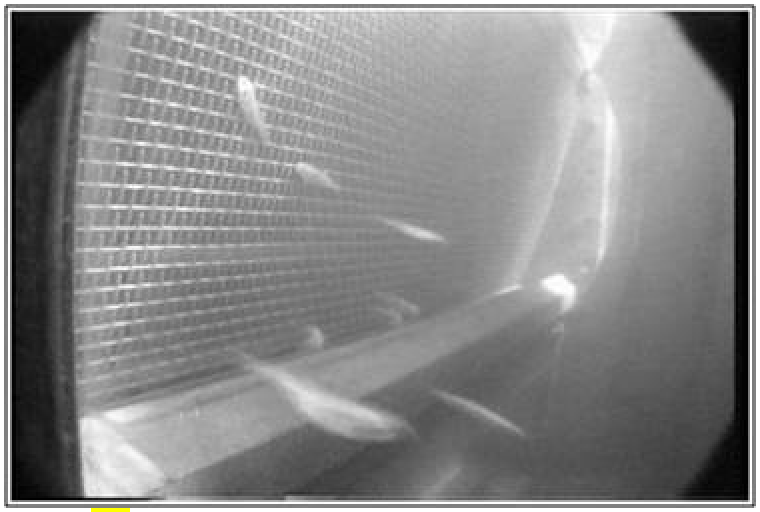

Figure XX. A juvenile striped bass impinging on a modified traveling water screen in the laboratory. Image Source: Alden Research Laboratory. Inc., http://www.aldenlab.com/services/desalination_intakes_and_discharges

While several studies have concluded that impingement and entrainment (I&E) associated with seawater intake operations are not expected to create biologically significant impacts under most circumstances (WateReuse 2011a), I&E are often the issue at the heart of environmental protests against large intake structures, whether for desalination or other industrial water needs, such as power plant cooling. These protests are often prompted or perpetuated by the public review process required for desalination project permitting in California. Therefore, the effects of impingement and entrainment require detailed baseline ecological assessments, impact studies, and careful monitoring (see Section ___ESA?).

In addition, best available site, design, technology, and when needed, mitigation measures, are prudent for minimizing loss of marine life and maintaining the productivity and vitality of the aquatic environment near the intake.

These measures may include:

- siting the intake outside of the littoral zone, i.e. near-shore areas within approximately 600 feet of the shoreline, where marine life concentrates;
- designing open intakes with technology to minimize impingement and entrainment, such as
    - velocity caps, which change the main direction of water withdrawal from vertical to horizontal, preventing vertical vortices and providing fish with a better indication of danger, and
    - wedgewire screens, which help minimize through-screen velocities and fine screen mesh sizes and result in naturally occurring high screen surface sweeping velocities;

- using subsurface intakes, were feasible and appropriate; and
- implementing other impingement and entrainment reduction technologies, such as acoustic barriers and strobe lights, which frighten fish away from intake locations.

2.2 Source water characterization

The concentrations of dissolved inorganic constituents in seawater are relatively constant in the open ocean, generally not varying geographically or temporally by more than +/- 10% from the global median value of approximately 35,000 mg/L total dissolved solids (TDS). In contrast, concentrations of other water quality parameters that are important to the desalination process - mainly turbidity, total organic carbon, and indicators of biological fouling potential - can vary greatly both geographically and over time at the same location, especially near coasts where, for example stormwater runoff can contribute large, sudden loadings of all three of the parameters listed above, to coastal waters (AWWA, 2011).

It is therefore important to characterize extensively the proposed source water in the immediate vicinity of the proposed intake location(s), over a long enough time to capture the expected variability in source water quality over the lifetime of the proposed project. This helps both to determine the relative advantages of the potential source water intake locations with respect to each of these water quality parameters, but also significantly informs the needs for pretreatment, as discussed in the next section. As a starting point, a survey of wastewater discharges near any potential intake location should be completed.

The AWWA Manual of Water Supply Practices on Seawater Desalination (AWWA, 2011) provides a summary of the source water conditions which would require pretreatment measures beyond the standard methods described in Section 2.3:

- turbidity greater than 20 NTU,
- measureable levels of hydrocarbon-based contaminants,
- significant occurrences of red tides or algae,
- high levels of pathogens,
- large variations in temperature of the raw water,
- moderate levels of total organic carbon (TOC), or
- severe water quality excursions caused by hurricanes or other sever storm events.

2.3 Pretreatment

The purpose of pretreatment systems is to protect the downstream SWRO membranes from water quality issues that could negatively affect the actual desalination process, resulting in problems such as membrane (bio)fouling, scaling, or damage to the membrane. Conventional pre-treatment processes generally include the following (AWWA, 2011):

- chlorination,
- coagulation, flocculation, and clarification,
- filtration,

- chemical dosage for scale inhibition,
- cartridge filtration, and
- dechlorination.

Membrane manufacturers of SWRO (and other spiral-wound) membrane elements generally require the feedwater to have < 1 NTU turbidity and a maximum silt density index (SDI) of 4 or 5. SDI is measured is based on the rate of plugging a standard 0.45 um membrane filter by ASTM method D4189 (AWWA, 2007).

Additional pretreatment measures that are often also implemented to protect SWRO membranes include the following processes, which may be in addition to, or used as substitutes for one or more of the processes listed above (AWWA, 2011):

- upflow solids contact clarification,
- dissolved air flotation (DAF),
- membrane microfiltration (MF) and ultrafiltration (UF), and
- micro-sand enhanced clarification (MES).

2.4 RO Configuration and Facilities

The heart of the desalination process, SWRO systems generally consist of feedwater pumps, RO membrane elements installed in pressure vessels, a support structure for the pressure vessels, valves, piping, instrumentation and controls, and sample panels. In seawater desalination applications, operating pressures are generally high enough to warrant the use of energy recovery devices to reduce the system's energy usage, which is a significant fraction of the total operating cost (see Section 4.2).

2.4.1 RO Membrane Elements

The vast majority of SWRO membranes are composed of three layers, (1) a backing layer generally made of cellulose, (2) a microporous polysulfone support layer that has filtration properties similar to those of micro- or ultrafiltration membranes, and (3) an ultra-thin layer of polyamide plastic which provides the actual semi-permeable barrier through which water can pass, but salt passes only to a small extent.

These membranes are sandwiched into stacks with spacer material separating each layer, and then spiral wound into membrane elements, usually 8 inches in diameter and 4 feet long (see Figure XX). Elements are then inserted end-to-end into long tubes called pressure vessels, which usually hold eight standard-sized elements. Pressure vessels are mounted on racks, such that they can be stacked more than one layer high in warehouse-style buildings.

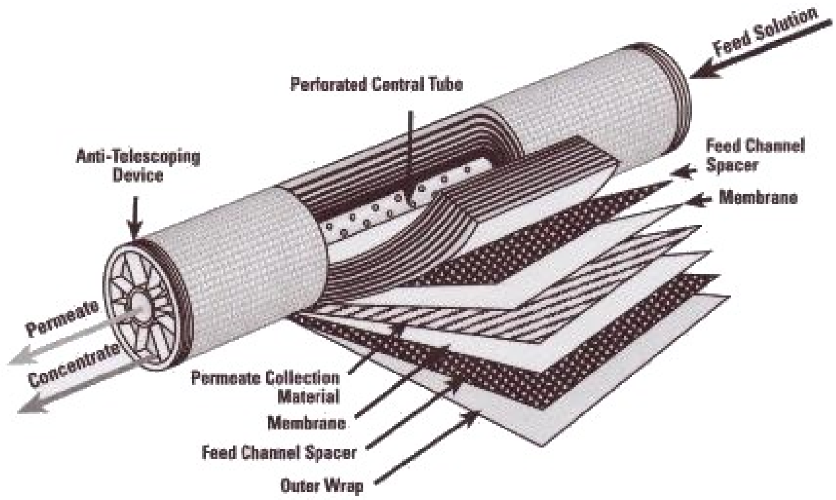

Figure XX. Cutaway Schematic of an RO Memembrane Element
(Image Source: http://www.desalsolutions.com.au/images/stories/membrane_cutaway.jpg)

2.4.2 RO System Configurations

Due to the modular nature of reverse osmosis elements and pressure vessels, RO systems can be operated in a number of different configurations, allowing designers and operators to fine-tune the treatment process.

Stages and Passes. At a conceptual level, systems can consist of several "stages", which means the concentrate from one set of membranes ("first stage") is used as the feed solution of a second set of membranes ("second stage"). This results in more product water and less concentrate, elevating the overall system recovery. As discussed in Section 2.4.3, higher recovery can also result in additional operational costs due to higher pressures or increased scaling on the membranes in the second stage. Systems can also consist of several "passes," which means the *permeate* from one set of membranes ("first pass") is used as the feed solution of the second set of membranes ("second pass"). This results in lower overall recovery, but may be necessary in cases where one pass is not sufficient to remove salt (or other constituents) to the desired concentrations.

Often, a second pass or second stage is partially bypassed, and the various permeate streams are then blended at the end of the system to obtain the desired product water quantity and characteristics at the lowest capital and operational costs. Occasionally, different membranes with different salt passage, fouling resistance, or other specific characteristics may be used in a second pass or second stage, or an internally staged design (ISD) is chosen, in which different membrane elements are placed within the same pressure vessel, i.e., the lead element in the vessel may be chosen to have a higher rejection and lower productivity than subsequent membranes. All of these options allow designers even more flexibility to optimize the process.

Treatment Trains. The modularity of the membrane process also manifests itself at the physical level. A treatment train is one set of membrane pressure vessels, manifolded together to create one "unit process" into which the RO feedwater enters, and the final RO permeate exits. A treatment train in a two-stage RO facility might consist of 12 first-stage pressure vessels, and 6 second-stage pressure vessels, constructed as one unit. This single treatment train produces a certain fraction of the facility's total production capacity. Generally, each treatment train can be shut down independently for cleaning and other maintenance without affecting the operation of the other treatment trains operating at the plant.

Figure XX. Membrane pressure vessels organized into treatment trains at the Sunrise, FL brackish water desalination plant (Image source: http://www.biwater.com/Images/content/1724/449510.jpg)

2.4.3 Basic Design Parameters: Flux and Recovery

The two main design parameters for RO treatment are flux and recovery, which are discussed in the following:

Flux. The membrane flux is given as a filtration rate per unit membrane surface area, often in gallons per day per square foot (gfd) or liters per meter squared per hour (LMH), and measures the "productivity" of the membrane at given operating conditions. Operating at a higher flux will provide more product water per membrane area, reducing the required number of membrane units, which reduces capital cost and facility footprint. However, this requires operating at higher pressures, which increases operational cost and can increase membrane fouling and scaling, which result in additional operational costs increases. A study performed by the Affordable Desalination Collaboration concluded that operating SWRO plants in the range of approximately 8 to 12 gfd flux resulted in lower average life cycle costs than the typical operating range of 8-12 gfd flux at SWRO facilities in operation today (AWWA, 2011). The optimum operating conditions for a give plant will vary depending on source water characteristics (e.g., salinity, biological fouling potential, and temperature) and other factors.

Recovery. Recovery is defined as the ratio of product water flow to the total feed water flow rate, measures the overall "efficiency" of the seawater desalination process, and is given as a percentage. Operating at higher recoveries means less "wasted" water sent back to the ocean, which results in smaller facilities overall, from intake to brine discharge. However, operating at higher recoveries also means that both the product water and the treatment residuals are more concentrated. Both high-flux and high-recovery operations result in operating at higher pressures and at higher fouling and/or scaling potential. Because of the high salinity of seawater compared to other RO applications such as brackish water desalination or water reuse, recovery in SWRO (40-55%) is generally lower than that of the other RO membrane applications (70-85%). This may also be due to the relative simplicity of disposing of the treatment residuals back in the ocean – inland desalting operations generally have higher concentrate disposal costs and thus operating at higher recoveries is favored in those applications (AWWA, 2011).

2.4.4 Energy Recovery

SWRO treatment is a very energy-intensive process mainly because of the high pressures required to overcome the osmotic pressure of the saline feed water and drive the water through the membranes. Because SWRO membranes are operated in a "cross-flow" configuration, the concentrate that exits each pressure vessel is still at a very high pressure, comparable to that of the feed water. Energy recovery devices (ERDs) aim to capture the energy contained in the high-pressure concentrate stream and use it to offset some of the pumping power needed to bring the feed water up to pressure.

ERDs come in many forms, but can generally be divided into two categories, centrifugal devices and positive displacement devices. The former include the Francis Turbine, the Pelton Wheel turbine, and the hydraulic turbocharger; the latter include the work exchanger and the pressure exchanger. In general, centrifugal devices are less mechanically efficient in transferring energy (65-80%), compared to the newer positive displacement devices (97-98%). Some small amount of overall efficiency may be lost in the latter due to some limited mixing of brine with incoming feed water within those devices. However, their high efficiency has resulted in significantly increased use at many recently built SWRO facilities (AWWA, 2011).

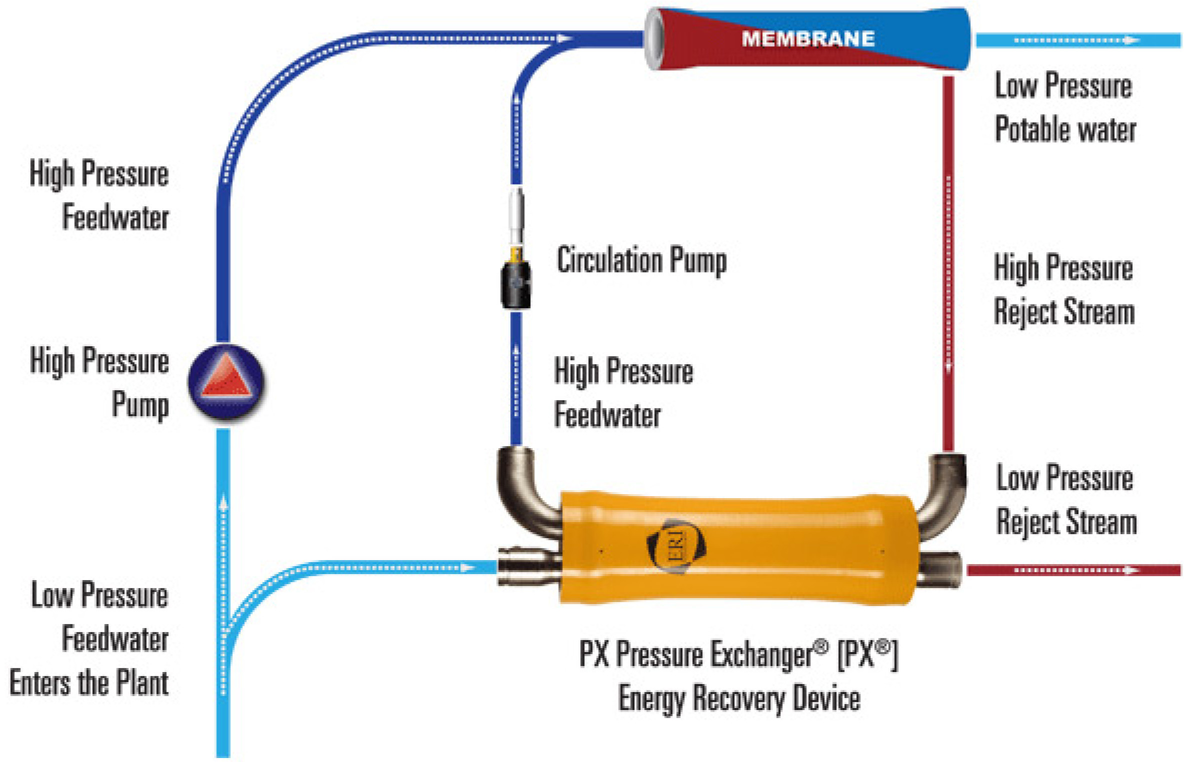

Figure XX. Schematic of the installation of a PX Pressure Exchanger, a positive displacement type energy recovery device. (Source: Energy Recovery, Inc. web site at http://www.energyrecovery.com/UserFiles/image/howitworks_new.jpg)

Overall, along with improvements in membrane performance, the development and refinement of ERDs has resulted in a significant decrease in the energy required for SWRO desalination, dropping by almost a factor of three between 1980 (27 kWh/kgal) and the early 2000s (2.6 kWh/kgal), (AWWA, 2011). This has also contributed to the dropping overall cost of SWRO desalination over the last several years (see Section 4.2).

2.5 Finished water objectives

2.5.1 Mineral Content

Desalination by SWRO removes almost all constituents from water, resulting in water that is low in hardness, low in alkalinity, and relatively high in chloride, which can cause corrosion problems in distribution systems. The water generally must be reconditioned such that it is both suitable for human consumption and does not damage pipelines on its way to that destination.

Generally, the only constituent that has a significant risk of exceeding current state or federal water quality requirements is boron, because it is poorly removed by SWRO membranes (California notification level is 1 mg/L). In recent years, many membrane manufacturers have developed membranes specialized in boron removal, in case this parameter is what drives the desalination process design.

Chloride has a secondary MCL of 250 mg/L, due to aesthetic concerns. Depending on the membrane type, RO product from a single-pass system can range from 100 to 200 mg/L (AWWA, 2011), which may be sufficient to achieve the MCL, but might be higher than the desired level.

2.5.2 Organic Content

Non-regulated contaminants of emerging concern are being studied in the context of many conventional and non-conventional water sources. Seawater rarely contains concentrations of such compounds at levels as high as are commonly found in freshwater supplies. In addition, the SWRO process is one of the most effective treatment technologies in removing a wide array of small compounds. In contrast, algal toxins associated with periodic algal blooms or red tide events are unregulated contaminants that are a problem generally specific to seawater desalination. Recent pilot tests conducted at several California coastal locations have demonstrated successful removal of algal toxins released by algae during large blooms and red tide events (AWWA, 2011).

2.5.3 Pathogen Removal

Seawater is considered a surface water supply in the US. Pathogen removal requirements for surface waters used for drinking water are defined in the USEPA Surface Water Treatment Rule (SWTR), which requires 4-log removal of viruses, 3-log inactivation *Giardia* cycsts, and turbidity reduction, and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which requires between 2-log and 5.5-log removal and inactivation for *Cryptosporidium*. Additional discussion on this topic is provided in Section 2.6.2.

2.6 Post treatment requirements

2.6.1 Harness, Alkalinity, and pH

As discussed in Section 2.5.1, RO permeate must be remineralized to prevent corrosion in distribution system piping and to produce finished water that tastes acceptable to customers. Hardness can be added by dosing calcium oxide (quicklime), calcium hydroxide (hydrated lime), or calcium carbonate (limestone or calcite). The latter is generally the more operationally simple option, whereas the first two options can be cheaper for large facilities. Alkalinity is generally added in the form of carbon dioxide, and the resulting acidic pH of the water is adjusted using sodium hydroxide to match the existing pH within the distribution system. Finally, blending with a source of hard water can also achieve the desired effects, while reducing hardness in the blending water from their potentially undesirably high levels (AWWA, 2007).

2.6.2 Disinfection

California's Department of Public Health (CDPH) has granted RO membrane processes only a 2-log removal credit for viruses, *Giardia*, and *Cryptosporidium*. This is not because SWRO membranes are expected to let 1% of these pathogens pass, in fact, SWRO membranes have effective pore sizes that are much too small to allow bacteria, spores, and viruses to pass at all. However, the integrity of SWRO membranes, and thus their ability to remove these pathogens, can only be monitored continuously by measuring the removal of TDS, which is generally expected to range between 2-log and 3-log (i.e., 99.0%-99.9%) removal. To date, CDPH has not accepted the measurement of any other surrogate to indicate integrity of RO membranes, and therefore has not granted RO processes any additional log removal credits. Additional disinfection is therefore generally needed to achieve the disinfection credit requirements (see Section 2.5.3).

2.7 Concentrate and residuals management

The main byproduct of reverse osmosis desalination, constituting 90-95% of the total residual volume, is generally referred to as "concentrate" or "brine." Additional treatment residuals include byproducts from other treatment process steps, such as backwash water from pretreatment filters and membrane cleaning solutions.

2.7.1 Concentrate Characteristics

Because SWRO desalination plants are generally designed for approximately 50% overall recovery, the concentrate stream has an approximately equal flow rate to the product water stream, i.e., a 10 MGD SWRO desalination plant will produce approximately 10 MGD of concentrate. The fresh water produced during SWRO desalination has a very low mineral content. The concentrate therefore contains 99% or more of all the source water salts and other dissolved constituents. At 50% recovery, the concentrate mineral content is therefore approximately twice as high as that of the source water. Otherwise, the concentrate stream is very similar to the source seawater, with high dissolved oxygen, and low TOC and BOD.

This significant concentrate stream must be disposed of appropriately. Unlike inland desalination installations, coastal, i.e., SWRO desalination facilities have the advantage of proximity to the ocean for concentrate disposal. The other significant residual streams can generally be treated on-site by settling, and after such treatment, do not significantly affect the quality of the overall concentrate stream. This means concentrate can, in many cases, be discharged directly back into the ocean through an ocean outfall without further treatment. Nevertheless, many significant issues must be addressed when designing an ocean outfall. These are discussed in Section 2.7.2.

2.7.2 Outfall Considerations

2.7.2.1 Ocean Outfall Types

New ocean outfalls are designed to dissipate RO concentrate within a short time and distance from the point of entrance into the ocean to minimize environmental impacts. This is generally accomplished in one of two ways: discharging near-shore to take advantage of its natural mixing capacity (surf, tidal movement, near-shore currents, and wind), or discharging beyond the near-shore zone using diffusers that release concentrate at high velocity to improve mixing. Although the near-shore mixing capacity may be significant, it may have a limited assimilative capacity for salinity. If hydrodynamic modeling suggests that excess salinity may begin to accumulate in the near-shore zone over time, an outfall structure equipped with diffusers located further into the ocean is more appropriate.

Figure XX An outfall diffuser nozzle at a desalination plant in Perth, Australia expelling concentrate colored with a red dye for a salinity dispersion test.
(Image Source: http://waterrecycling.blogspot.com/2007/07/desal-brine-disposal.html, photo credit to West Australian Newspaper)

The Long Beach Water Department is investigating and plans to construct an “under Ocean Floor Seawater Intake and Discharge Demonstration System,” in which essentially two filtration galleries are constructed, one for ***in***filtration, i.e. through which feed water will be collected, and one for ***ex***filtration, i.e., through which the concentrate will be discharged. Both systems are intended to reduce the environmental impacts of the intake and outfall for the demonstration facility (Long Beach, 2012). (When ESA fills in their parts, check that this is not a repeat)

2.7.2.2 Salinity Discharge Limits

The salinity of the concentrate (approximately 50-70 g/L TDS) is generally the only significant difference between it and seawater (33-35 g/L TDS in the US). Many marine organisms have no difficulty adjusting to increased salinity in this range, but some species, such as abalone and sea urchins, have lower salinity tolerances. There are currently no salinity-specific discharge requirements in the US, rather, discharge limits are determined by establishing project-specific acute and chronic Whole Effluent Toxicity (WET) objectives (WateReuse, 2011b). That said, the specific discharge permits for several existing SWRO desalination plants in the US also contain specific numeric salinity limits that range from approximately 20% above ambient (Carlsbad average TDS discharge limit) to almost 40% above ambient (Tampa, average and maximum TDS discharge limit). Definition of the discharge requirement relative to the ambient salinity is important because the background salinity, especially in near-shore areas, may vary significantly with seasonal, tidal, and weather changes.

Acute and chronic WET objectives are applied at different distances from the outfall and are dependent on the actual dispersion and mixing patterns achieved by the outfall type. For example, the California Ocean Plan defines the application of toxicity criteria relative to the space in which initial dilution is completed, defining initial dilution as "the process which results in the rapid and irreversible turbulent mixing of wastewater with ocean water around the point of discharge" (SWRCB, 2010, Appendix I).

Determining this "zone of initial dilution" (ZID), in which the discharge salinity plume is dissipated to near-ambient salinity levels, requires discharge salinity dispersion modeling.

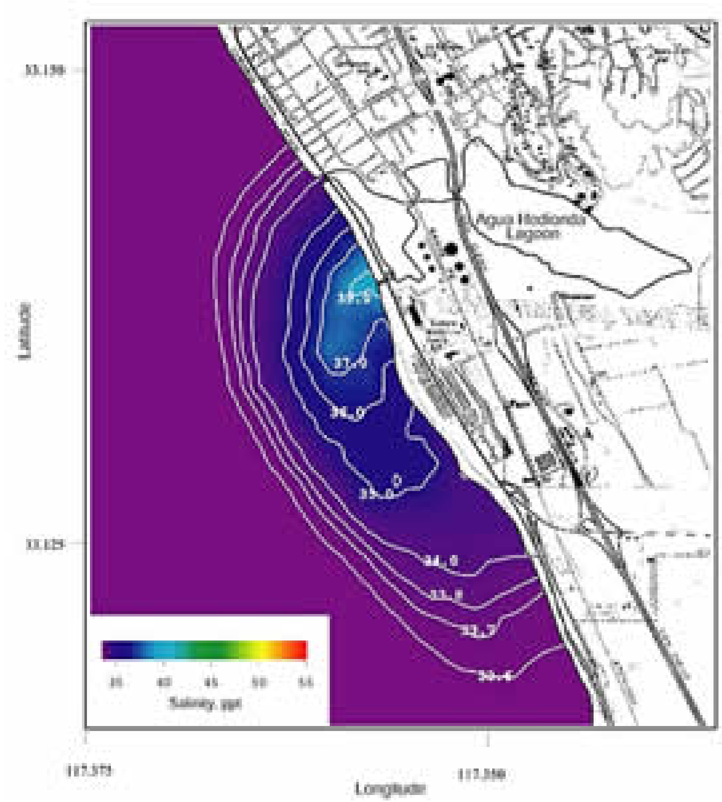

Figure xx. Simulated Salinity Dispersion from a Proposed Desalination Plant in California (Image Source: Scott Jenkins/Scripps, http://www.underwatertimes.com/news.php?article_id=24311079560)

2.7.2.3 Outfall Site Considerations – Potential Synergies

Intake and outfall requirements and considerations often drive the site selection for SWRO plants. This is, particularly for US facilities, due in large part to vocal opposition from environmental groups to the installation of such structures in the ocean (see also Section _ESA?). Therefore, several of the SWRO facilities in the US have relied on existing structures to provide either raw water intake, concentrate outfall, or both.

Several SWRO plants are *collocated* with coastal power plants that operate once-through cooling processes that withdraw vast amounts of seawater to provide cooling, and return the water to the ocean through open ocean outfalls. SWRO plants collocated with such power plants typically withdraw their feed water from the power plant's discharge pipeline, and return the concentrate to the existing discharge pipeline slightly further downstream.

SWRO plants generally require only a small portion of the water utilized by the power plants, such that initial mixing and significant dilution of the concentrate may take place within the discharge pipeline before the water reaches the outfall structure, reducing or eliminating the necessity for diffuser systems. Collocation with power plants provides the additional benefit that the cooling water discharged from the power plant is by definition warmer than the ocean water. Warmer water reduces the power required for the RO separation process, which is the major power requirement in a SWRO plant, resulting in potentially significant power savings at the facility.

Another common strategy to avoid the construction, permitting, and environmental review costs of a new, dedicated outfall structure is to discharge RO concentrate into an existing wastewater treatment plant ocean outfall. As with the power plant collocation, this strategy not only avoids the need for a new outfall structure, but also provides for some initial mixing and dilution of the RO concentrate. This actually benefits both dischargers, as the denser, more saline concentrate is given the opportunity to mix with the less dense freshwater wastewater effluent, bringing the average salinity of the discharged mixture closer to that of the seawater. In addition, the water quality produced by most SWRO plants is likely higher than that of the wastewater effluent. Together, these effects may result in a reduced wastewater discharge plume.

2.8 Finished water storage and conveyance

[still to be added…]

3.0 KEY SOCIAL ISSUES AND PUBLIC CONCERNS

Amongst the general populace, there are both supporters and detractors of seawater desalination. Support for desalination is generally found in the communities most affected by water shortages, where both the rising costs and questionable reliability of other water sources are readily apparent. However, there are many social and public perception issues with which seawater desalination has to contend, especially in California. The following sections present these issues, grouped by the general type of concern voiced.

To date, very few municipal desalination plants have been built in California, and of those (Morro Bay[1], Santa Barbara, Santa Catalina Island, and Marina Coast Water District), none are operating today due to the high cost of desalinated water [fact-check against ESA info, other sources]. It is therefore difficult to draw lessons for public outreach from existing seawater desalination facilities in California. In general, the most successful California projects to deliver water from unconventional sources, such as indirect potable reuse, have deployed significant public education and outreach campaigns to provide positive information and build a base of support in the affected population.

The Carlsbad Desalination Project provides an illustrative example of how public opposition can significantly affect the progress of a coastal desalination project. The project, privately

[1] The seawater desalination plant at Morro Bay was operated twice in water supply emergencies, in 1992 and 1995. It has since been expanded to include brackish water RO trains to treat water from brackish wells. The brackish water desalination portion of the plant operates with some regularity, but it is unclear whether the seawater desalination portion has operated at any time since 1995.

financed and developed by Poseidon Resources Corporation (Poseidon), was proposed in 1998, spent ten years in planning and six years negotiating the permitting process. A total of 13 cases were filed against the project between 2006 and 2009. A lawsuit was filed in April 2010 against the San Diego Regional Water Quality Control Board by the Surfrider Foundation, challenging the Board's approval to withdraw seawater for the desalination plant. In June 2011, the California Superior Court upheld the Board's approval to construct the plant[2]. According to the project web site[3],

> *"In November 2011, the Water Authority and Poseidon began direct negotiations on the draft [water purchase agreement (WPA)], and Poseidon is now reviewing a second draft of the agreement […] The project's current cost of water is estimated at \$1,865/AF (\$1.51/m^3; \$5.72/kgal) and its capital cost is estimated at \$780 million. If the Water Authority approves the WPA this summer, desalted water from the Carlsbad project should be available by 2016 – 18 years after Poseidon began to develop the project – and will comprise seven percent of the total regional supply."*

3.1 Aesthetic Concerns

The California coast is one of the state's many stunning geographic features, and many people settle near the California coast to enjoy its beautiful scenery and the wide-open ocean views. It is no surprise, then, that there is a significant segment of the population that is opposed to the construction of any industrial facilities on or near the shoreline. This includes the construction of large arrays of beach wells for subsurface intakes, other structures to support open or subsurface intakes and outfalls, and in some cases, even the SWRO facility itself.

Figure XX. Intake Beach Wells for a 4 MGD Desalination Plant in Santa Cruz, Mexico. (Source: http://www.waterworld.com/index/display/article-display/208958/articles/water-

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[2] http://www.water-technology.net/projects/carlsbaddesalination/ - add to references (URL giving error as of 3/26/12)

[3] http://www.carlsbad-desal.com/news.aspx?id=275, as viewed on March 26th, 2012.

wastewater-international/volume-19/issue-4/editorial-focus/beach-wellsbrvsbropen-surface-intake.html)

One can have some measure of success in avoiding public opposition to the project for aesthetic reasons by designing aesthetically pleasing facilities. Considerations on this front should not only include aesthetically pleasing architecture, but perhaps also some form of aesthetic “mitigation” within the plant site. One might choose to site the facility in a location that was previously already considered an eye-sore to create the perception of improvement. Another option would be to include an area dedicated to public education and recreation that looks and feels an integral part of the facility rather than an “add-on.”

LEED certification, though based fundamentally on environmental concepts and therefore discussed further in Section 3.2, may also play an important role in improving the project’s perceived aesthetic value.

3.1.1 Construction Noise and Traffic

Another, related issue is some people’s concern about the impact of the actual construction project. SWRO plants may take years to construct, and people are often worried about the level of noise, and construction vehicle traffic that might accompany the construction phase in generally already congested coastal areas. Careful traffic planning, construction scheduling, and significant and ongoing public education campaigns can avoid larger problems.

3.1.2 Finished Water Quality

A small subset of the population is concerned about the impact that desalinated water will have on the quality of their drinking water. These concerns are rarely about hard-and-fast water quality parameters (i.e., mineral content and hardness), but more general questions regarding “how will my water taste?” and “is it safe to drink?” In this case, again, public education campaigns can be very useful, especially if concerned citizens can be invited to learn more about the project, and, for example, taste some finished water that might be available at the pilot site.

3.2 Environmental Concerns

The main opposition to seawater desalination facilities is rooted in the environmental community, which is particularly vocal in California. Many aspects of seawater desalination can provoke consternation in the environmental community, ranging from disturbances to the ocean’s ecosystem to the high energy cost of operating an SWRO facility.

[ESA to write…]

3.2.1 Ocean Habitat Disturbance

- infiltration galleries:

- o designed as slow-sand filters, so get 0.05-0.10 gpm/sf.
- o Scale that to 10 MGD plant at 50% recovery, and you need 4.3 acres of ocean floor filtration bed at 0.075 gpm/sf
- o must excavate this area 6-8 feet deep and landfill the sediments

(reference WateReuse, 2011c)

3.2.2 Entrainment and Impingement (E&I)

Entrainment and Impingement (E&I) are one of the most …

3.2.3 Energy Use and Green House Gases

3.2.4 Concentrate Disposal

3.2.5 Anti-Growth Arguments

Some community members desire to avoid growth in their communities. They oppose the creation of any new water sources, including desalination, because they view this process as a threat to their no-growth preferences, as the availability of additional water could allow for additional unwanted or uncontrolled growth (Bourne, 2008).

Figure xx. Protesting against the financial and climatic costs of desalinated water from the proposed Wonthaggi SWRO desalination facility near Melbourne, Australia. (Image Sources: http://www.greenfudge.org/wp-content/uploads/2010/03/desalination-water-crisis.jpg and http://www.melbourne.foe.org.au/files/imce/desal_rally_may_2009.jpg)

3.3 Cost Concerns

As discussed in more detail in Section 4.2, the cost of desalinating seawater is significantly higher than the cost of delivering water from conventional water sources. Even in Southern California, where local conventional water sources are insufficient and the price of imported water is rising steadily, it is difficult for desalination water to compete from a cost perspective. The argument for desalination is generally that it is one of the most reliable forms of water supply, and will become cost-competitive as other water sources become more expensive or simply unavailable.

4.0 KEY FINANCIAL ISSUES OF CONCERN FOR DESALINATION PROJECTS

4.1 Project delivery mechanisms

Because desalination projects are often large and expensive due both to their size and the fact that they are generally not straightforward projects from a planning, permitting, and public perception perspective, they involve large amounts of risk (WateReuse, 2011d).

The traditional design-bid-build (DBB) public project delivery model allows for a high degree of involvement and control by the public water provider, but it is often not used for seawater desalination projects, as the public water provider often bears too a large portion of the project risk under this model. An additional drawback to the DBB model is that most DBB contracts are evaluated based on cost alone and awarded to the lowest responsive and responsible bidder. This tends to avoid proprietary processes and equipment, which often results in low-technology solutions. More importantly, the operating costs for SWRO plants represent a significant fraction of the total cost of water, and with typical DBB contracts, neither the design engineer nor the construction contractor have any incentive to reduce the operating and maintenance costs (NRC, 2008).

Three common alternative project delivery methods, design-build, design-build-operate, and design-build-own-operate-transfer offer advantages over the traditional DBB model by reducing the public water provider's risk and simplifying the contracting process. The trade-off is generally that the public water provider cedes decision-making power over design details.

The design-build (DB) model is most similar to the traditional DBB approach. The only difference is that for a DB project, a single contractor both develops the project design and oversees the construction, reducing the potential for disagreements, and providing the water utility with a guaranteed cost, schedule, and plant performance. The facility is then operated by the owner (i.e., water utility), or a separate contractor.

The design-build-operate (DBO) model travels further down the continuum towards less owner risk and less owner control. This model involves a interfacing with a single contractor for overall design, construction, and long-term operation (NRC, 2008). The DBO takes the DB model and adds the operation and maintenance to the responsibilities of the contractor, providing the public water provider with cost, schedule, and performance guarantees for both initial and ongoing performance. DBOs are especially applicable for projects that have short timelines and are technologically complex, because contractors have a vested interest in reducing the overall production costs and are willing to take risks on innovative technologies to achieve those reductions (NRC, 2008).

Design-build-own-operate-transfer (DBOOT) projects expand one step further on the DBO concept. The significant departure for this model is the "own" portion, which means the contractor is responsible not only for all the technical and construction aspects of the desalination facility, but also for the permitting and financing. The public water provider signs a water purchase agreement in which it commits to buy a certain quantity of water at a predetermined price over a specified period of time. The contract also generally contains provisions to transfer ownership of the facility to the public water utility after a certain term.

On paper, a DBOOT contract completely decouples the public water provider from the risks associated with the project. However, the public water provider is still ultimately responsible to its users if the one or more of the contractors involved in the project are unable to deliver on their contractual obligations. The Tampa Bay Seawater Desalination Project, originally conceived as a DBOOT project, but restructured into a DBO arrangement after the bankruptcies of several contractors and subcontractors, serves as an example of how even the DBOOT process does not necessarily insulate the public water provider from the risks associated with a seawater desalination project (NRC, 2008).

[[“owner-engineer alliance” approach (Australia) – mentioned in WateReuse, 2011d)]]

4.2 Cost Summary

4.2.1 General Observations

The costs of desalination plants are very difficult to predict. This is due to a number of qualitative reasons, including the site-specificity of many important aspects, the economies of scale, and the strong dependence of operational cost on the cost of energy, which fluctuates significantly over time. Therefore, the following summary of costs, obtained largely from the WateReuse White Paper on Seawater Desalination Costs (WateReuse, 2011d), must be interpreted as a collection of information on the costs of existing plants, which may or may not translate well to any particular future project, especially if significant swings in energy cost occur in the interim (Bourne, 2008).

Over the last thirty years, the cost of membrane desalination has declined significantly, mainly due to improvements in technology that make desalination less energy-intensive (both better membranes, and the advent of high-efficiency energy recovery devices). In 1982, desalinated water cost $1.50/m3 ($5.69/kgal), whereas by 2010, the cost had dropped to approximately $0.70/m3 ($2.65/kgal; WateReuse, 2011d).

Even with the significant modularity of membrane processes, the economies of scale can place a significant role in the cost per unit water produced. WateReuse places the unit construction cost of a 0.5 MGD plant at approximately $14 million per MGD, whereas the cost for a 100 MGD facility is estimated at just over $6 million per MGD (WateReuse, 2011d).

4.2.2 Costs by Process Step

Basic construction cost ranges for each process step are presented Table X.X. The large variations in each category serve to illustrate the difficulty of predicting seawater desalination costs without a detailed study of site-specific conditions.

Table X.X SWRO Costs by Process Step
Technical Memorandum on Desalination
City of Oxnard

Process Step	Cost Range[1] ($ million per MGD)	Factors that Affect Cost[1]
Intakes		
Open	0.5 – 1.5	collocation reduces construction
Subsurface/Complex	up to 3.0	and permitting costs
Outfalls		
New with diffusers	2.0 – 5.5	
Existing (co-location)	0.2 – 2.0	
Zero liquid discharge	up to 15	
Pretreatment	0.5 -1.5	conventional treatment is on lower end; MMF / MF or MMF/UF is higher
RO	1.5 – 4.0	single-stage/single-pass is lower cost; two-stage/two-pass and more complex configurations at higher end
Distribution	Varies	Cost of distribution varies from negligible, if tie-in is near plant, to a significant fraction of the total SWRO project cost

Notes:
(1) Cost ranges and factors that affect cost are taken from WateReuse (2011d).

4.2.3 Costs by Associated with Planning

While the cost of design and engineering associated with the various construction steps shown in Table X.X (SWRO Costs by Process Step) can be approximated as a certain percentage of the construction cost, there are additional, often significant costs associated with the planning aspects of desalination plants.

The costs of permitting and subsequent regulatory requirements vary widely, and depend on the regulatory structure in place in the planned location of the plant. Especially in California, the attitude and political sway of a vocal minority towards the project can have a surprisingly large effect on the cost, and even viability, of SWRO projects. For example, the permitting costs for the 25 MGD Tampa desalination plant are estimated at $2.5-$5 million (WateReuse, 2011d). The permitting costs for 10-50 MGD California plants have been in the range of $10-$20 million, and are expected to rise due to continuing uncertainties in the permitting process (WateReuse, 2011d).

4.2.4 Operations & Maintenance and Annualized Costs

Annual operations and maintenance (O&M) costs for SWRO desalination facilities are dominated by the cost of power needed to push the water through the membranes. The relative costs of the O&M costs are summarized in the following (WateReuse, 2011d):

- power = 55%
- filter and membrane replacement = 11%
- labor = 6%
- chemicals = 6%
- equipment maintenance = 6%
- waste solids disposal = 4%
- legal/permitting (monitoring and compliance) = 2%
- other = 10%

Annualized capital and O&M costs vary widely from $2.00/kgal to $12.00/kgal. The facilities at the higher end of the cost spectrum are generally either very small capacity, or have site-specific challenges related to intake and outfall structures. If one removes such facilities, the general range of the annualized cost to produce desalinated water is reported by WateReuse (2011d) as $2.00/kgal to $6.00/kgal.

Figure XX. Cost of Desalinated Water in Southern California, as published online by National Geographic (Image Source: Excerpted from graphic at http://ngm.nationalgeographic.com/big-idea/09/desalination; Art by Bryan Christie. Sources: Tom Pankratz, Global Water Intelligence; International Desalination Association; Mark A. Shannon, University of Illinois; Aleksandr Noy, University of California, Merced)

The annualized cost breakdown for a SWRO facility shows the relative significance of the initial capital investment and the power usage - even when annualized capital costs are included, the cost of power to run the facility is more than a quarter of the cost. The relative annualized capital and O&M costs, as published by WateReuse (2011d), is shown below:

- SWRO system construction = 31%
- power = 26%
- intake & discharge construction = 11%
- pretreatment construction = 12%
- project design & permitting = 7% (likely higher in CA)
- SWRO membrane replacement = 6%
- other = 9%

Cooley et al. (2006) provide a similar breakdown of annualized costs, as shown in Figure xx; as do Manning Hudkins et al. (2009), shown in Figure yy.

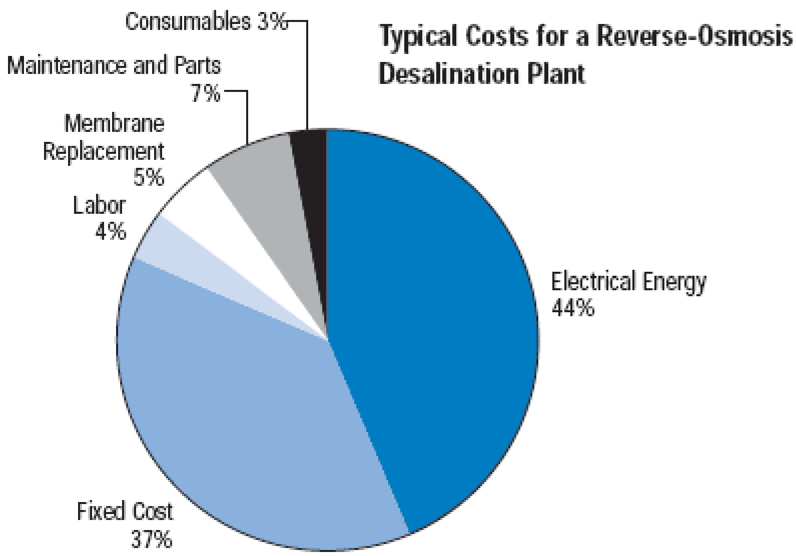

Figure xx. Cost breakdown of RO desalination per the Pacific Institute (Cooley et al.,2006) (Image Source: http://www.pacinst.org/reports/desalination/20060627.html)

Note that the proportion of electrical energy costs is much higher in the numbers published by Cooley et al. (44%) than those published by WateReuse (26%), while the estimate by Manning Hudkins et al. (34%) is somewhere in between. On the other hand, the relative proportion of the capital costs published by WateReuse, which sum to over 60%, is much higher than the relative “fixed cost” or “capital cost” published by Cooley et al. (37%) and Manning Hudkins et al. (41%), respectively. Once again, this highlights the difficulty in achieving an accurate generalized cost model for SWRO desalination plants as a category.

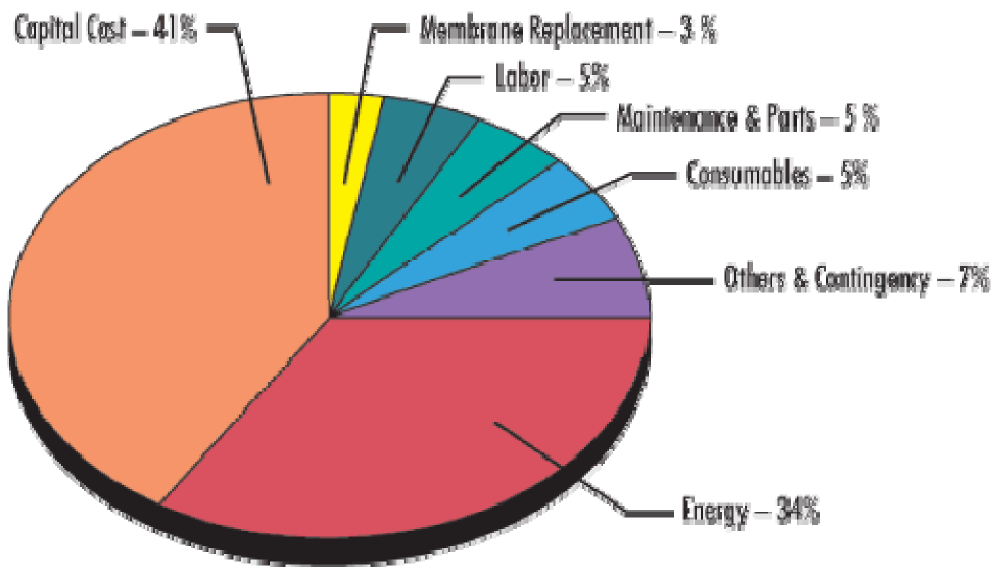

Figure yy: Cost breakdown of RO desalination per Manning Hudkins et al. (2009),
(Image Source: http://www.waterworld.com/index/current-issue/membranes/volume-2/issue-30.html)

4.2.5 Other Costs Considerations

- Other costs – power, proximity, labor
  - skilled labor was a challenge in Australia
  - proximity to water users
  - proximity to power

5.0 KEY ENVIRONMENTAL ISSUES OF CONCERN FOR DESALINATION PROJECTS

[ESA to write…]

- Need for water/goals and objectives
- Intake
  - Subsurface vs. open water
  - Entrainment/Impingement
  - Co-location with power plants/once thru cooling
  - Intake feasibility studies
- Brine discharge
  - Effect on marine water quality and marine life
  - Geophysical investigations
  - Brine discharge/dilution studies
- CEQA-Ready project description

6.0 PERMITS REQUIRED

[ESA to write…]

- Key CA Coastal Commission issues of concern for desalination
  - Land Use Consistency
  - Coastal Dependency
  - Energy/GHG
  - Subsurface Intake feasibility
- Federal agencies
  - US Fish and Wildlife Service
  - NOAA Fisheries
  - US Army Corps of Engineers
- State agencies
  - California Coastal Commission
  - Regional Water Quality Control Board
  - California State Lands Commission
  - California Department of Fish and Game
  - California Department of Health Services
  - California Department of Transportation
- Local agencies
  - Ventura County Public Works
  - Ventura County Environmental Health Division
  - Ventura Air Pollution Control District
  - City of Oxnard

7.0 IMPLEMENTATION SCHEDULE

Implementation schedules for SWRO facilities vary significantly from project to project. The major variability arises from differences in permitting and public communication timelines. In California, these aspects generally require several years to complete, due to requirements for extended baseline environmental studies, frequent vocal public opposition that has to be managed, and uncertainties in the permitting requirements. Figure X.X (separate file, in Excel, landscape format) shows an example schedule for implementation of a hypothetical California SWRO desalination facility. This schedule is based on the proposed and in some cases partially implemented schedules for several current desalination projects in California, including the Monterey Bay Regional Desalination Project (MBRDP, 2011), the Bay Area Regional Desalination Project (BARDP, 2012), the Santa Cruz Water scwd^2 desalination project[4] (SCWD2, 2008), and a Work Plan for Project Implementation for desalination at the City of San Luis Obispo, CA (Boyle, 2007).

[4] scwd^2 represents the Seawater Desalination Program Task Force with members from the Santa Cruz City Council and the Soquel Creek Water District Board.

[add text re: schedule after in house review]

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Additional Photos / Graphics of Potential Interest:

Figure xx. Aerial photograph of the 70 MGD Kurnell Desalination Plant near Sydney, Australia (Image Source: http://www.sydneywater.com.au/education/Tours/tourKDP.cfm)

APPENDIX I – ENERGY BENCHMARKING REPORT

LINCUS INCORPORATED

Energy Efficiency

Engineering

City of Oxnard
Water System Optimization:

Preliminary Benchmarking Report

Water Infrastructure and System Efficiency (WISE™) Program

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March 10, 2015

DISCLAIMER AND CONFIDENTIALITY

This report is not intended to serve as an engineering design document, but is intended to provide estimated energy-efficiency savings, possible utility/federal incentives, and Return-On-Investment (in years) associated with the proposed energy-efficiency measures (EEM) for the specific locations at the City of Oxnard Water Systems. The information and recommendations represented in this report are very high level and not for design or construction. Prior to any installation, it is highly recommended that a detailed energy audit is conducted.

It is to be noted that the savings estimates presented herein have been based on the available data, and information obtained from Southern California Edison (SCE). Lincus, Inc. and/or SCE are not liable if the projected estimated savings or economics are not actually achieved because of varying operating conditions at the site. All the savings and cost estimates are for informational purposes, and are not to be construed as a design document or as guarantees. The customer should independently evaluate the information presented in this report, and in no event will Lincus, Inc. or SCE be held liable if the customer fails to achieve a specified amount of energy savings, operation of their facilities, or any incidental or consequential damages of any kind in connection with this report or the installation of the recommended measures.

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Executive Summary

Lincus was requested by Southern California Edison ("SCE") to assist the City of Oxnard ("City") in identifying energy-efficiency opportunities at their Water Pumping stations. As a part of this effort, Lincus conducted a very high level analysis using available and empirical data to estimate the potential savings opportunity based on the available plant data and historical pump test results for the City. The pumps tests that were used in this analysis were noted to be conducted between years 2000 and 2010. The benchmarking analysis presented here assumes that all pumps for which pump tests were provided are currently operational. Further, the analysis also assumes that these pumps have not been retrofitted since the pump tests were completed. Actual site conditions will be verified during a detailed system audit.

Table 1 below provides a high-level summary of the recommended Energy Efficiency Measures (EEMs). Lincus has developed the following "Low Range and "High Range" savings estimates based on multiple approaches in calculating system efficiency. The proposed energy efficiency measures provide a total energy savings of 891,507 to 1,158,838 kWh/year and 125 to 221 Peak kW[1], which equates to an annual utility cost savings[2] of $82,346 to $109,661. The total cost to implement these measures is estimated to be $484,500 to $911,250 which along with the estimated SCE incentives of $170,359 to $230,145 puts the simple payback period between 3.8 to 6.2 years. As a part of the detailed audit, Lincus engineers will work closely with the City and SCE to identify eligible program measures and maximize the total utility incentives possible from the measures identified.

Table 1: Estimated Savings

			EEM 1		EEM 2		EEM 3	
	Project Total		System Optimization of Well Pumps		System Optimization of Booster Pumps		Pump Efficiency Improvement	
	Low Range	High Range	Low Range	High Range	Low Range	High Range	Low Range	High Range
kWh/yr. Savings	891,507	1,158,838	37,113	301,580	0	0	854,394	857,258
Peak kW Savings	125	221	7	45	0	0	119	176
Measure Cost	$484,500	$911,250	$64,500	$204,250	$0	$0	$420,000	$707,000
Utility Savings	$82,346	$109,661	$3,796	$30,849	$0	$0	$78,550	$78,813
SCE Incentive	$170,359	$230,145	$7,303	$57,966	$0	$0	$163,056	$172,179
Net Cost	$314,141	$681,105	$57,197	$146,284	$0	$0	$256,944	$534,821
Simple Payback	3.8	6.2	15.1	4.7	n/a	n/a	3.3	6.8

[1] System Optimization Peak kW savings calculated by dividing the annual kWh savings by pump by the ratio of the annual kWh usage and measured motor kW to obtain the annual operating hours and multiplying by a 0.65 CDF. Pump Efficiency Improvement Peak kW savings calculated using a 0.65 CDF.

[2] Based on average utility rate of $0.09/kWh for well pumps and $0.116/kWh for booster pumps using billing analysis, Incentive rate of $0.08/kWh plus a partnership kicker of $0.06/kWh, maximum SCE incentive = 80% of project cost.

Benchmarking Methodology

This preliminary benchmarking analysis is based on the available pump test results conducted between 2001 and 2014 for the City's pumps that were collected by SCE Hydraulic Services. This type of benchmarking process provides a very high level overview of savings potential present in the system. This process also yields a first iteration of a list of pumps that deserve a more detailed analysis for system optimization.

Lincus' purpose in this two-step process is to first identify projects at a high level to ensure that the client is still interested in moving forward with energy efficiency projects. Once this step is determined based on the magnitude of savings and input from the water district, Lincus will address system optimization measures as well as detailed savings and estimated costs within the second step. In addition to providing a list of possible measures that could be potentially targeted using a detailed analysis, this preliminary benchmarking analysis also provides an indication of time investment needed by water agencies in supporting the program, i.e. data requests, on site audits, whetting different approaches to system optimization etc.

Pump System Benchmarking

Benchmarking in this program is done using existing pump test data. Based on available test results for the City's pumps between 2000 and 2010 and that are used as a first pass to estimate the potential of the energy savings that could be attained at the sites. Pump test data, based on the actual operational data, provides a temporal snapshot of the system and the current analysis assumes that all of the pumps presented here are operational and that no retrofit operations had been performed. These assumptions will be validated during the detailed audit procedure. Initially, for fair comparison, Lincus separated the pump test data into:

- Well Pumps
- Booster Pumps

With this separation, Lincus is better able to make a reasonable comparison of pump operation within the client's system. There are certain cases where a well pump discharges directly into the distribution system; under this scenario, the pump is operating both as a well pump and a booster pump (dual role). Lincus observes discharge pressure readings to provide an indication of situations where a pump is satisfying dual roles. These pumps will have to be dealt with on a case-by-case basis for benchmarking.

The benchmarking process is based on comparing calculated energy intensities (kWh/AF converted to kWh/MG) against reference points. These reference points are normalized based on per foot of pump head so that all pumps are compared fairly. This is done using two methods. The first method is by comparing this intensity to published state averages for well pump and booster pump operations separately. The second method is by figuring out an internal reference point within the system and comparing intensities of other pumps in the system to this internal reference point. This is again done separately for well pumps and booster pumps. The idea is to bring the rest of the system to the reference points identified, be it California state averages or an internal point within the system being analyzed. This gives us a range of savings possible with the distribution system.

The following Energy Efficiency Measures ("EEMs") are preliminarily identified as measures that may be applicable to significantly and economically optimize energy use. Please note that there may be many other measures identified resulting from an energy audit of the district's system.

1) EEM 1: System Optimization of Water Distribution System Well Pumps;
2) EEM 2: System Optimization of Water Distribution System Booster Pumps;
3) EEM 3: Pump Efficiency Improvement.

Water system optimization includes multiple measure opportunities, including, but not limited to optimize pump controls, VFD applications on pumps, optimize VFD set-points, optimize pump system control valves, pressure management, optimize pump sequencing, install air release valves at pump discharge and optimize use of water storage. Specific opportunities will be evaluated upon an on-site audit and detailed analysis of existing systems.

The implementation of the pump efficiency improvement measure may include, but may not be limited to pump bowl assembly and impeller repairs or replacements, impeller trimming, pump operation improvement, and right sizing of equipment.

Energy Efficiency Measures

EEM 1 & 2: System Optimization of Water Distribution System Well & Booster Pumps

Generally, Lincus may identify:

1) Optimize Pump Controls
2) VFD Applications on Pumps
3) Optimize VFD Set-points
4) Optimize Pump System Control Valves
5) Pressure Management using Pressure Reducing Valves (PRVs) or In-Conduit Generation
6) Optimize Pump Sequencing
7) Install Air Release Valves at Pump Discharge
8) Optimize Use of Water Storage

Optimize Pump Controls

For water systems with varying water demands and pressure requirements, there is need for flow rate and/or discharge pressure controls. Possible flow rate control strategies include throttling valves, on-off control, or other flow control valve strategies. These are inefficient ways of flow control due to the high amount of energy wasted. This measure recommends decommissioning the existing flow control valves and installing a variable frequency drive (VFD) or proportional-integral-derivative (PID) control for flow control. Controls will modulate the speed of the motors as per system requirements. PID controls enable tighter control of system parameters, especially pressure. This allows pumps serving the system to operate in an optimal fashion.

VFD Applications on Pumps

A variable-frequency drive (VFD) controls the rotational speed of an electric motor by varying its input voltage and frequency, thus changing water flow rates. This allows the delivery of the water to track the load of that system.

For example, when the water demand is relatively low, the well and booster pumps of a city water distribution system modulate to lower speeds, delivering just the right amount of water required to maintain system pressure. The baseline would be flow control through a throttling valve, on-off control, or another flow control valve strategy. These baseline flow control strategies described above are inefficient ways of flow control due to the high amount of energy wasted.

Optimize VFD Set-points

A variable-frequency drive (VFD) controls the rotational speed of an electric motor by varying its input voltage and frequency, thus changing water flow rates. This allows the delivery of the water to track the load of that system.

VFDs are programmed to meet system demands based on a set-point that typically tracks system pressure or flow rate range. For VFDs with a system pressure set-point, if the system pressure decreases below the low pressure set-point, the VFD will ramp up the pump. Conversely, if the system pressure exceeds the high pressure set-point, the VFD will ramp down the pump. A similar method is used for VFDs with flow rate set-points.

Fully commissioned VFDs, may not be meeting the system demand as there are changes in the pump operations, water system demand, water system upgrades, water table changes. The original VFD set-points may no longer meet system requirements due to the system changes, thus this measure updates the VFD set-point to meet current system requirements.

Optimize Pump System Control Valves

Pumping system control valve inefficiencies in plant operations offer opportunities for energy savings and reduced maintenance costs. Valves that consume a large fraction of the total pressure drop for the system or are excessively throttled can be opportunities for energy savings. Pressure drops or head losses on liquid pumping systems increase the energy requirements of these systems. Pressure drops are caused by the resistance or friction in piping and in bends, elbows, joints, as well as by throttling across control valves. The power required to overcome a pressure drop is proportional to the flow rate and the magnitude of the pressure drop.

The friction loss and pressure drop caused by fluids flowing through valves and fittings depend on the size and type of pipe and fittings used, the roughness of interior surfaces, and the fluid flow rate and viscosity and is typically characterized using K values. Typical ranges of head loss coefficients (K values) for various fittings are given in Table 2[3].

Table 2: Range of Head-loss Coefficients (K) for Water Flowing through Valves

Fitting Description	K Value
Globe valve, fully open	3 - 8
Ball valve, fully open	0.04 - 0.1
Check valve, fully open	2
Gate valve, fully open	0.03 - 0.2
Butterfly valve, fully open	0.5 - 2

[3] "Flow of Fluids: Through Valves, Fittings and Pipe", Technical Paper No. 410

The measure recommends decommissioning the existing pump system control valve with another valve of lower K Value.

Pressure Management using PRVs or In-Conduit Turbine

A water distribution system spanning a service territory with vast elevation changes may experience increases in system pressure as water moves through the system from higher elevation to lower elevation. Pumps with automated flow rate controls serving the water distribution system may operate under varying pressure set-points. For pumps meeting the water system demand with pressure set-points in excess of 60 psi, there may be opportunity to decrease the overall system pressure via pressure reducing valves (PRVs) installed upstream of the pumps to decrease the pressure set-point requirements, thus reduce the energy consumed by the pumps downstream of the PRVs.

PRVs work by dissipating higher pressure that is upstream of the valve thus resulting in a lower pressure downstream of the valve. This can result in wasting valuable hydraulic energy. Instead of using a PRV, pressure reductions can be made possible by installing In-Conduit Turbines (ICTs). ICT can assist in pressure reductions by using excess head in a pipeline to generate electric power. Please contact your SCE account representative regarding incentive information for the implementation of ICTs.

Optimize Pump Sequencing

Process equipment like pumps lose efficiency over time due to normal equipment wear and tear. Overall equipment efficiency (OPE) is also affected by system conditions and how far off they are from equipment design conditions. Pumps with greater OPEs consume less energy for similar volumes of water pumped.

Booster stations may include 1 pump or multiple pumps. For booster stations with multiple pumps in parallel, there may be a pump with a greater OPE relative to the other pumps within the booster station. This measure sequences the pump operations such that the pump with the greatest OPE is the primary pump. Once the demand exceeds the capacity of the primary pump, the pump with the next greatest OPE is turned on to meet the demand, and so on. This pump sequencing optimizes the energy consumed to meet system demands.

Install Air Release Valves at Pump Discharge

The measure includes the installation of air release valves immediately after the pump discharge. Air release valves remove air build up within the pipeline. Air build up essentially reduces available pipe cross sectional area to move water. For the same gallons per minute flow, a reduction in cross sectional area results in a higher fluid velocity going through the pipeline. Frictional pressure loss in a pipeline is proportional to the square of fluid velocity. Addressing air build up in a pipeline can therefore result in a lower frictional pressure drop. With appropriate controls, lower frictional pressure drop will result in less energy consumption at the pump.

Optimize Use of Water Storage

The measure includes sequencing pump operation based on optimal use of water storage tanks. Ensuring proper use of storage tanks will result in proper cycling of pumps. This would in turn mean that there are less frequent start/stop situations. In addition, depending on the amount of storage available, some pumps can even be switched off during peak periods which further bring down cost of operation.

EEM 3: Pump Efficiency Improvement

Process equipment like pumps lose efficiency over time due to normal equipment wear and tear. Overall equipment efficiency is also affected by system conditions and how far off they are from equipment design conditions. The measure is a pump that is overhauled for improved efficiency to better match the design of the pump to the actual system operating conditions. Doing so will improve the overall plant efficiency (OPE) of the pump. Table 3 below shows the typical Overall Plant Efficiency percentages as a function of motor HP for the well and booster pumps as recommended by the industry experts[4].

Table 3 Typical Pump Overall Plant Efficiencies

Motor HP	Low%	Fair %	Good %	Excellent		
				Well Pump	Booster	Submersible
3 - 5	≤ 41.9	42.0 - 49.9	50.0 - 54.9	≥ 55.0	≥ 55.0	≥ 52.0
7.5 - 10	≤ 44.9	45.0 - 52.9	53.0 - 57.9	≥ 58.0	≥ 60.0	≥ 55.0
15 - 30	≤ 47.9	48.0 - 55.9	56.0 - 60.9	≥ 61.0	≥ 65.0	≥ 58.0
40 - 60	≤ 52.9	53.0 - 59.9	60.0 - 64.9	≥ 65.0	≥ 70.0	≥ 62.0
75 - up	≤ 55.9	56.0 - 62.9	63.0 - 68.9	≥ 69.0	≥ 72.0	≥ 66.0

Implementation of this measure includes, but not limited to

- Replacing and/or repairing bowl assembly, impellers and other integral equipment components of the pump.
- Improving pump operations.
- Installing right sized equipment that will improve the overall plant efficiency of the pump operation.

4 Overall Plant Efficiency Chart, California Public Utilities Commission Efficiency Ranges

Figure 1 shows the pump equipment contributing to the OPE and a visual representation of systems to evaluate when implementing this measure.

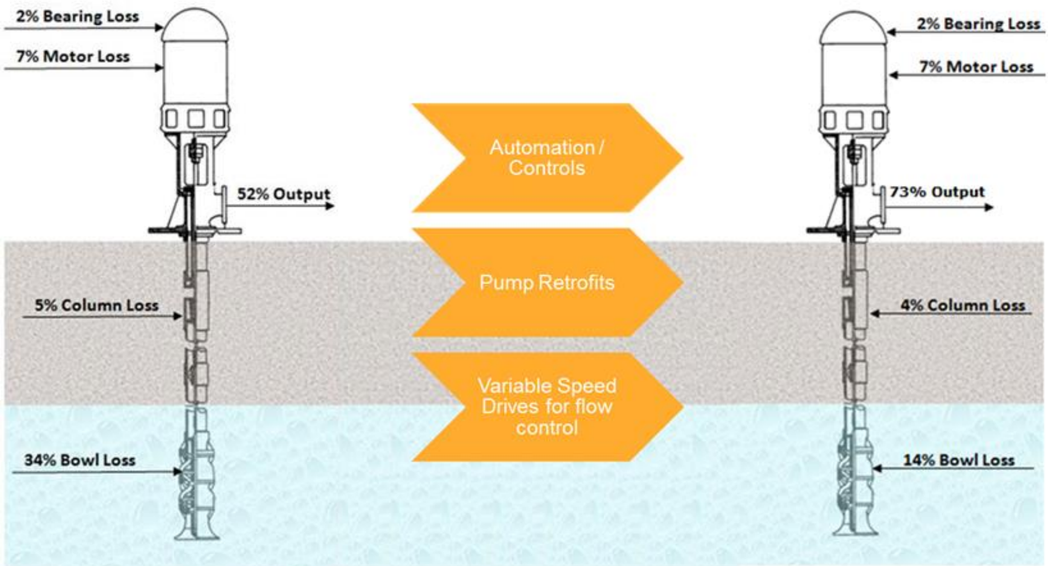

Figure 1: Pump Efficiency Improvement Example

MODEL BASED CONTINUOUS OPTIMIZATION OF PUMP SYSTEMS (iPT)

The measure includes the installation of the Lincus Integrated Pump Tool (iPT) via the installation pump system controls and software with the capability of calculating pump OPE on a real-time basis. This tool provides opportunity for implementation for optimized pump sequencing. It also informs operators when there is opportunity for pump efficiency improvement based on OPE thresholds. The controls also enable the pump system's eligibility to participate in Auto Demand Response Programs.

The measure may also include the development of a hydraulic model via WaterCAD and/or WaterGEMS to verify the overall system efficiency. The model may be re-run annually to ensure persistence of implemented measures and identification of degradation of overall system efficiency.

Appendix: Savings Output

The following tables include specific energy efficiency and consumption calculation information on each pump Lincus has reviewed.

Table 4: System Optimization and Pump Efficiency Improvement of Water Distribution System Well Pumps

								System Optimization						Pump Efficiency Improvement					
								Low Range			High Range			Low Range			High Range		
SCE Service Account #	Pump Name	Test Date	Pump Location	Motor HP	Test Eff. %	Impr. Eff. %	After Pump Overhaul kWh/MG	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)
009-4642-10	WELL #16	7/18/2000	1001 RICHMOND AV	300	55.4	55.4		-	-	-	-		-	-	-	-	-	-	-
010-6117-37	WELL #1	7/6/2000	251 SO HAYES AV	40	40.7	40.7		-	-	-	-		-	-	-	-	-	-	-
010-6117-37	WELL #3	7/6/2000	251 SO HAYES AV	40	39.4	39.4		-	-	-	-		-	-	-	-	-	-	-
010-6117-37	WELL #4	7/6/2000	251 SO HAYES AV	75	23.9	23.9		-	-	-	-		-	-	-	-	-	-	-
010-6117-36	WELL #21	7/19/2001	251 SO HAYES AV	300	46.2	70.0	496	37,113	6.63	64,500	-	-	-	252,536	45.08	105,000	252,536	45.08	105,000
010-6117-37	WELL #20	6/8/2009	251 S HAYES AVE	300	68.9	68.9	1,181	-	-	-	-	-	-	-	-	-	-	-	-
010-6117-36	WELL #23	6/8/2009	251 S HAYES AVE	250	52.2	70.0	1,007	-	-	-	-	-	-	-	-	-	571	30.91	87,500
010-6117-37	WELL #22	6/8/2009	251 S HAYES AVE	300	59.7	70.0	1,003	-	-	-	-	-	-	-	-	-	350	18.94	105,000
030-1287-46	WELL #32	10/20/2010	242 3RD ST	450	59.6	74.0	1,638	-	-	-	222,786	17.78	96,750	370,911	29.60	157,500	370,911	29.60	157,500
030-1287-46	WELL #33	10/20/2010	242 3RD ST	600	70.5	70.5	1,345	-	-	-	-	-	-	-	-	-	-	-	-
030-1287-46	WELL #34	10/20/2010	242 3RD ST	500	75.8	75.8	1,749	-	-	-	78,794	26.87	107,500	-	-	-	-	-	-
027-2806-13	WELL #28	6/15/2009	1700 SOLAR AVE	300				-	-	-	-	-	-	-	-	-	-	-	-
027-2806-13	WELL #29	6/15/2009	1700 SOLAR AVE	450				-	-	-	-	-	-	-	-	-	-	-	-
027-2806-13	WELL #30	6/15/2009	1700 SOLARAVE	300				-	-	-	-	-	-	-	-	-	-	-	-
027-2806-13	WELL #31	6/15/2009	1700 SOLARAVE	250	63.3	69.0	972	-	-	-	-	-	-	-	-	-	234	6.34	87,500

Table 5: System Optimization and Pump Efficiency Improvement of Water Distribution System Booster Pumps

								System Optimization						Pump Efficiency Improvement					
								Low Range			High Range			Low Range			High Range		
SCE Service Account #	Pump Name	Test Date	Pump Location	Motor HP	Test Eff. %	Impr. Eff. %	After Pump Overhaul kWh/MG	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)	Estimated Savings (kWh/yr)	Estimated Peak kW Savings	Measure Cost ($)
010-6117-1	BOOSTER #1	7/17/2001	251 SO HAYES AV	150	57.3	70.0	602	-	-	-	-	0.00	-	78,974	14.56	52,500	78,974	14.56	52,500
010-6117-1	BOOSTER #2	7/17/2001	251 SO HAYES AV	150	58.3	70.0	617	-	-	-	-	-	-	67,595	13.52	52,500	67,595	13.52	52,500
010-6117-1	BOOSTER #3	7/17/2001	251 SO HAYES AV	150	56.3	70.0	601	-	-	-	-	-	-	84,379	15.97	52,500	84,379	15.97	52,500

APPENDIX J – WEAP MODEL SUMMARY

City of Oxnard, California

Integrated Water Resources Master Plan

Water System

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WEAP MODEL

2.1 INTRODUCTION

This section will focus on the Water Evaluation And Planning (WEAP) software that was developed for the City as a part of the Public Works Integrated Master Plan (PWIMP). WEAP is a flow and mass balance model that was developed and supported by the Stockholm Environment Institute (SEI), and with enhancements funded by the Hydraulic Engineering Center of the US Army Corps of Engineers.

The Oxnard water system was modeled as a skeletonized system in WEAP, including drinking water sources, blending and treatment via the desalters, potable and recycled water demands, and wastewater treatment for indirect potable and non-potable reuse, and discharge. The recommended projects were included to verify that water quality objectives could be met. Figure 1 shows the Oxnard system as represented in the WEAP model.

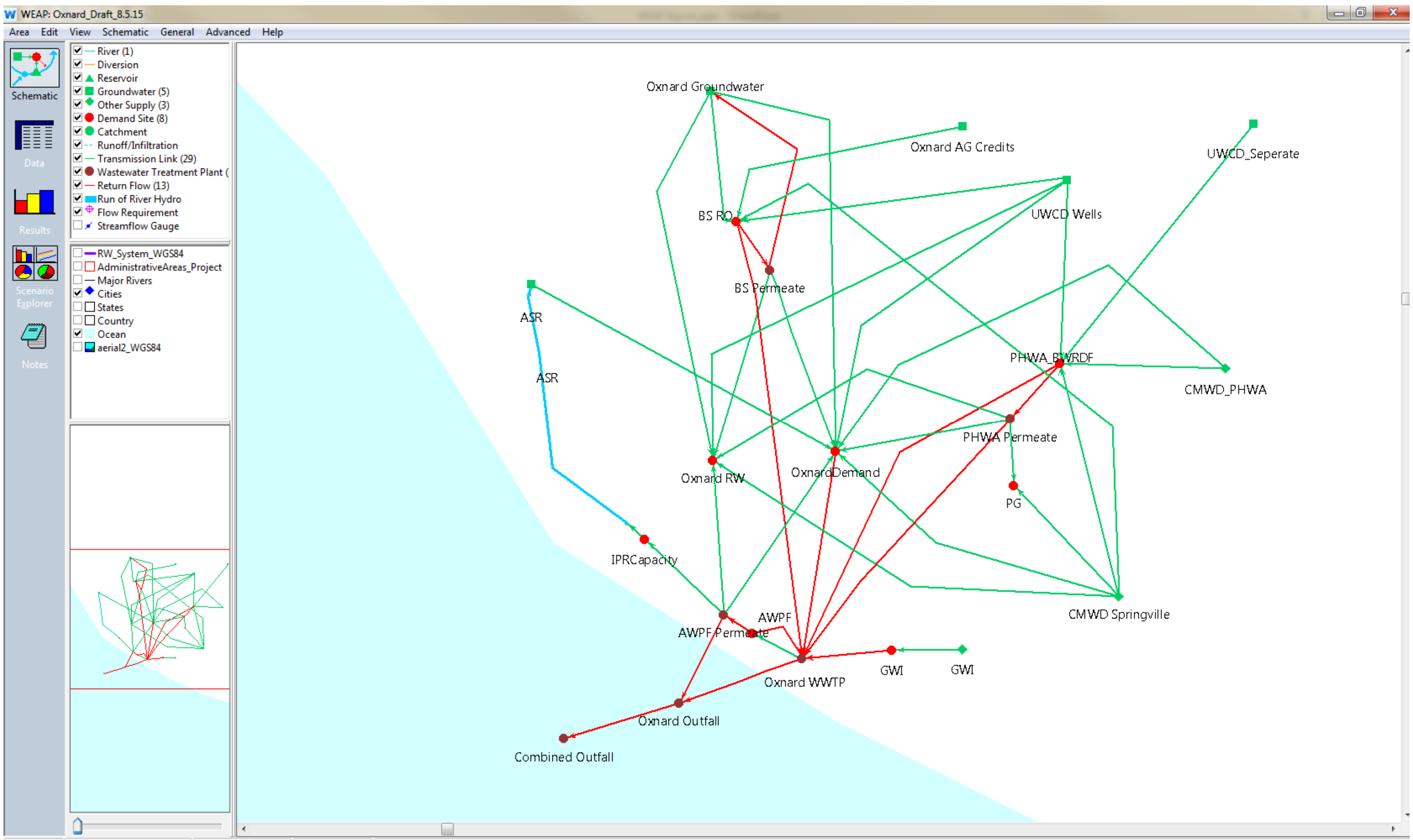
The WEAP model was developed as one of the tools available to the project team to predict the water quality for the recommended projects. The primary water quality parameters tracked within the WEAP model for Oxnard were hardness and total dissolved solids (TDS). Although other water quality parameters are important and discussed in Section 5.0 of PM 2.5, only TDS and hardness were tracked since these were key, governing parameters for the additional use of treated water for eventual usage in the potable supply system. The existing system and the recommended projects identified in PM 2.5 were modeled.

2.2 MODEL COMPONENTS AND INPUTS

The Oxnard system was constructed in the WEAP model as a simplified, skeletonized system. The following sections describe the key model components and inputs, including:

- Water supplies, quantity and quality.
- Potable and recycled water demands.
- Water quality objectives for potable water distribution.
- Water and wastewater treatment.
- Water demands prioritization and supply preferences.

Figure 1. Oxnard skeletonized system modeled in WEAP©.



2.2.1 Water Supplies

The water supplies that were modeled in WEAP were the same as previously discussed in PM 2.5, Section 3.0, Existing and Future Water Supplies. Table 1 is a summary of the existing and future water supplies with the recommended projects in place. A plot of the Table 1 water supply data is shown below Table 1.

Table 1 Summary of Projected Supply with Recommended Projects

Public Works Integrated Master Plan

City of Oxnard

Supply	Projected Supply (AFY)												
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Local Groundwater(2)	6,705	6,705	6,705	6,705	6,705	6,705	16,383	16,383	26,061	26,061	26,061	26,061	26,061
Baseline	954	954	954	954	954	954	954	954	954	954	954	954	954
Historical Use	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751
Water improvements													
Expand desalter @ BS1/6 to 11.25mgd	12,610	12,610	12,610	12,610	12,610	12,610	12,610	18,915	18,915	18,915	18,915	18,915	18,915
3 new potable wells @ BS1/6	0	0	0	0	0	0	9,678	9,678	9,678	9,678	9,678	9,678	9,678
2 new potable wells @ BS1/6, 1 new stainless steel well @ BS3	0	0	0	0	0	0	0	0	9,678	9,678	9,678	9,678	9,678
RW improvements	0	3,226	6,452	9,678	12,904	12,904	12,904	12,904	19,356	19,356	19,356	19,356	25,808
AWPF expansion (see RW offset)													
ASR wells @ Campus Park	0	3,226	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452
ASR wells @ BS1/6	0	0	0	3,226	6,452	6,452	6,452	6,452	12,904	12,904	12,904	12,904	12,904
ASR wells @ BS3	0	0	0	0	0	0	0	0	0	0	0	0	6,452
UWCD(3)	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535
CMWD(4)	13,826	13,826	13,826	13,826	13,826	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443
PHWA Exchange(5)	700	700	700	700	700	700	700	700	700	700	700	700	700
Ag Development Re-Allocation(6)	0	0	0	0	0	149	149	149	149	376	376	376	376
Subtotal Supply	25,766	28,992	32,218	35,444	38,670	37,436	47,114	47,114	63,244	63,471	63,471	63,471	69,923
Recycled Water Offset(7)	21,017	21,017	21,017	21,017	21,017	21,017	21,017	21,017	21,017	21,017	21,017	21,017	31,525
RW Pump Back Allocation(8)	0	0	0	0	0	0	0	0	0	0	0	0	0
Loss (Brine)(9)	-10,526	-11,252	-11,978	-12,704	-13,430	-13,152	-15,329	-15,329	-18,959	-19,010	-19,010	-19,010	-22,826
Total Firm Supply	36,257	38,757	41,257	43,757	46,257	45,301	52,801	52,801	65,302	65,478	65,478	65,478	78,623

Supply	Projected Supply (AFY)												
	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Local Groundwater(2)	26,061	26,061	26,061	26,061	26,061	26,061	26,061	26,061	26,061	26,061	26,061	26,061	26,061
Baseline	954	954	954	954	954	954	954	954	954	954	954	954	954
Historical Use	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751	5,751
Water improvements													
Expand desalter @ BS1/6 to 11.25mgd	18,915	18,915	18,915	18,915	18,915	18,915	18,915	18,915	18,915	18,915	18,915	18,915	18,915
3 new potable wells @ BS1/6	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678
2 new potable wells @ BS1/6, 1 new stainless steel well @ BS3	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678	9,678
RW improvements	25,808	32,260	32,260	32,260	32,260	32,260	32,260	32,260	32,260	32,260	32,260	32,260	32,260
AWPF expansion (see RW offset)													
ASR wells @ Campus Park	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452	6,452
ASR wells @ BS1/6	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904
ASR wells @ BS3	6,452	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904	12,904
UWCD(3)	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535	4,535
CMWD(4)	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443	12,443
PHWA Exchange(5)	700	700	700	700	700	700	700	700	700	700	700	700	700
Ag Development Re-Allocation(6)	376	376	603	603	603	603	603	830	830	830	830	830	1,057
Subtotal Supply	69,923	76,375	76,602	76,602	76,602	76,602	76,602	76,829	76,829	76,829	76,829	76,829	77,056
Recycled Water Offset(7)	31,525	31,525	31,525	31,525	31,525	31,525	31,525	31,525	31,525	31,525	31,525	31,525	31,525
RW Pump Back Allocation(8)	0	0	0	0	0	0	0	0	0	0	0	0	0
Loss (Brine)(9)	-22,826	-24,278	-24,329	-24,329	-24,329	-24,329	-24,329	-24,380	-24,380	-24,380	-24,380	-24,380	-24,431
Total Firm Supply	78,623	83,623	83,799	83,799	83,799	83,799	83,799	83,975	83,975	83,975	83,975	83,975	84,151

Notes:

(1) A restriction in the groundwater pumping of 50% of historical allocation (regulated by the FCGMA) is assumed on all groundwater sources, unless otherwise noted.

(2) The City's groundwater allocation is made up of a baseline and historical use allocation. The assumed FCGMA restriction on groundwater pumping is applied to the historical allocation only. Additional ASR wells are assumed not to be subject to pumping restrictions and are captured within local groundwater.

(3) The assumed FCGMA restriction is applied to the historical UWCD allocation.

(4) CMWD projection is based on Jan 13, 2015 Recycled Water Council Presentation done by the City. It does not include 4,700 AFY allocated to PWHA.

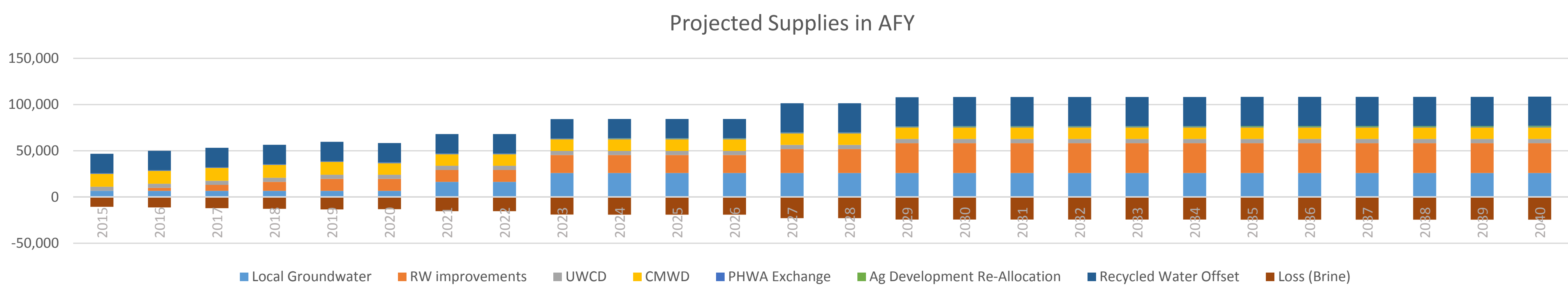
(5) Annual transfer of FCGMA credits from PHWA, per 2002 Three Party Water Supply Agreement.

(6) Estimate for ag re-allocation is based upon planned ag conversion acreage through 2040 and using a re-allocation factor of 1 AFY per acre converted.

(7) Assumes all of AWPF capacity is used as RW supply.

(8) Based on a 0.5:1 pump-back allocation ratio of RW supplied to ag users (Southland, Houweling, Reiter, and River Ridge Golf Course)

(9) Assuming 77.5% recovery for desalter & AWPF (same assumption as previous Table 2)



2.2.2 Potable and recycled water demands

The projected potable and recycled water demands were based on the information presented in PM 2.2. Table 2 is a summary of the potable and recycled water demands included in the WEAP model. A plot of the Table 2 water demand data is shown below Table 2.

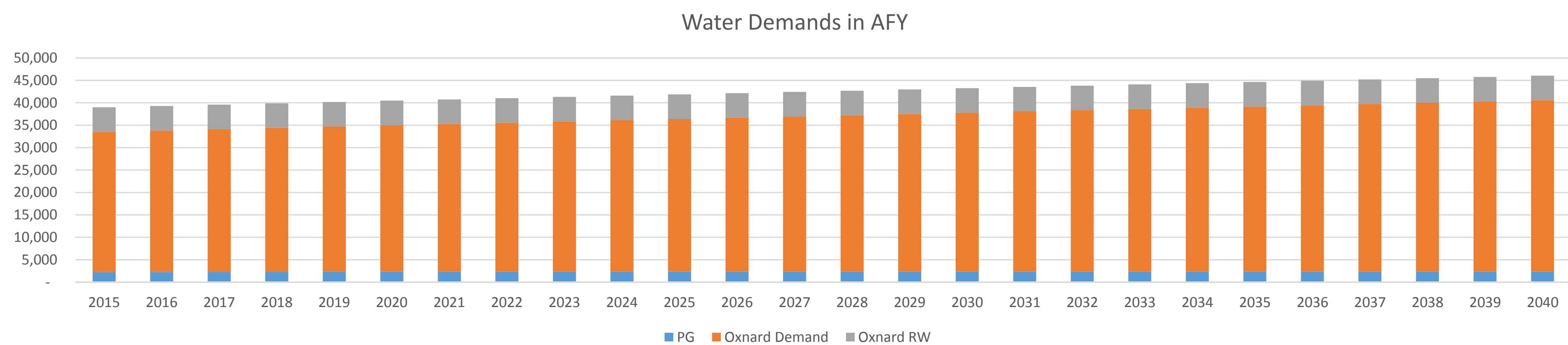
Table 2 Summary of Projected Demands in AFY

Public Works Integrated Master Plan

City of Oxnard

Demand node	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
PG	2,238	2,257	2,277	2,296	2,316	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335
Subtotal	2,238	2,257	2,277	2,296	2,316	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335
Oxnard Demand													
Residential	19,629	19,804	19,978	20,153	20,327	20,502	20,676	20,851	21,025	21,200	21,374	21,549	21,723
Commercial	2,662	2,686	2,709	2,733	2,756	2,780	2,804	2,827	2,851	2,874	2,898	2,922	2,946
Industrial Institutional	6,654	6,713	6,772	6,832	6,891	6,950	7,009	7,068	7,128	7,187	7,246	7,305	7,364
Ag	665	671	677	683	689	695	701	707	713	719	725	731	737
Other	1,664	1,679	1,693	1,708	1,722	1,737	1,752	1,767	1,781	1,796	1,811	1,826	1,841
Subtotal	31,274	31,552	31,830	32,108	32,386	32,664	32,942	33,220	33,498	33,776	34,054	34,332	34,610
Oxnard RW													
NewIndyPaper	800	800	800	800	800	800	800	800	800	800	800	800	800
RiverRidgeGC	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
RiverPkDev	175	175	175	175	175	175	175	175	175	175	175	175	175
Southland	800	800	800	800	800	800	800	800	800	800	800	800	800
Reiter	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Houweling	800	800	800	800	800	800	800	800	800	800	800	800	800
Subtotal	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475
Totals	38,987	39,284	39,582	39,879	40,177	40,474	40,752	41,030	41,308	41,586	41,864	42,142	42,420

Demand node	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
PG	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335
Subtotal	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335	2,335
Oxnard Demand													
Residential	21,898	22,072	22,247	22,422	22,596	22,771	22,945	23,120	23,294	23,469	23,643	23,818	23,992
Commercial	2,969	2,993	3,017	3,041	3,064	3,088	3,111	3,135	3,159	3,182	3,206	3,229	3,253
Industrial Institutional	7,423	7,482	7,541	7,600	7,659	7,719	7,778	7,837	7,896	7,955	8,015	8,074	8,133
Ag	743	749	755	760	766	772	778	784	790	796	801	807	813
Other	1,855	1,870	1,885	1,900	1,915	1,929	1,944	1,959	1,974	1,989	2,003	2,018	2,033
Subtotal	34,888	35,166	35,445	35,723	36,001	36,279	36,557	36,835	37,113	37,391	37,668	37,946	38,224
Oxnard RW													
NewIndyPaper	800	800	800	800	800	800	800	800	800	800	800	800	800
RiverRidgeGC	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
RiverPkDev	175	175	175	175	175	175	175	175	175	175	175	175	175
Southland	800	800	800	800	800	800	800	800	800	800	800	800	800
Reiter	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Houweling	800	800	800	800	800	800	800	800	800	800	800	800	800
Subtotal	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475	5,475
Totals	42,698	42,976	43,255	43,533	43,811	44,089	44,367	44,645	44,923	45,201	45,478	45,756	46,034



2.2.3 Supply water qualities and objectives

The water quality for all water supplies included in the WEAP model were the same as shown in Table 4 of PM 2.5. The indirect potable reuse (IPR) source water quality was assumed to be the same as AWPF treated effluent. The water quality objectives for all water demands were assumed to be TDS less than 500 mg/L and hardness less than 100 mg/L.

2.2.4 Water and wastewater treatment

The water treatment facilities included in the WEAP model were:

- BS 1/6 desalter.
- PHWA desalter.
- AWPF.

The OWTP was included to represent secondary wastewater treatment with an assumed capacity of 31.7 mgd.

The treatment capacities of the BS 1/6 desalter and the AWPF are included in Table 1. The PHWA desalter capacity is limited to 700 AFY to match the annual transfer of FCGMA credits from PHWA, per the 2002 Three Party Water Supply Agreement.

2.2.5 Water demands prioritization and supply preferences

Two strengths of the WEAP model are that 1) it allows for the prioritization of meeting water demands, and 2) it allows for supply preferences. For example, the model can be set up to meet all potable water demands before using available supplies to meet recycled water demands. Also, the user can indicate preference for a demand to utilize all of the available recycled water prior to supplementing with potable water to meet remaining demands.

The water demands prioritizations input to the WEAP model are summarized in Table 3. The following demand nodes were ranked as the highest priority of 1 so that downstream demands could be met:

- Desalter.
- PHWA BWRDF.
- AWPF.
- IPR.

Table 3	Water Demands Prioritization Public Works Integrated Master Plan City of Oxnard
Water Demand Node	**Priority**
Oxnard	1
Groundwater infiltration (GWI)	99
Desalter	1
PG	2
PHWA BWRDF	1
AWPF	1
Oxnard RW	2
IPR Capacity	1

The Oxnard demand node was also ranked as the highest priority of 1 so that all potable demands would be met first, then Oxnard recycled water and PG demands. GWI was ranked as the lowest priority possible (99) in the WEAP model so that other demands would be met first.

2.3 MODEL RESULTS

WEAP is a mass and flow balance model. The WEAP model computes water inflows to and outflows from every node and link in the system. This includes calculating withdrawals from supply sources to meet demand. A linear program (LP) is used to maximize satisfaction of requirements for demand sites, subject to demand priorities, supply preferences, mass balance, and other user-defined constraints. The LP solves the set of simultaneous equations. Detailed information on the WEAP model calculations are available at:

http://www.weap21.org/WebHelp/index.html

Once the Oxnard system with the recommended projects was constructed within the WEAP model, the values for supplies and demands, source water qualities and objectives, and wastewater treatment were input to the model. The model calibration included varying the water demand priorities and supply preferences to balance the supplies with demands. The calibrated model included the demand prioritization summarized previously in Table 3.

Variable supply preferences did not impact the model results. Therefore, all supplies were listed as the default value of 1. With no supply preference required, the WEAP model LP determines the optimal supply portfolio based on water quality objectives.

2.3.1 Demand Balance

The WEAP model results showed that all demands could not be met with the recommended projects in place. Figure 2 summarizes the water balance for all demands by supply source with the recommended projects. The main constraint is due to the hardness goal of 100 mg/L.

Figure 2 shows that the Oxnard demands are met for all years with the recommended projects installed. The water demands for PG and Oxnard RW are not met in 2015 due to supply shortages. All water demands are met from 2016 onwards with the recommended projects in place. Note that Figure 2 shows the supply sources for all demands; however, different combinations of supply sources are possible to meet the water demands and water quality objectives.

2.3.2 Water Quality Analysis

The blended water qualities for TDS and hardness for Oxnard are shown in Figure 3 with the recommended projects installed.

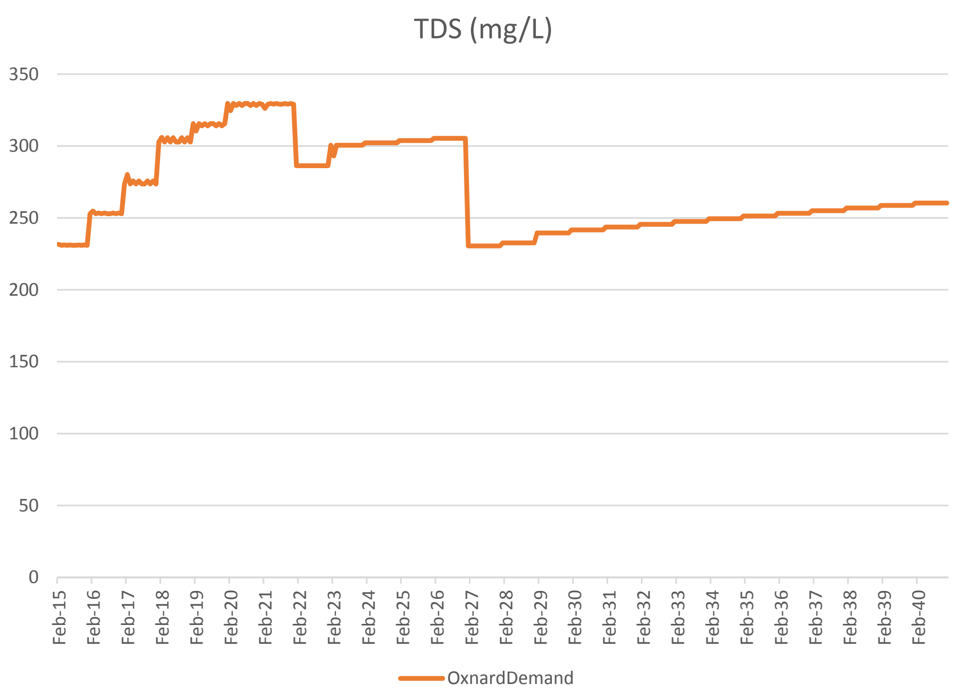
The average hardness and TDS concentrations for all demands are shown in Table 4. As noted in the demand balance discussion, note that Figure 3 and Table 4 show a snapshot of possible water quality results; however, different combinations of supply sources are possible that could result in different water qualities while meeting water quality objectives.

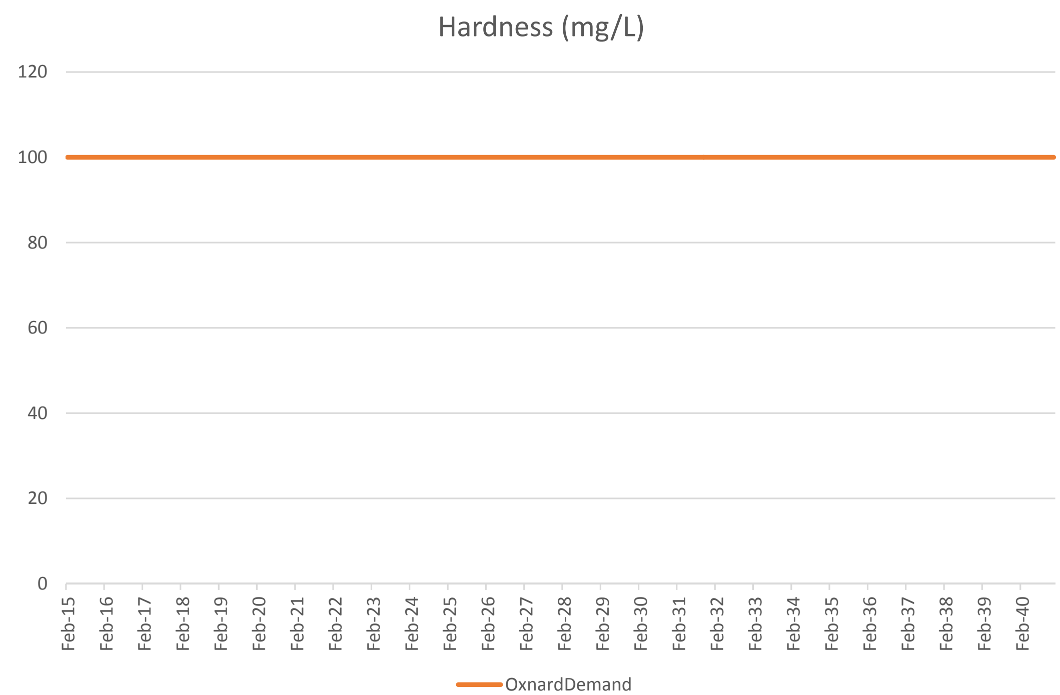
Table 4 Average Water Quality Delivered to Demands for Recommended Projects
Public Works Integrated Master Plan
City of Oxnard

Demand	Average hardness (mg/L)	Average TDS (mg/L)
Oxnard RW	77	171
Oxnard	100	269
PG	95	283

Figure 2. Water balance for all demands by supply source with the recommended projects installed in AFY.

Figure 3. Blended water qualities for TDS and hardness for Oxnard with recommended projects installed





2.4 CONCLUSIONS

The WEAP model results show that hardness governs (versus TDS) in meeting water quality objectives for the water demands. The modeling results also show that the recommended projects can meet water quality objectives in 2016 and beyond; however, 2015 water demands cannot be met with the given water quality criteria.

APPENDIX K – GREAT PROGRAM PROJECT COSTS PROVIDED BY THE CITY

GREAT PROGRAM
Minimum Startup Pipeline & ASR
Monthly Payment (Estimated)

Item	Description	Budget ($)	Month: Mar-15 ($)	Apr-15 ($)	May-15 ($)	Jun-15 ($)	Jul-15 ($)	Aug-15 ($)	Sep-15 ($)	Oct-15 ($)	Nov-15 ($)	Dec-15 ($)
1	Hueneme Road Phase 2											
	- Pipeline (Jensen)	$9,862,720	$450,000	$450,000	$450,000	$450,000	$200,000	$200,000	$2,200,000	$2,743,787	$543,787	$543,787
	- Right-of-way property acquisition (Jensen)	$606,690	$303,345	$303,345								
	- Repair damaged asphalt (Jensen)	$611,150										
	- Hwy 1 crossing (Jensen)	$366,690										$183,345
2	AWPF Completion											
	- Advanced oxidation/chlorine residual (Carollo)	$119,742			$11,840	$11,840						
	- Security (Carollo)	$712,035			$70,200	$70,200						
	- Audio/Video (City)	$276,568										
3	Recycled Water Retrofits											
	- River Ridge Golf Course (Carollo)	$847,802			$635,851	$105,975	$105,975					
	- River Park (Carollo)	$304,336				$228,252	$38,042	$38,042				
	- Southland & Reiter turnouts (Jensen)	$329,460						$164,730	$164,730			
	- New Indy (City)	$522,011				$391,508	$65,251	$65,251				
5	AMR Replacement (1)	$14,000,000										
6	Wells 23 & 31 Rehab	$275,000		$137,500	$137,500							
7	Wells Electrical & VFD Replacement	$1,027,000					$100,000	$100,000	$413,500	$413,500		
8	Sodium Hypochlorite Feed Replacement	$28,000	$28,000									
9	Emergency Turnouts	$26,500			$26,500							
10	Generators & ATS Service	$21,000			$21,000							
11	Cathodic Protection	$3,000,000			$66,667	$66,667	$66,667					$933,333
12	Freemont North Neighborhood CIP Replacement	$2,300,000								$575,000	$575,000	$575,000
13	Bryce Canyon South Neighborhood CIP Replacement	$1,500,000										
14	Redwood Neighborhood CIP Replacement	$2,750,000										
15	La Colonia Neighborhood CIP Replacement	$2,000,000										
	Total	$54,457,570	$781,345	$890,845	$2,911,036	$2,815,920	$1,289,967	$1,282,056	$3,103,540	$4,057,596	$1,118,787	$2,235,465

Item	Description	Jan-16 ($)	Feb-16 ($)	Mar-16 ($)	Apr-16 ($)	May-16 ($)	Jun-16 ($)	Jul-16 ($)	Aug-16 ($)	Sep-16 ($)	Oct-16 ($)	Nov-16 ($)	Dec-16 ($)
1	Hueneme Road Phase 2												
	- Pipeline (Jensen)	$543,787	$543,787	$543,787									
	- Right-of-way property acquisition (Jensen)												
	- Repair damaged asphalt (Jensen)		$305,575	$305,575									
	- Hwy 1 crossing (Jensen)	$183,345											
2	AWPF Completion												
	- Advanced oxidation/chlorine residual (Carollo)			$0	$32,020	$32,020	$32,020						
	- Security (Carollo)			$0	$190,545	$190,545	$190,545						
	- Audio/Video (City)			$138,284	$138,284	$0	$0						
3	Recycled Water Retrofits												
	- River Ridge Golf Course (Carollo)												
	- River Park (Carollo)												
	- Southland & Reiter turnouts (Jensen)												
	- New Indy (City)												
5	AMR Replacement (1)	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667
6	Wells 23 & 31 Rehab												
7	Wells Electrical & VFD Replacement												
8	Sodium Hypochlorite Feed Replacement												
9	Emergency Turnouts												
10	Generators & ATS Service												
11	Cathodic Protection	$933,333	$933,333										
12	Freemont North Neighborhood CIP Replacement	$575,000											
13	Bryce Canyon South Neighborhood CIP Replacement							$375,000	$375,000	$375,000	$375,000		
14	Redwood Neighborhood CIP Replacement			$687,500	$687,500	$687,500	$687,500						
15	La Colonia Neighborhood CIP Replacement									$500,000	$500,000	$500,000	$500,000
	Total	$2,652,132	$2,199,362	$2,242,635	$3,933,586	$3,744,480	$2,267,154	$1,732,088	$1,782,911	$1,291,667	$1,291,667	$916,667	$916,667

Item	Description	Jan-17 ($)	Feb-17 ($)	Mar-17 ($)	Apr-17 ($)	May-17 ($)	Jun-17 ($)	Jul-17 ($)	Aug-17 ($)	Sep-17 ($)	Oct-17 ($)	Nov-17 ($)	Dec-17 ($)	Jan-17 ($)	Feb-17 ($)
1	Hueneme Road Phase 2														
	- Pipeline (Jensen)														
	- Right-of-way property acquisition (Jensen)														
	- Repair damaged asphalt (Jensen)														
	- Hwy 1 crossing (Jensen)														
2	AWPF Completion														
	- Advanced oxidation/chlorine residual (Carollo)														
	- Security (Carollo)														
	- Audio/Video (City)														
3	Recycled Water Retrofits														
	- River Ridge Golf Course (Carollo)														
	- River Park (Carollo)														
	- Southland & Reiter turnouts (Jensen)														
	- New Indy (City)														
5	AMR Replacement (1)	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$166,667	$166,667
6	Wells 23 & 31 Rehab														
7	Wells Electrical & VFD Replacement														
8	Sodium Hypochlorite Feed Replacement														
9	Emergency Turnouts														
10	Generators & ATS Service														
11	Cathodic Protection														
12	Freemont North Neighborhood CIP Replacement														
13	Bryce Canyon South Neighborhood CIP Replacement														
14	Redwood Neighborhood CIP Replacement														
15	La Colonia Neighborhood CIP Replacement														
	Total	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$416,667	$166,667	$166,667

Notes:

(1) - 2016 & 2017 @ $5,000,000/yr; 2018 @ $2,000,000/yr; 2019 & 2020 @ $1,000,000/yr