Hazen

Indio Water Authority
Your Water. Our Responsibility.

VALLEY SANITARY DISTRICT

Recycled Water Program Development Feasibility Study

Technical Memorandum No. 1
Indio Water Authority / Valley Sanitary District
(East Valley Reclamation Authority)

March 2018

Hazen *Technical Memorandum*

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Abbreviations/Acronyms

ac	Acre(s)
ADD	Average day demand
AF	Acre-Feet
AFY	Acre-Feet per Year
AMSL	Above mean sea level
AOP	Advanced oxidation process
ASR	Aquifer Storage and Recovery
bgs	Below ground surface
BOR	Bureau of Reclamation
CCI	Construction Cost Index
CDPH	California Department of Public Health
cfs	Cubic feet per second
CIP	Capital Improvement Program/Plan
cm	Centimeter
CPC	California Plumbing Code
CPT	Cone penetrometer test
CSD	Coachella Sanitation District
CVRWMG	Coachella Valley Regional Water Management Group
CVSC	Coachella Valley Stormwater Channel
CVWD	Coachella Valley Water District
CWA	Coachella Water Authority
DDW	California State Water Resources Control Board Division of Drinking Water
DFA	Division of Financial Assistance
DPR	Direct Potable Reuse
DSOD	Division of Safety of Dams
DU	Dwelling Unit
DWR	California Department of Water Resources
ENR	Engineering News-Record
EVRA	East Valley Reclamation Authority
ft	Foot, feet
FTE	Full time equivalent
gpd	Gallon(s) per day
gpm	Gallon(s) per minute
GRF	Groundwater Replenishment Facility
GRRP	Groundwater Replenishment Reuse Project
GRRW	Groundwater Recharge with Recycled Water
HDD	Horizontal directional drilling
HOA	Homeowner Association
HP	Horsepower

in	Inch(es)
IPR	Indirect Potable Reuse
IRWM	Integrated Regional Water Management
IWA	Indio Water Authority
JPA	Joint Powers Authority
kWh	kilowatt-hour
L	Liter(s)
MBR	Membrane bioreactor
MCL	Maximum Contaminant Level
MDD	Maximum day demand
MF	Microfiltration
mg	Milligram(s)
MG	Million gallon(s)
MGD	Million Gallon(s) per Day
Min.	Minimum
MJ	Millijoules
mL	Milliliter(s)
MPN	Most probable number
MSL	Mean sea level
MSWD	Mission Springs Water District
NPR	Non potable reuse
NTU	Nephelometric Turbidity Unit
O&M	Operation and maintenance
PFD	Process flow diagram
PS	Pump station
psi	Pounds per square inch
psig	Pounds per square inch (gauge)
PVDF	Polyvinylidene fluoride
Req'd	Required
RO	Reverse Osmosis
RW	Recycled water
RWC	Recycled water contribution
RWMP	Recycled Water Master Plan
RWTM	Recycled water transmission main
sq	Square
SWP	State Water Project
TDS	Total dissolved solids
TM	Technical Memorandum
TOC	Total organic carbon
TSS	Total suspended solids
UV	Ultraviolet
UVT	Ultraviolet Transmittance

VFD	Variable frequency drive
VSD	Valley Sanitary District
WMP	Water Master Plan
WRF	Water Reclamation Facility
µg	Microgram(s)

Executive Summary

Coachella Water Authority (CWA) / Coachella Sanitation District (CSD), Mission Springs Water District (MSWD), Indio Water Authority (IWA) and Valley Sanitary District (VSD) collectively received a Proposition 84, Integrated Regional Water Management (IRWM) Grant to complete a recycled water study to evaluate the use of recycled water within each agency's respective jurisdictional regions. To bring value to each of the participating agencies, and the objective of this study, recycled water alternatives were identified and evaluated for each of the participating agencies' service areas individually as well as collectively with the evaluation of regional alternatives. Three separate technical memoranda (TM) addressing the individual evaluations were prepared as follows:

1. TM-1 for IWA and VSD;
2. TM-2 for MSWD; and
3. TM-3 for CWA/CSD

In addition, a summary report was prepared that identified and evaluated regional recycled water alternatives. Presented herein, and the subject of this TM (TM-1) are the recycled water alternatives that were identified and evaluated within the IWA and VSD service areas.

Project Scope

This study builds upon previous studies and reports prepared for IWA and VSD and incorporates an evaluation of two proposed developments: Stonewater and Grand Valley (formerly known as Citrus Ranch). The study area encompasses IWA's service area and the City of Indio Sphere of Influence with an emphasis on the areas surrounding the VSD WRF and proposed Grand Valley and Stonewater developments.

The project scope included the following:

- Development of recycled water project alternatives including an evaluation of surface spreading, groundwater injection and landscape irrigation,
- Identifying distribution system requirements including transmission mains, pumping, and storage for the recycled water project alternatives developed,
- Evaluating existing wastewater quality to determine the appropriate treatment technology for the proposed recycled water uses,
- Conducting a broad hydrogeologic analysis to identify opportunities for groundwater spreading and/or injection at the most effective locations,
- Preparation of capital and operations and maintenance opinions of probable costs for each alternative,
- Rank project alternatives based on criteria important to IWA and VSD and identify a priority project and,
- Identify project funding for the priority project.

In addition, a two-month pilot study was to be conducted at CSD's WWTP to assist in getting the priority project closer to implementation. However, this would not benefit all the agencies participating in the study and therefore, a bench scale pilot study was also conducted at VSD to provide information on the filterability of the secondary effluent that allows for a better estimate of pretreatment needs and a better estimate of the types of filters needed to meet the water quality requirements for each recycled water application being evaluated.

Project Alternatives

Investigations within the VSD WRF's service area were conducted and information gathered indicates that the main recycled water uses available for the reclamation facility's effluent are landscape irrigation and aquifer recharge via surface spreading or injection. The project alternatives identified specific to IWA and VSD are summarized in Table ES-1.

Table ES - 1: Summary Recycled Water Alternatives

Project Alternative	Description
1	Status quo – "Do Nothing"
2	Surface spreading at VSD WRF
3	Deliver to recycled water customers for landscape irrigation and surface spreading at VSD WRF
4	Groundwater injection at VSD WRF
5a	Deliver to recycled water customers for landscape irrigation and surface spreading at Posse Park
5b	Deliver to recycled water customers for landscape irrigation and groundwater injection at Posse Park
6	Deliver to recycled water customers for landscape irrigation and excess to Coachella Valley Storm Channel (CVSC)

Economic Analysis

Utilizing the Cost Estimate Classification System guidelines published by the Association for the Advancement of Cost Engineering International (AACEI), a Class 4 cost estimate for each alternative was developed. The costs were escalated to February 2019 dollars and take into consideration that the project is located in the Coachella Valley. Land and right of-way costs were not included. Table ES-2 summarizes the total capital costs for each alternative and project component.

Table ES-2: Capital Cost Estimates by Alternative and Component

Alternative	Tertiary Treatment ($M)	Advanced Treatment ($M)	Recycled Water Distribution ($M)	Spreading Basins ($M)	Groundwater Injection ($M)	Total ($M)
1 – Status Quo	-	-	-	-	-	**-**
2 – Spread at VSD	37.0	-	-	6.7	-	**43.8**
3 – RW Distribution and Spread at VSD	37.0	-	82.9	6.5	-	**126.5**
4 – Inject at VSD	-	49.3	-	-	21.0	**70.4**
5a – RW Distribution and Spread at Posse Park	37.0	-	33.9	18.4	-	**89.4**
5b – RW Distribution and Inject at Posse Park	37.0	44.3	46.5	-	16.5	**144.4**
6 – RW Distribution and Excess to CVSC	37.0	-	82.7	-	-	**119.7**

Annual operation and maintenance (O&M) costs that included power costs, chemical costs, annual maintenance and labor were developed based on estimates at similar facilities. A life cycle analysis was then developed based on the capital and O&M estimates assuming a 30-year term at an interest rate of 1.6 percent. The lifecycle costs for each alternative are presented in Table ES-3.

Table ES-3: Lifecycle Estimates

Alternative	Annualized Capital Cost ($M)	Annual O&M Cost ($M)	Annualized Lifecycle Cost ($M)	Cost Per Acre-foot[1] ($)
Alt 1[2]	-	-	-	5,321
Alt 2	1.85	1.67	3.52	524
Alt 3	5.34	2.75	8.10	1,205
Alt 4	2.97	4.60	7.57	1,127
Alt 5a	3.78	2.27	6.05	900
Alt 5b	6.10	4.22	10.31	1,535
Alt 6	5.06	2.62	7.67	1,141

[1] Based on a maximum plant flow of 6 mgd at VSD and 4.5 mgd at Posse Park (after customer demands).
[2] Average of the reliability-adjusted costs for State Water Project purchase deals presented in IWA's Supplemental Water Supply Program and Fee Study.

Alternatives Analysis and Ranking

A decision model was created to evaluate the costs and non-monetary benefits important to VSD and IWA. Selection criteria was initially established in a workshop with VSD and IWA and the agencies completed weighting sheets independently such that an average weighting could be distributed relative to the primary criteria's importance. The results of the criteria weighting and scoring is shown in Table ES-4. Higher scores were considered more favorable.

Table ES-4: Criteria Weighting and Scoring Summary

Alternative	Score	Ranking
2 – Spread at VSD	84	1
4 – Inject at VSD	70	2
3 – RW Distribution and Spread at VSD	65	3
5a – RW Distribution and Spread at Posse Park	60	4
1 – Status Quo	53	5
6 – RW Distribution and Excess to CVSC	51	6
5b – RW Distribution and Inject at Posse Park	47	7

Funding Opportunities

There are many grant and loan opportunities to fund the design and construction of the recycled water alternative projects identified herein. There is grant funding currently available through the California State Water Resources Control Board (SWRCB) through Proposition 1, as well as grant funding under the United States Bureau of Reclamation (USBR) WaterSMART and Title XVI Programs. Low interest loans are available as well and generally the loan rate is one half of the State of California's most recent general obligation bond rate. As of March 2017, the interest rate being offered was 1.8%. A combination of State and Federal funding is permitted. The challenge with the grant and loans are the timing of availability and their fluidity. IWA and VSD will need to determine the preferred alternative and the timeline in which the agencies wish to proceed and then immediately begin applying for grants. There should be sufficient information developed within this report to apply for further planning such as conducting a full- scale pilot study and preparing a preliminary design report.

Conclusions

Through this study, groundwater recharge via spreading or injection is the most favorable. Alternatives that included distribution of recycled water for landscape irrigation ranked less favorable due to the extensive and expensive conveyance infrastructure requirements and potential underutilization of the recycled water. Groundwater recharge at the VSD WRF site is dependent on confirming the ability to percolate water at a reasonable rate and therefore, percolation testing and soil borings are needed in or near the existing evaporation ponds on the VSD site to confirm the hydrogeological findings and adequacy for percolation.

If the percolation tests show that groundwater recharge via spreading is not a viable alternative and IWA and VSD desires to implement the next most cost-effective alternative, which is groundwater recharge via injection at VSD WRF, it is recommended that IWA and VSD consider conducting a full-scale pilot study. This will help further determine if some or all the filtration alternatives under consideration are indeed viable for this specific water quality and assist in establishing design criteria. The bench scale pilot study conducted for this TM indicates that the wastewater is filterable. Pilot testing typically should be conducted over a 6-month period for the information to be conclusive. This greatly effects the projected cost estimates for the advanced treatment processes, chemical storage, and feed systems as a more conservative approach must be taken without additional wastewater quality information. Conservative assumptions were made in determining the design criteria presented herein.

1. Introduction

As severe droughts in California continue and imported and local groundwater supplies are becoming taxed, water utilities are seeking alternative water supplies to meet growing water demands. Recycled water is a significant local resource that, depending on the level of treatment, may be utilized for landscape irrigation, industrial applications, and strengthening groundwater recharge.

Coachella Water Authority (CWA) / Coachella Sanitation District (CSD), Mission Springs Water District (MSWD), and Indio Water Authority (IWA) / Valley Sanitary District (VSD) collectively received a Proposition 84, Integrated Regional Water Management (IRWM) Grant to complete a recycled water study to evaluate the use of recycled water throughout the Coachella Valley. To bring value to each of the participating agencies, recycled water alternatives were identified and evaluated for each of the participating agencies' service areas individually as well as collectively with the evaluation of regional alternatives. Three separate technical memoranda addressing the individual evaluations were prepared as follows:

1. TM-1 for IWA and VSD;
2. TM-2 for MSWD; and
3. TM-3 for CWA/CSD

In addition, a summary report has been prepared that identifies and evaluates regional recycled water alternatives. Presented herein and the subject of this TM (TM-1) are the recycled water alternatives that were identified and evaluated within the IWA and VSD service areas. The results of these technical memoranda and regional recycled water feasibility study will be utilized to prioritize projects, identify appropriate grant funding, and prepare grant funding applications for the design and implementation of the priority projects.

1.1 Background

IWA was formed as a Joint Powers Authority (JPA) in the year 2000 to deliver water to the City of Indio, located in the Coachella Valley in Riverside County, California. The City of Indio encompasses approximately 38 square miles with an additional 22 square miles in its sphere of influence. VSD was formed in 1925, primarily serving the City of Indio while also serving small portions of the Cities of La Quinta, Coachella, and unincorporated Riverside County, with a service area of approximately 19.9 square miles. In 2013, the East Valley Reclamation Authority (EVRA) was created under a joint powers agreement between the City of Indio through IWA and VSD to plan, implement, and operate a recycled water program.

Initially discussed in Indio Water Authority's (IWA) 2007 Water Master Plan (Dudek), IWA has been evaluating different options to diversify its water supply through development of local drought-proof supplies. Recycled water is a key local asset that, in coordination with Valley Sanitary District (VSD), has the potential to supplement IWA's and the Coachella Valley's water supplies, groundwater aquifers, and reduce dependence on imported water and groundwater storage as identified in the 2012 Coachella Valley Groundwater Management Plan Update. IWA began evaluating the potential for recycled water use in more detail recently beginning with the Water Reclamation Facilities for Reuse and Groundwater Recharge –

Phase 1 Environmental Program, Technical Memorandum No. 1 – Market and Demand Assessment (Carollo, January 2010) and Technical Memorandum No. 4 – Recycled Water Treatment Alternatives and Delivery Corridor Options (Carollo, January 2010). These memoranda detailed major turf irrigation customers as potential recycled water users, quantified estimated demands, identified potential customer concerns, developed a proposed recycled water delivery infrastructure, and identified VSD Water Reclamation Facility (WRF) treatment alternatives and layouts.

Following those memoranda, a Recycled Water Master Plan was prepared in 2011 (Carollo, December 2011) that established design criteria and developed a more refined phased recycled water system with a Capital Improvement Program (CIP).

Most recently, a Recycled Water Feasibility Study (Carollo, January 2016) was prepared for the Bureau of Reclamation (BOR) Title XVI program, structured to address the requirements outlined in the Reclamation Manual Directives and Standards (WTR 11-01) for feasibility studies conducted under BOR's Title XVI program. The proposed recycled water system was divided into two phases: Phase 1 addressing the northeastern section of the service area including groundwater recharge via aquifer storage and recovery (ASR) wells at Posse Park, and Phase 2 addressing the southeastern section. It was also suggested that the first portion of Phase 1 may include a pipeline to a City of Indio-owned golf course to establish recycled water polices prior to constructing the remaining portions of Phase 1. The report proposed a total of 9,243 acre-feet per year (AFY) of recycled water would be served through implementation of Phase 1 (3,356 AFY) and Phase 2 (5,887 AFY). The major proposed infrastructure includes the addition of approximately 8.9 miles of pipelines, 2 pump stations, and 2 storage tanks. The cost of recycled water was found to be comparable to the cost of Colorado River replenishment water, and utilizing recycled water to offset potable demands would benefit the region by removing less groundwater and reduce reliance on imported water. The main constraints to overcome included gaining public acceptance for the use of recycled water and pursuing grant funding to address the high capital costs associated with the construction of a recycled water distribution system.

Also, an assessment was conducted of the potential impacts of deactivating the biological treatment ponds at the VSD WRF to determine if puncturing the liners could potentially contaminate the groundwater (refer to Deactivation of Biological Treatment Ponds Technical Memorandum, MWH Global a part of Stantec, January 24, 2017.).

A list of references used in the preparation of this Study is included in **Appendix A**.

1.2 Project Scope

The project scope for the Recycled Water Feasibility Study included evaluating regional projects as well as projects specific to the individual agencies service areas. This TM covers the alternatives specific to IWA and VSD. This Study builds upon the previous studies and reports prepared for IWA and VSD and incorporates an evaluation of two proposed developments: Stonewater and Grand Valley (formerly known as Citrus Ranch). Distribution system requirements are identified, which includes transmission mains, pumping, and storage. Available water quality is evaluated to determine the appropriate treatment technology for the proposed recycled water use. The study also covers a broad hydrogeologic analysis to identify opportunities for groundwater spreading and/or injection at the most effective locations. Capital as well as operations and maintenance opinions of probable costs are prepared for each alternative and projects ranked based on selection criteria. Regional treatment alternatives, including partnering with participating agencies, is included the Recycled Water Program Development Feasibility Study Report being prepared under a separate cover.

1.3 Study Area

For the purposes of this TM, the study area encompasses IWA's service area and the City of Indio Sphere of Influence with an emphasis on the areas surrounding the VSD WRF and proposed Grand Valley and Stonewater developments (see Figure 1-1).

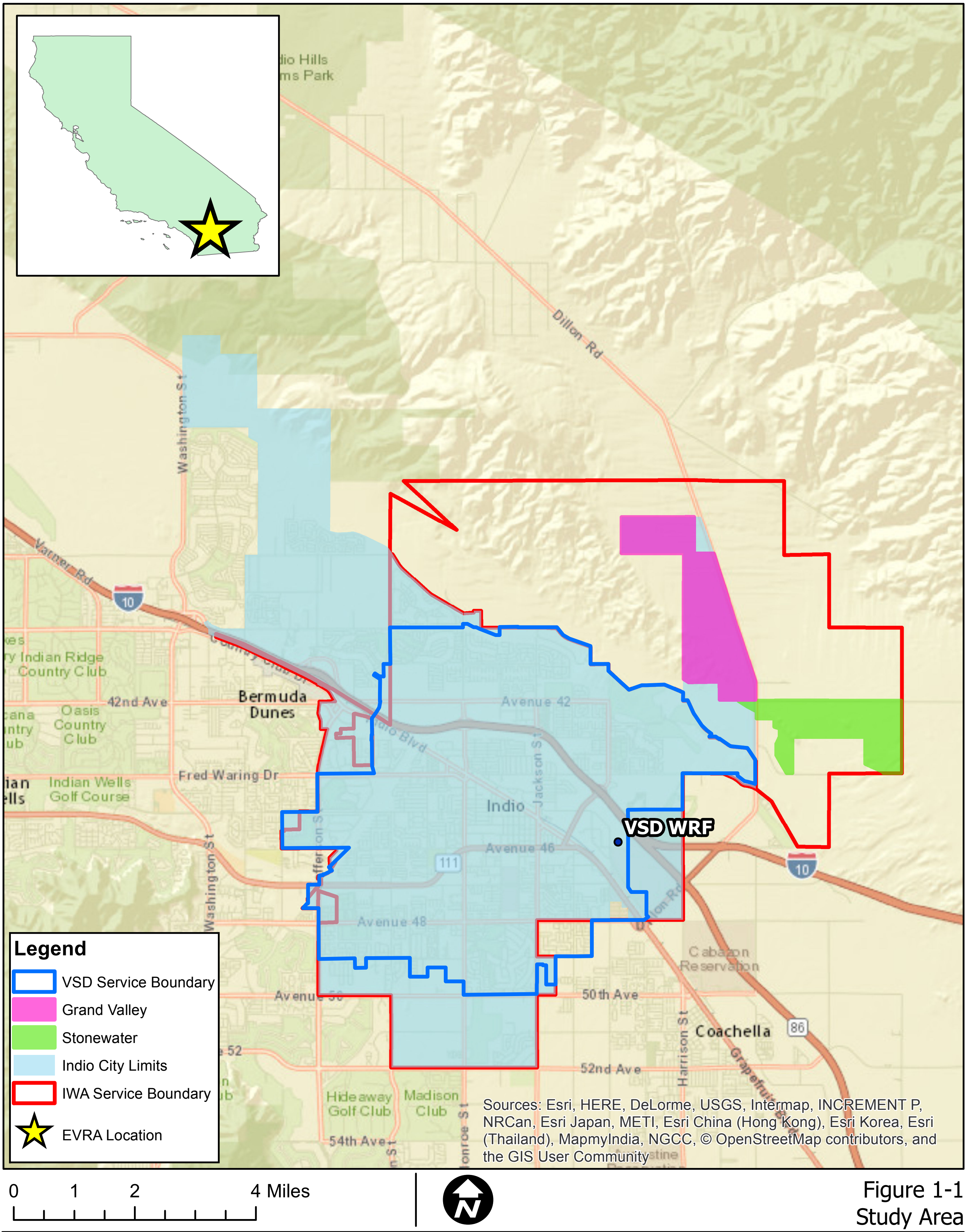

Figure 1-1
Study Area

Hazen

Recycled Water Program Development Feasibility Study
Indio Water Authority / Valley Sanitary District

2. Project Alternatives

Working in conjuction with IWA and VSD, a series of the most potentially viable alternatives have been developed for the preparation of this Study. Each alternative is described briefly below, and subsequent sections of this technical memorandum cover the specific detailed components – from treatment, to hydrogeology, to conveyance as they specifically relate to each alternative.

2.1 Alternative 1 – Status Quo

Alternative 1 represents the status quo in terms of operation of the VSD WRF and the groundwater basin, which is disinfected secondary that is discharged to the Coachella Valley Stormwater Channel (CVSC) (see Figure 2-1). The "Do Nothing" alternative is typically used as a comparison to justify if a proposed alternative is worth the additional investment.

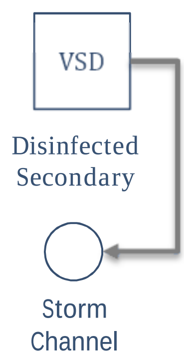

Figure 2-1 – Alternative 1

2.2 Alternative 2 – Surface Spreading at VSD WRF

Alternative 2 includes the addition of tertiary treatment and on-site recharge via spreading basins at the VSD WRF (see Figure 2-2).

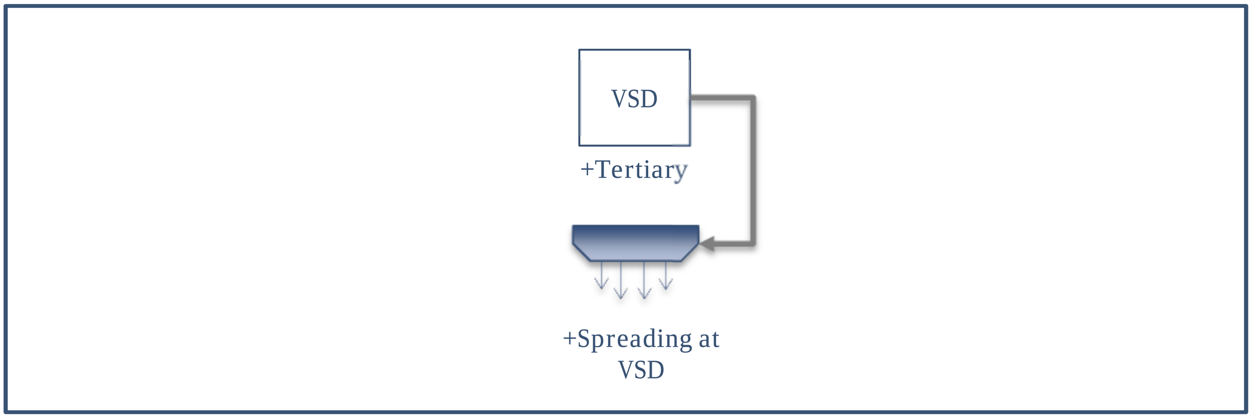

Figure 2-2 – Alternative 2

2.3 Alternative 3 – Deliver to Recycled Water Customers and Surface Spreading at VSD WRF

Alternative 3 includes the addition of tertiary treatment at the VSD WRF, construction of a recycled water distribution system to serve IWA recycled water customers, and recharging excess flows via on-site spreading basins (see Figure 2-3).

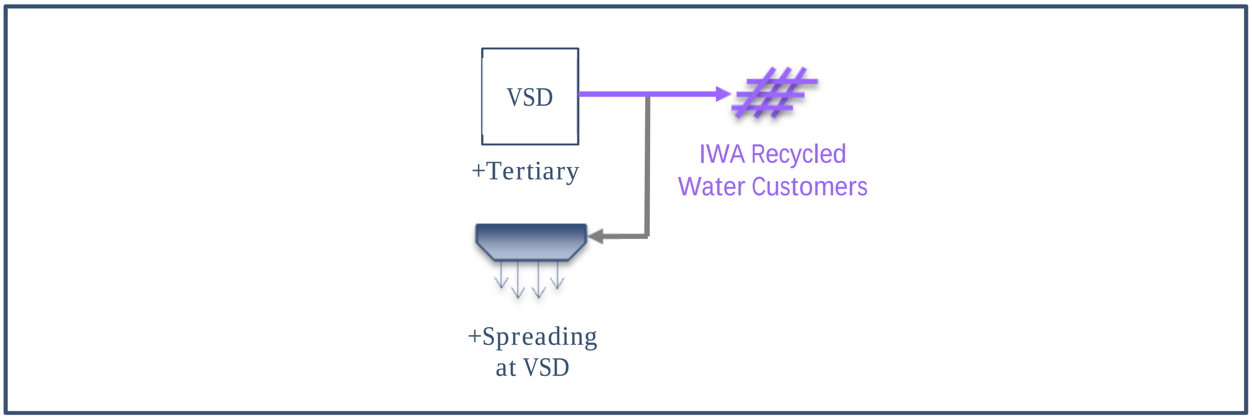

Figure 2-3 – Alternative 3

2.4 Alternative 4 – Groundwater Injection at VSD WRF

Alternative 4 includes the addition of advanced treatment at the VSD WRF and on-site recharge via injection wells (see Figure 2-4).

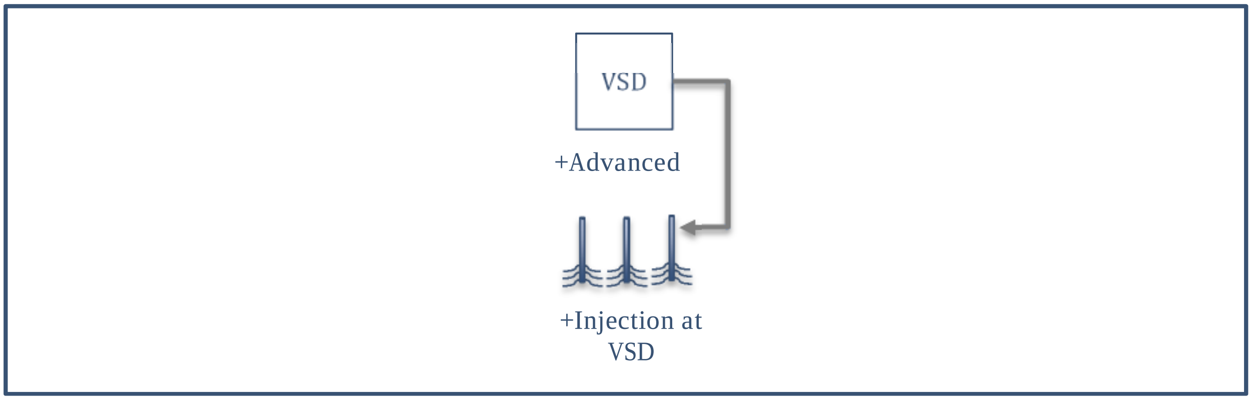

Figure 2-4 – Alternative 4

2.5 Alternative 5a – Deliver to Recycled Water Customers then Surface Spreading at Posse Park

Alternative 5a includes the addition of tertiary treatment at the VSD WRF and construction of a recycled water transmission main (RWTM) to convey the flow to Posse Park for recharge via spreading basins. Posse Park is a City of Indio-owned property approximately 2.5 miles north of the VSD WRF. The specific location is shown in Figure 7-4. Recycled water customers conveniently located along the recycled water transmission main route will be served tertiary water with the excess being spread at Posse Park. See Figure 2-5.

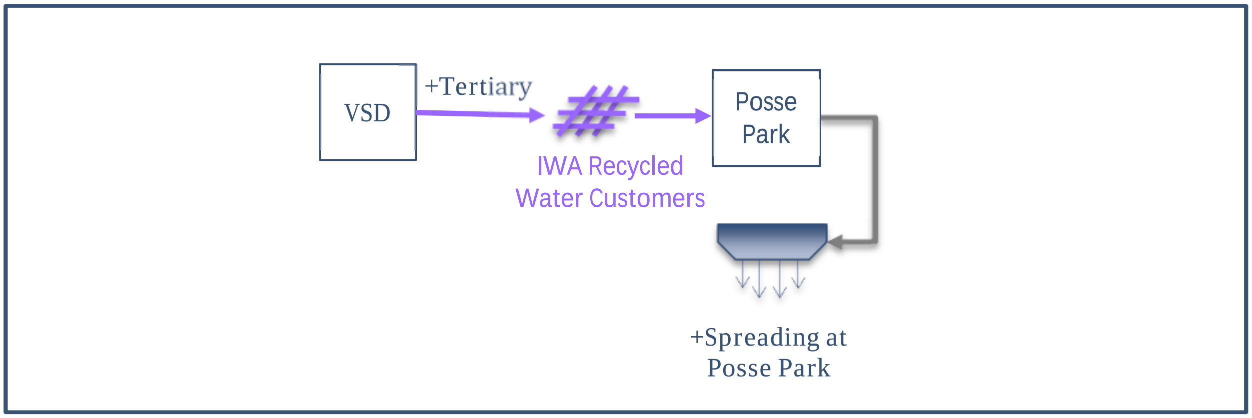

Figure 2-5 – Alternative 5a

2.6 Alternative 5b – Deliver to Recycled Water Customers then Groundwater Injection at Posse Park

Alternative 5b includes the addition of tertiary treatment at the VSD WRF, construction of a recycled water transmission main to convey the flow to Posse Park, and advanced treatment facilities for recharge at Posse Park via injection wells. Recycled water customers conveniently located along the recycled water transmission main route will be served tertiary water. In order to maintain constant flow to the advanced treatment facilities, excess flows during low recycled water demand periods will be discharged as secondary treated wastewater to the CVSC. Posse Park's close proximity to the Coachella Canal, operated by CVWD, could also potentially offer some additional flexibility as an option for or supplementing customer service or injection. See Figure 2-6.

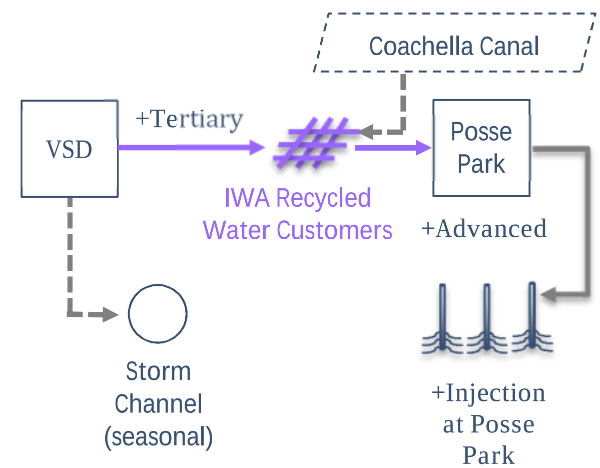

Figure 2-6 – Alternative 5b

2.7 Alternative 6 – Deliver to Recycled Water Customers and Excess to CVSC

Alternative 6 includes the addition of tertiary treatment at the VSD WRF, construction of a recycled water distribution system to serve IWA recycled water customers, and discharging excess flows as secondary treated wastewater to the CVSC. See Figure 2-7.

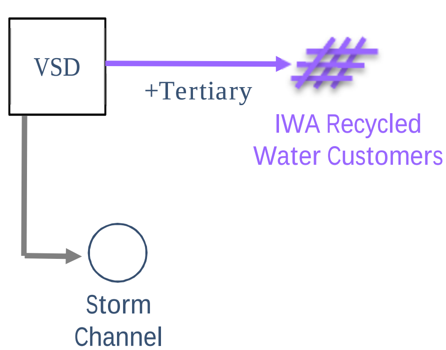

Figure 2-7 – Alternative 6

2.8 Direct Potable Reuse

Direct potable reuse (DPR) is a topic that is being discussed widely in the water reclamation industry as s a potential option for recycled water use. To further evaluate DPR, the California State Water Resources Control Board’s (State Water Board) Division of Drinking Water (DDW) convened an Advisory Group in 2014 on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse in accordance with the California Water Code Sections 13560-13569. The primary purpose of the Advisory Group was to advise the State Water Board and an expert panel on the feasibility of developing criteria for DPR in the State of California the final report, *Recommendations of the Advisory Group on the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse,* June 2016, may be found on the State Water Board’s website.

In summary, there are currently two ways of accomplishing planned DPR. These include:

1. Advanced treated water is produced at an advanced water treatment facility (AWTF) and is introduced into a raw water supply immediately upstream of a drinking water treatment facility. To date there are a few permitted projects of this type in the United States. Utilizing recycled water for DPR in this manner could be a viable option for IWA and VSD. Recycled water could be blended with raw Colorado River Water which is then sent to a surface water treatment plant. IWA’s intention to purchase Colorado River water from CVWD to be treated at a future surface water treatment plant is briefly discussed in IWA’s 2015 UWMP. This option would need further development if IWA and VSD desire to pursue this an alternative.

2. Finished water is produced at an AWTF that is also permitted as a drinking water treatment facility and the water is introduced directly into the drinking water supply distribution system. To date, DPR in this form has not been permitted in the United States.

Due to current regulatory limitations and the cost prohibitive nature of DPR (i.e., the cost to build an additional water treatment facility), DPR was not specifically evaluated as a viable alternative as part of this Study.

3. Recycled Water Quality Objectives

3.1 Regulatory Requirements

In June 2014, the California Department of Public Health (CDPH) has adopted regulations for the use of recycled water, referred to as Title 22. The Title 22 regulations stipulate water quality limits and required treatment processes and applies them to non-potable applications for which recycled water may be used. These non-potable applications include various types of irrigation, recreational impoundments, toilet flushing, and industrial cooling tower use. Additionally, water quality limits and required treatment processes have been established for aquifer replenishment via spreading and injection. This application is termed indirect potable reuse (IPR).

Table 3-1 lists all non-potable applications addressed by the Title 22 regulations. The main water quality limits addressed pertain to total coliform and turbidity levels.

Table 3-1: California State Water Reuse Criteria for Selected Non-potable Applications (Title 22)

Non-potable Applications	Quality Limits	Treatment Required
Fodder Crop Irrigation	Not Specified	Secondary
Processed Food Crop Irrigation	Not Specified	Secondary
Food Crop Irrigation	2.2 total coliform/100 mL 2 NTU(1)	Secondary Coagulation Filtration Disinfection
Restricted Recreational Impoundments	2.2 total coliform/100 mL	Secondary Disinfection
Restricted Access Irrigation	23 total coliform/100 mL	Secondary Disinfection
Unrestricted Access Irrigation	2.2 total coliform/100 mL 2 NTU	Secondary Coagulation Filtration Disinfection
Toilet Flushing	2.2 total coliform/100 mL 2 NTU	Secondary Filtration Disinfection
Industrial Cooling Water	2.2 total coliform/100 mL 2 NTU	Secondary Coagulation Filtration Disinfection

(1) Nephelometric Turbidity Unit (NTU)

Table 3-2 presents specific requirements for groundwater recharge into potable aquifers, also included in the Title 22 regulations. The constraints that must be met for recycled water to be used for groundwater recharge are more extensive than those that apply to irrigation.

Table 3-2: Draft California Regulations for Groundwater Recharge into Potable Aquifers (Title 22)

<table>
<tr><th>Water Quality Limits for Recycled Water</th><th>Treatment Required</th><th>Other Selected Requirements</th></tr>
<tr><td>• ≥12-log virus reduction
• ≥10-log Giardia cyst reduction
• ≥10-log Cryptosporidium oocyst reduction
• Drinking water MCLs (except for nitrogen)
• Action levels for lead and copper
• ≤10 mg/L total nitrogen
• TOC ≤0.5 mg/L/RWC</td><td>Spreading
• Oxidation
• Filtration
• Disinfection
• Soil aquifer treatment

Spreading with full advanced treatment
• Oxidation
• Reverse osmosis
• Advanced oxidation process
• Soil aquifer treatment

Injection
• Oxidation
• Reverse osmosis
• Advanced oxidation process</td><td>• Industrial pretreatment and source control program
• Initial maximum RWC ≤20% for spreading tertiary treated water
• Initial maximum RWC for injection based on California Department of Public Health (CDPH) review of engineering report and other information from public hearing
• ≥2-month retention (response) time underground
• 1-log virus reduction credit automatically given per month of subsurface retention
• 10-log Giardia reduction and 10-log Cryptosporidium reduction credit given to spreading projects that have at least 6 months' retention time underground
• Monitor recycled water and monitoring wells for priority toxic pollutants, chemicals with state notification levels specified by CDPH, and unregulated constituents specified by CDPH
• Operations plan
• Contingency plan
• Spreading projects with full advanced treatment must meet the requirements for injection projects, except that after one year of operation the project sponsor may apply for a reduced monitoring frequency for any monitoring requirement</td></tr>
</table>

3.2 Recycled Water Quality Goals

Currently, all the effluent from VSD's Water Reclamation Facility (WRF), approximately 5.6 MGD, is discharged to the CVSC. With the exception of an estimated minimum flow of about 0.5 MGD required to maintain existing riparian vegetation in the channel, the remaining effluent is available for use as recycled water.

As shown previously on Table 3-1, Title 22 regulations stipulate allowable levels of total coliform and turbidity for various non-potable water applications. Effluent data for both of these parameters is not currently available for the VSD WRF; however, it is recommended that this data be gathered for documentation and analysis during the further analysis and testing phase of this project as discussed further in Section 6-4. Given historical data from the region, it appears that with the addition of coagulation and filtration processes to the existing treatment train, both the total coliform and turbidity limits from the Title 22 regulation could be satisfied. Study of the data gathered during the further analysis and testing phase of the project will serve to confirm this assumption and further refine the design criteria for the required treatment process upgrades.

3.3 Types of Recycled Water Use

Title 22 regulations provide requirements for eight different non-potable applications for recycled water. Table 3-3 describes the applications in further detail and provides the minimum level of allowable treatment for each.

Table 3-3: Title 22 Non-potable Applications for Recycled Water

Non-potable Applications	Description	Minimum Level of Allowable Treatment
Irrigation		
Fodder Crop	Pasture for milk animals for human consumption	Disinfected Secondary-23[1]
	Fodder and fiber crops and pasture for animals not producing milk for human consumption	Undisinfected Secondary
Processed Food Crop	Food crops undergoing commercial pathogen-destroying processing before consumption by humans	Undisinfected Secondary
Food Crop	Food crops where recycled water contacts the edible portion of the crop, including all root crops	Disinfected Tertiary
	Surface-irrigated food crop, above-ground edible portion not contacted by recycled water	Disinfected Secondary-2.2[2]
Restricted Access	Area where public access is controlled so that areas irrigated with recycled water cannot be used freely by the public (i.e., park, playground, or school yard) and where irrigation is conducted only in areas and during periods when the golf course is not being used by golfers	Disinfected Secondary-23
Unrestricted Access	Parks and playgrounds, school grounds, residential landscaping, unrestricted-access golf courses	Disinfected Tertiary
Other	Any other irrigation uses not specifically prohibited by other provisions of the ***California Code of Regulations***	Disinfected Tertiary
Impoundments (body of water confined by an enclosure, as a reservoir)		
Restricted Recreational	Recreation limited to fishing, boating, and other non-body contact activities; and publicly accessible fish hatcheries	Disinfected Secondary-2.2
Non-Restricted Recreational	Impoundment of recycled water in which no limitations are imposed on body-contact water recreational activities	Disinfected Tertiary
Landscape	Recycled water is stored or used for aesthetic enjoyment or landscape irrigation, not intended for public contact (no decorative fountains)	Disinfected Secondary-23
Industrial Cooling/Air Conditioning		

Non-potable Applications	Description	Minimum Level of Allowable Treatment
With Cooling Tower	Industrial or commercial cooling or air conditioning involving cooling tower, evaporative condenser, or spraying that creates a mist	Disinfected Tertiary
Without Cooling Tower	Industrial or commercial cooling or air conditioning not involving cooling tower, evaporative condenser, or spraying that creates a mist	Disinfected Secondary-23
Other Uses		
	Flushing toilets and urinals, priming drain traps; Industrial process water that may contact workers; Structural firefighting; Decorative fountains; Commercial laundries; Consolidation of backfill material around potable water pipelines; Artificial snow making for commercial outdoor use; Commercial car washes, not heating the water, excluding the general public from the washing process	Disinfected Tertiary
	Industrial process water that will not come into contact with workers; Industrial boiler feed; Nonstructural firefighting; Backfill consolidation around non-potable piping; Soil compaction; Mixing concrete; Dust control on roads and streets; Cleaning roads, sidewalks and outdoor work areas	Disinfected Secondary-23
	Flushing sanitary sewers	Undisinfected Secondary
Groundwater Recharge (returning water to underground aquifers)		
Surface Spreading	Recycled water is deposited over an area, such as a percolation pond, and allowed to move downward from surface to aquifer over time	Allowed under special case-by-case permits by the Regional Water Quality Control Board
Injection	Artificial recovery (AR) and Aquifer Storage and Recovery (ASR) wells inject recycled water directly into the aquifer	

(1) Disinfected Secondary–23: Recycled water that has been oxidized and disinfected so that the median concentration of total coliform bacteria in the effluent is no greater than a most probable number (MPN) of 23 per 100 milliliters.

(2) Disinfected Secondary–2.2: Recycled water that has been oxidized and disinfected so that the median concentration of total coliform bacteria in the effluent is no greater than a MPN of 2.2 per 100 milliliters.

Investigations within the VSD WRF's service area were conducted and information gathered indicates that the main recycled water uses available for the reclamation facility's effluent are unrestricted access irrigation and aquifer recharge via surface spreading or injection. The VSD WRF currently employs oxidation, secondary treatment, and disinfection treatment processes. The reclamation facility would require the addition of tertiary treatment, consisting of coagulation and filtration processes to serve some types of irrigation customers with recycled water, or to recharge the aquifer via surface spreading. The coagulation requirement is typically met with the addition of polymer, or other coagulant chemical such as alum, to the secondary clarifier effluent. While there are various types of filtration methods available, sand filters and cloth/disk filters are two reliable technologies that will be discussed in more detail in **Section 6.2** of this technical memorandum. The addition of microfiltration, reverse osmosis, and advanced oxidation treatment processes would be required for the VSD WRF effluent to be used for aquifer recharge via injection.

3.4 Regulatory Requirements for Groundwater Recharge with Recycled Water

A proposed Indirect Potable Reuse (IPR) project is subject to DDW Recycled Water Regulations for Groundwater Recharge with Recycled Water (GRRW). Articles 5.1 and 5.2 apply to Groundwater Replenishment Reuse Projects (GRRPs), for which recharge is accomplished with surface application methods (i.e., spreading basins) and subsurface application methods (i.e., injection wells), respectively. Key requirements for new GRRPs that affect project feasibility include the satisfaction of pathogen reduction requirements and establishment of an appropriate response retention time based on anticipated underground retention of recharge water between the recharge facility and nearest public water supply well(s). Depending on the project goals for pathogen reduction and recycled water storage, these requirements are likely to be critical factors in evaluating the project feasibility and conceptual design of an IPR project.

3.4.1 Pathogenic Microorganism Control

Section 60320.108 (Pathogenic Microorganism Control) of the recycled water regulations states that at least three treatment processes be used to achieve 12-log enteric virus bacteria, 10-log Giardia Cyst, and 10-log Cryptosporidium reduction. No single treatment process may be credited with more than 6-log reduction, and each treatment process must be able to achieve 1-log reduction.

Underground retention of recycled water can represent one treatment process. For each month of underground retention, the recycled municipal water is credited with 1-log pathogen reduction. At a minimum, the recycled municipal water applied at a GRRP shall receive treatment that meets the definition of filtered wastewater and disinfected tertiary recycled water (pursuant to Section 603001.320).

The underground retention time of recycled water needs to be demonstrated using one of four accepted methods. These include (1) an added tracer study, (2) an intrinsic tracer study, (3) application of a calibrated numerical groundwater flow model, and (4) analytical modeling. Regardless of the method used, hydraulic conditions evaluated need to be representative of normal GRRP operations. If an added tracer is used, 1-log pathogen reduction is credited per month of underground retention time demonstrated. If an intrinsic tracer study is used, 0.67 log pathogen reduction is credited per month of underground retention time demonstrated. If a calibrated numerical groundwater flow model is used, 0.50 log pathogen reduction is credited per month of underground retention time demonstrated. Finally, if analytical modeling is used (e.g., calculation using Darcy’s Law using simplifying aquifer assumptions), 0.25 log pathogen reduction is credited for each month of underground retention time demonstrated.

3.4.2 Response Retention Time

Section 60320.124 (Response Retention Time) states that recycled municipal wastewater applied at the GRRP needs to be retained underground for an appropriate period of time to allow for sufficient response time to evaluate treatment failures and implement actions (including supplying an alternative source of drinking water supply to users of a water supply well potentially impacted by the GRRP) appropriate for the protection of public health. The response retention time shall be no less than two months.

3.4.3 Monitoring Wells

Prior to operating a GRRP, two monitoring wells need to be constructed downgradient of the recharge area. One well should be located between 2 weeks and 6 months of travel through the saturated zone affected by the GRRP and 30 days or more upgradient of the nearest water supply well. A second well should be located between the first monitoring well and nearest water supply well. Each well shall be validated (with an added or intrinsic tracer test) during initial operation of GRRP operations as receiving recharge water from the GRRP.

4. Hydrogeologic Evaluation

The feasibility of implementing an IPR project along with the suitability of surface or subsurface recharge methods is dependent on a combination of hydrogeologic and operational factors. These include (1) the lithology and permeability of vadose zone and saturated zone sediments, (2) groundwater occurrence and flow, (3) distance between recharge facilities and water supply wells, (4) local production well yields, (5) groundwater quality, and (6) timing, location, and rates of recharge.

Surface recharge methods (i.e., spreading basins) are applicable where the vadose zone does not have extensive fine-grained (clay) layers that would restrict vertical migration of recharge water and form perched groundwater conditions that could reduce surface infiltration rates. Underlying aquifers should generally be unconfined and sufficiently permeable to accommodate lateral and vertical flow of the infiltrating water away from the recharge area without forming an excessive groundwater mound that interferes with the infiltration process. Depth to water is also a consideration for the implementation of surface recharge facilities, as a shallow water table can adversely impact infiltration rates.

Subsurface recharge methods (e.g., injection wells) are applicable where the vadose zone or upper saturated zone contains restrictive layers, land is limited, and/or target receiving aquifers are deep and/or confined. Injection wells can be used to bypass the vadose zone and replenish the aquifer directly.

For this study, existing hydrogeologic information was used to characterize local hydrogeologic conditions and support the evaluation of IPR project feasibility. A three-dimensional MODFLOW groundwater flow model was constructed and applied to predict groundwater flow conditions resulting from conceptual IPR projects based on spreading basins and injection wells at the VSD WRF. Specifically, the model was used to estimate groundwater mounding in the vicinity of potential recharge facilities at the VSD WRF, subsurface flowpaths of recycled water, and subsurface retention time of recycled water between the VSD WRF and nearest downgradient production wells.

Hydrogeologic conditions pertinent to recharge feasibility, key findings from groundwater model simulations, and recommendations for addressing technical knowledge gaps are described below.

4.1 Hydrogeologic Setting

The VSD WWTP is located in the Thermal Subarea of the Whitewater River (Indio) Subbasin of the Coachella Valley Basin (Basin) (see Figure 4-1). The Indio Subbasin is separated from the Desert Hot Springs Subbasin to the northeast by the Banning-Mission Creek Fault, which serves as a partial barrier to groundwater flow between the subbasins. Basin fill deposits in the Study Area are comprised primarily of interbedded predominantly coarse-grained Pleistocene and Holocene alluvial fan and stream wash deposits and fine-grained lake deposits. Based on available well driller’s logs, the thickness of basin fill deposits exceeds 1,400 feet in this area. Rainfall on the valley floor averages about 4 inches per year and does not contribute significantly to groundwater recharge. Accordingly, aquifers in the Study Area are fed primarily by subsurface inflows from the west-northwest and anthropogenic return flows (primarily from turf and landscape irrigation) and upstream recharge operations managed by the Coachella Valley Water District.

4.2 Subsurface Lithology, Groundwater Occurrence and Flow

As shown on Figure 4-1, a regional Pleistocene clay aquitard (orange hatched area on Figure 4-1), based on review of well driller’s logs by DWR (1964), extends across much of the Study Area. Where present, the clay aquitard is 100 to 200 feet thick and partially restricts flow between a shallow (upper) aquifer zone and deeper (lower) aquifer zone. The top of the clay aquitard occurs at approximately 300 to 400 feet below ground surface (feet-bgs).

Groundwater flows in a northwest-to-southeast direction (perpendicular to groundwater elevation contours) and occurs under unconfined conditions in the upper aquifer system and under semi-confined to confined conditions in the lower aquifer system[1]. The regional clay aquitard is not mapped beneath the VSD WRF, indicating that locally there is a lesser degree of confinement in the lower aquifer system and better hydraulic connection between shallow and deeper aquifers.

Figure 4-2 shows a 16-mile long hydrogeologic cross section (A-A’) that crosses through the VSD WRF (the cross section location is shown on Figure 4-1). The cross section was developed from lithologic, well construction, water level, and water quality data for IWA, CWA, and CVWD municipal production wells.

The upper left cross section on Figure 4-2 shows the depth of well screens for IWA and CWA municipal production wells, the distribution of coarse-grained (sand/gravel) and fine-grained (silt/clay) deposits identified in well driller’s logs, and 2015 groundwater levels. The cross section reveals the following local hydrogeologic conditions pertinent to recharge feasibility:

- Ground surface elevation ranges from about 20 feet above mean sea level (feet msl) in the northwest to -150 feet msl in the southeast.
- While site-specific information at the VSD WRF is not available, review of well driller’s logs for production wells adjacent to the VSD WRF (IWA BB, IWA 1B, and CWA 17) indicate that surficial sediments (upper 100 feet) in the vicinity are comprised predominantly of coarse-grained sand and gravel deposits with relatively thin clay lenses.
- The estimated depth to groundwater beneath the VSD WRF based on water level measurements in adjacent production wells is approximately 90 feet-bgs.
- Where present along the cross section, the Pleistocene clay aquitard occurs between -350 and -550 feet msl and ranges in thickness from about 150 to 200 feet.

It should also be noted that potential recharge via spreading basin alternatives identified at the VSD WRF site as a result of hydrogeological analysis performed as part of this Study are not believed to be in conflict with the conclusions reached in the Deactivation of Biological Treatment Ponds Technical

[1] The degree of lower aquifer confinement is likely greater where the clay aquitard is mapped.

Memorandum, MWH Global a part of Stantec, January 24, 2017. The conclusions reached therein were based upon the lack of leachable contaminants in the sludge in the biological treatment cells, not necessarily the likelihood of percolated water reaching the aquifer.

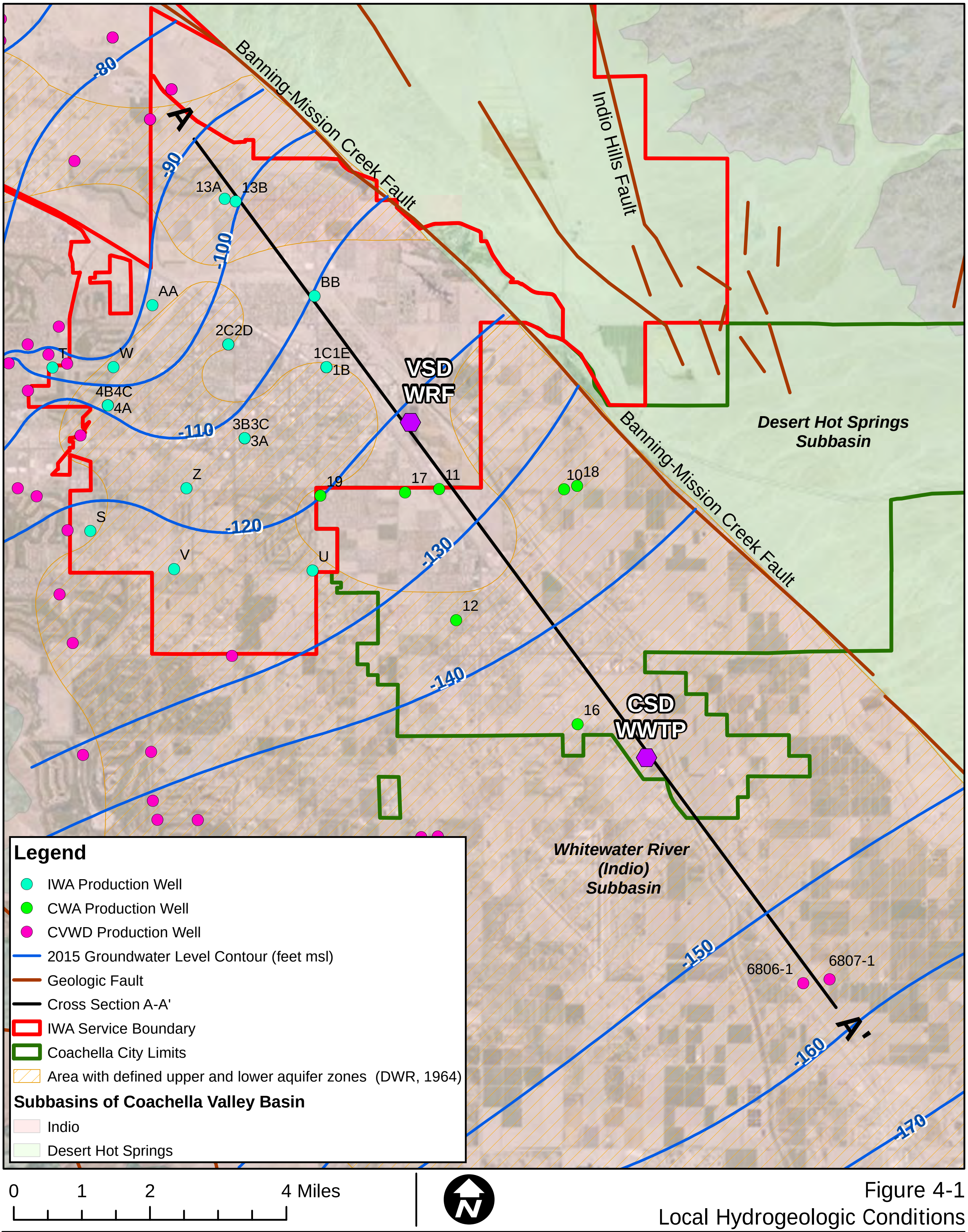

Figure 4-1
Local Hydrogeologic Conditions

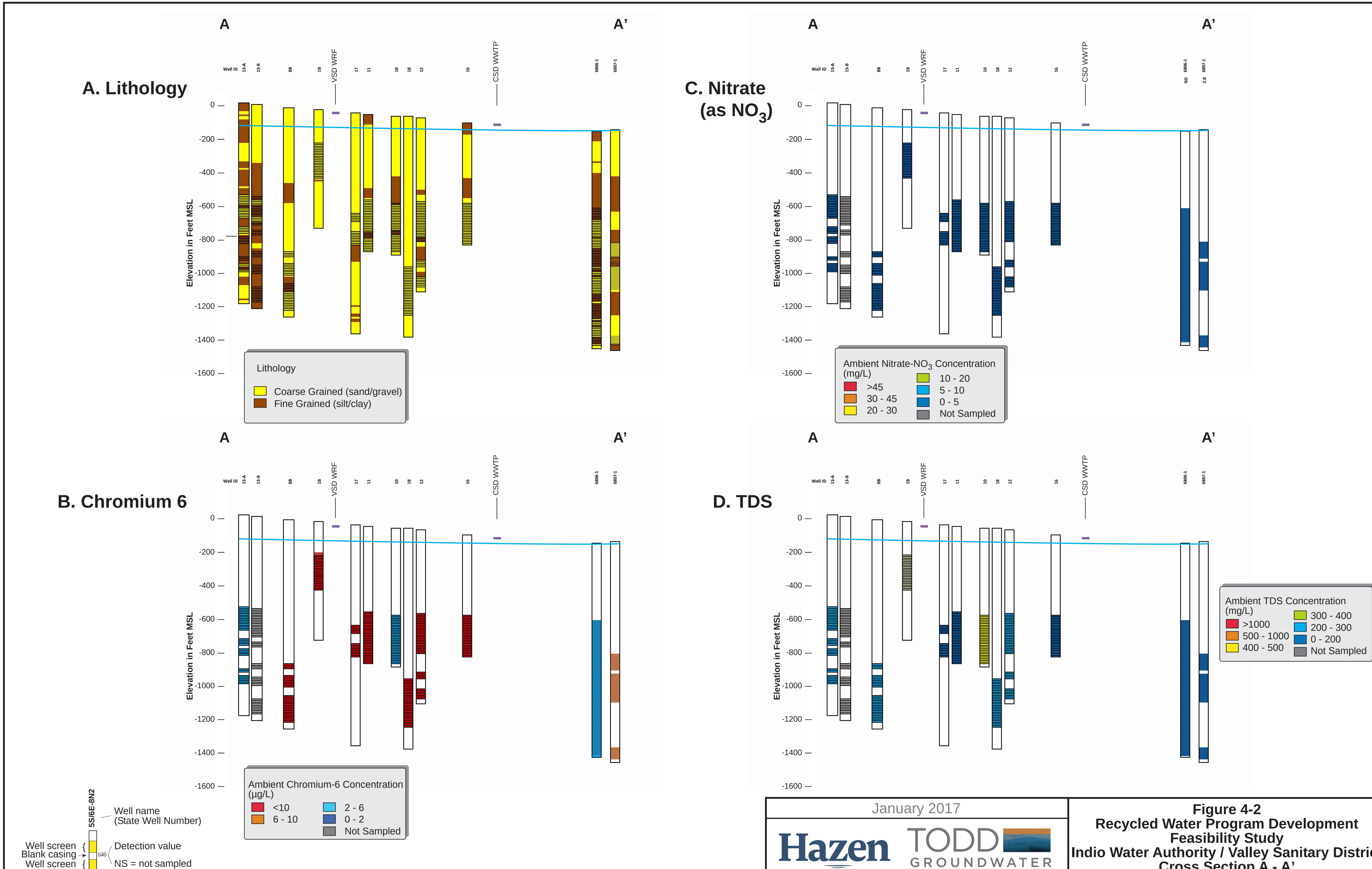

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Figure 4-2
Recycled Water Program Development Feasibility Study
Indio Water Authority / Valley Sanitary District
Cross Section A - A'

- Fine-grained deposits associated with the Pleistocene clay aquitard are thin or non-existent in well driller's logs of the three municipal production wells closest to the VSD WRF (IWA 1B, CWA 11, and CWA 17). The absence of significant clay deposits in the vicinity of the VSD WRF are in agreement with the mapped extent of areas in which upper and lower aquifer zones are defined by DWR.

- IWA production wells are located west (upgradient and side-gradient) of the VSD WRF, while CWA wells are located south (downgradient) of the VSD WRF. IWA and CWA production wells on the cross section are screened in deeper aquifers, with screen intervals ranging from 500 to 1,300 feet-bgs.

- CWA 11 and CWA 17 are located approximately 0.75 miles south of the VSD WRF property and represent the closest downgradient public water supply wells from the VSD WRF site.

4.3 Production Well Yields

Well yields of local IWA and CWA production wells provide an indication of the permeability of saturated zone sediments and potential injection well capacities. IWA production wells in the vicinity are generally constructed of 18-inch diameter steel casing and louvered screens, with some smaller diameter casings/screens associated with deeper well completions. Well yields of active IWA wells range from 1,100 to 3,350 gpm, with an average yield of about 2,300 gpm. Initial specific capacities range from 25 to greater than 100 gallons per minute per foot of drawdown (gpm/ft), with an average specific capacity of about 80 gpm/ft.

CWA 11 and CWA 17 are constructed of 10-inch and 16-inch diameter and steel casing and louvered screen. The well yields of CWA 11 and 17 are 1,200 and 2,000 gpm respectively. Initial specific capacities of CWA 11 and 17 were measured at 9 and 62 gpm/ft, respectively.

4.4 Groundwater Quality

The upper right and two lower cross sections on Figure 4-2 show the distribution of selected groundwater quality parameters (nitrate as NO_3, chromium-6, and TDS) in municipal production well screens in the vicinity of the VSD WWTP. Screen intervals are color-coded according to the most recent concentration for three target constituents of concern as reported between 2013 and 2015. The water quality concentrations in many local production wells exceed the primary maximum contaminant level (MCL) of 10 micrograms per liter (ug/L) for chromium-6, a naturally-occurring metal present in geologic sediments in the Basin. Nitrate concentrations in municipal production wells range from 1 to 5 mg/L as NO_3, well below the MCL of 45 milligrams per liter (mg/L). TDS concentration in municipal production wells generally range from less than 200 to 300 mg/L, below the recommended secondary MCL range of 500 to 1,000 mg/L.

4.5 Surficial Soil Layers and Infiltration Rates

Surface spreading basins require permeable surface soils to achieve high infiltration rates and reduce land requirements. The infiltration rate in surface spreading varies with the hydraulic conductivity of the vadose zone, depth to water, water quality, and other factors. Infiltration typically decreases over time due to physical, chemical, and/or biological clogging of the basin floor. Clogging can be controlled by reducing the total suspended solids (TSS) in the source water.

Sustainable infiltration rates of wastewater effluent ponds and groundwater replenishment facilities (GRFs) operated by CVWD in the central and eastern portions of the Coachella Valley range from about 2 to 3 feet per day (CVWD Water Reclamation Plant 10 and Thomas E. Levy Groundwater Replenishment Facility [GRF]). The CVWD facilities mentioned above are located along the southern margins of the basin and may have more permeable near-surface deposits compared to those at the VSD WRF.

The approximate 20-acre area located to the south of the VSD WRF site where the former biological treatment ponds are located has been identified as a potential area for spreading in terms of percolation and in minimizing conveyance infrastructure. While infiltration rates of surface soils at the VSD WRF are not well documented, well driller's logs show that surficial deposits (upper 100 feet) in municipal production well closest to the VSD WRF (IWA BB, IWA 1B, and CWA 17) are comprised predominantly of coarse-grained sand and gravel deposits with minor clay lenses.

4.6 Key Findings from Model Simulations

The local groundwater flow model developed for this Study was used to estimate groundwater mounding in the vicinity of potential surface recharge facilities and injection wells at the VSD WRF, subsurface flowpaths of recycled water, and subsurface retention time of recycled water between the VSD WRF and nearest downgradient production wells. The local model was constructed on the basis of available geologic, aquifer property, and groundwater flow data and uses three layers to simulate upper and lower aquifers and the regional clay aquitard that separates the two aquifer systems over much of the region. The model was first calibrated to 2015 groundwater level conditions, then used to simulate recharge under steady-state conditions.

The local model incorporates several simplifying assumptions. The model is based on the use of steady-state groundwater flow. Estimates of aquifer thickness and hydraulic conductivity values were made for each model layer. Additionally, groundwater pumping from municipal production wells was not simulated. These input parameter assumptions yield uncertainty in model predictions. Accordingly, simulated groundwater elevations, flow rates and directions should be considered relative estimates of potential recharge system performance. Additional simulations incorporating site-specific aquifer characteristics and under transient flow conditions can be conducted as a part of future design phases.

For the simulation of a conceptual spreading basin project, recharge of the potential current excess flows from the VSD WRF (6 MGD) was applied over the former biological treatment pond area[2]. For simulation of a conceptual injection well project, 6 MGD of recycled water was injected into four injection wells screened in the lower aquifer (Model Layer 3), equally spaced along the perimeter of the former biological ponds area[3]. A second injection well simulation was also conducted wherein 12 MGD of recycled water was injected into eight injection wells equally spaced along the perimeter of the former biological ponds.

Results of groundwater flow modeling for the spreading basin scenario indicate the following:

1. The available subsurface storage can accommodate estimated maximum groundwater mound heights beneath simulated spreading basins (55 feet). Results are considered conservative, as a continuous 100-foot clay aquitard was simulated beneath the VSD WRF site and across the model area. Given a current depth to water of 90 feet-bgs, the recharge mound should remain well below the base of the spreading basins and not adversely impact surface infiltration rates in the basins.

2. Analysis of recharge flowpaths indicate that recycled water flows radially and downgradient away from the VSD WRF, spreading out over an area approximately 3 miles at its maximum width.

3. A significant portion of the recycled water migrates through the intervening clay aquitard and enters into the lower aquifer zone. While IWA wells are not expected to recover recycled water, positive water level changes in the lower aquifer at the two nearest IWA wells (IWA 1B and IWA U) are predicted (approximately 5 feet of water level increase). Recycled water is expected to reach the production zone aquifer at the nearest downgradient municipal production wells (CWA 11 and CWA 17) in approximately 15 to 20 years.

Results of groundwater flow modeling for the injection well scenarios indicate the following:

1. Given a current depth to water of 90 feet-bgs and design injection rates of 1,042 gpm per well, the estimated maximum water level mound height in an individual injection well is approximately 35 feet.

2. Analysis of recharge flowpaths indicate that recycled water flows radially and downgradient away from the VSD WRF, spreading out over an area approximately 4 miles at its maximum width, or about 1 mile wider than the surface spreading scenario.

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[2] Assuming basin berms, side slopes, ramps, and freeboard requirements use 40 percent of the 20 acre biological pond area, 6 MGD would require a basin infiltration rate of approximately 1.5 feet per day.

[3] Equal spacing of injection wells around the site perimeter to minimize well interference during injection. Four wells each with an injection capacity of 1,042 gpm each is needed to inject 6 MGD. This injection rate is reasonable, given that 1) individual well yields for IWA and CWA production wells average about 2,300 gpm, and 2) yields during injection are commonly one-half of yields during extraction. Backflushing at up to twice the injection rate is recommended. Therefore, a preliminary injection well design would be 16 to 24 inches and include a pumping system to backflush the well screens to mitigate clogging.

3. While IWA wells are not expected to recover recycled water, groundwater mounding in the lower aquifer at IWA 1B (10 feet) and IWA U (6 feet) are predicted. Recycled water is expected to reach the nearest downgradient municipal production wells (CWA 11 and CWA 17) in approximately 7 to 8 years.

4.7 Hydrogeologic Conclusions

Based on the evaluation of local hydrogeologic conditions and results of groundwater flow modeling, the following conclusions can be made:

1. An IPR project of 6 MGD at the VSD WRF using surface spreading basins or injection wells appears to be technically feasible. Assuming 12 acres of infiltrating area (60 percent of the 20-acre former biological pond area), recharge of 6 MGD through spreading basins requires an infiltration rate of 1.5 feet per day or greater.

2. An IPR project would increase local groundwater storage and stabilize groundwater levels in lower production zone aquifers.

3. Given that advanced treatment of recycled water is needed for injection wells, decreased concentrations of water quality constituents of concern (e.g. TDS, nitrate, and chromium 6) would be expected. Based on the modeling results, potential water quality benefits in downgradient production wells (CWA 11 and CWA 17) would be expected approximately 7 to 8 years after the project inception for an IPR project utilizing injection wells and approximately 15 to 20 years after project inception for an IPR project utilizing spreading basins.

4. Estimated travel times of recycled water to the nearest downgradient municipal production wells indicate that an IPR project using either spreading basins or injection wells would satisfy the subsurface retention time needed to receive maximum pathogen log-reduction credits (i.e., 6-log reduction credit for 6 months subsurface retention time demonstrated with an added tracer test or for 1 year subsurface retention time demonstrated with an intrinsic tracer test).

5. The VSD WRF site may be able to support an IPR project at recharge rates higher than 6 MGD. In order to achieve 12 MGD through spreading basins, an infiltration rate of 3.0 feet per day or greater would be required. Simulation of a 12 MGD IPR project (using eight 1,042-gpm injection wells equally spaced around the perimeter of the biological ponds) indicates that maximum mound height in an individual injection well would be about 60 feet.

Conclusions are based on evaluation of available hydrogeology for the Study Area. The following additional data collection and evaluation tasks are recommended to support design, costing, and implementation of an IPR project at the VSD WRF site:

1. A field program involving a combination of cone penetrometer tests (CPTs) and drilling of soil borings at the former biological pond area is recommended to confirm whether the lithologic distribution of vadose zone sediments is favorable for recharge using surface spreading basins. Soil borings could be drilled using the hollow-stem auger or sonic drilling method. Small-

diameter monitoring wells could be installed in the borings to facilitate performance monitoring during infiltration tests and monitoring of long-term operation of the future recharge facilities.

2. Long-term infiltration tests (up to 30 days) should be conducted either in or adjacent to the former biological ponds at the VSD WRF site to confirm surface infiltration rates. Infiltration tests could involve the recharge of currently treated effluent. Should infiltration testing be conducted within the former biological ponds, the upper 5 feet of sediment and debris should be removed prior to testing. If an area adjacent to the ponds are used, soils should be excavated to create a temporary test basin with sufficient area to minimize the effect of lateral spreading of recharge water (e.g., 25 feet x 25 feet). During the test, the discharge rate and ponded water level should be measured and converted to a vertical infiltration rate.

3. Refined groundwater flow and solute transport modeling could be conducted to further evaluate and optimize recharge (and recovery) operations and provide support for DDW GRRP permit requirements.

5. Reuse Opportunities

5.1 Indirect Potable Reuse

A proposed IPR project would involve the treatment of wastewater generated from the VSD WRF and subsequent groundwater recharge and storage of the recycled water in the groundwater system. The primary objective of an IPR project may involve seasonal to long-term banking with or without recovery of the recycled water by extraction wells.

5.2 Groundwater Recharge

While knowledge gaps of site hydrogeologic conditions remain, an IPR project at the VSD WRF using injection wells appears to be technically feasible. An IPR project with spreading basins may be feasible pending confirmation of the sustainable infiltration capacity of surficial sediments and the extent and thickness of clay deposits in the vadose zone field investigations.

5.2.1 Cost Considerations for IPR Project using Injection Wells

Injection wells are likely to be a more expensive recharge facility option compared to surface spreading basins primarily because of the depth of drilling needed to reach and sufficiently screen across permeable sediments in the production zone aquifer. In addition, injection wells would require advanced wastewater treatment to prevent premature well clogging and have higher construction and maintenance costs compared with spreading basins. In developing a cost estimate for the construction of an injection well, the following project components are considered:

- Test injection well/monitoring well drilling, construction, and hydraulic testing
- Injection well drilling, construction, development, and hydraulic testing
- Turnouts and distribution pipelines
- Flow control valves and flowmeters
- Well pump for backflushing
- Electrical instrumentation
- Land acquisition
- Permitting and environmental compliance

A preliminary cost estimate to drill, install, equip, and test an injection well is approximately $1,500,000 per well. This estimate assumes a well casing and screen diameter of 16 inches and a well depth of 1,000 feet to sufficiently screen across permeable sediments in the lower production zone aquifer to provide 1,000 gpm injection capacity. The cost estimate does not include engineering, permitting, and environmental review costs. Refer to Section 8 for more detailed cost information.

5.3 Non-potable Reuse

Non-potable reuse consists of the use of recycled water for irrigation purposes, driven by large turf irrigation users such as golf courses, polo clubs, parks, and homeowner's associations (HOAs). Irrigation water use typically varies seasonally with peak use during the summer months and minimum use during the winter months. Non-potable reuse systems must be able to accommodate these variations in demand.

5.3.1 Potential Recycled Water Customers

Potential recycled water customers were identified beginning in the TM No. 1 – Market and Demand Assessment (Carollo, 2010) for the entire IWA and VSD service areas. In that study, a potential average annual irrigation water demand of 15,387 AFY was identified. This value was later refined in the 2011 RWMP to an average annual demand of 15,974 AFY, with a corresponding maximum day demand of 28.53 MGD. The 2011 RWMP identified that this demand was in excess of the ultimate VSD WRF capacity, even more so when accounting for the CVSC minimum discharge of about 0.5 MGD. Therefore, the service-area-wide recycled water system that was initially proposed, was scaled back to accommodate the existing and future capacity of the VSD WRF and split into two separate phases.

This Study does not attempt to revisit any of the work that was previously completed. However, this study does seek to build upon the previous work by evaluating two large proposed developments Grand Valley (formerly Citrus Ranch) and Stonewater. Both of these proposed developments are currently outside the limits of the City of Indio in unincorporated County of Riverside, although they are located within the City of Indio's Sphere of Influence, and are likely to be annexed in the near future (see Figure 5-1).

5.3.1.1 Grand Valley

A Specific Plan has been developed for Grand Valley (formerly Citrus Ranch) (Stantec, 2007). This Specific Plan describes Citrus Ranch as a "master-planned golf course community containing approximately 3,075 residential units ranging in density from 2.5 to 14 DU/ac within a 1,183 acre site." The project is located in the Indio Hills, generally bound by Avenue 42 / Fargo Canyon Road to the south, Dillon Road to the north/east, and hills to the west. The proposed land use breakdown is included in Table 5-1.

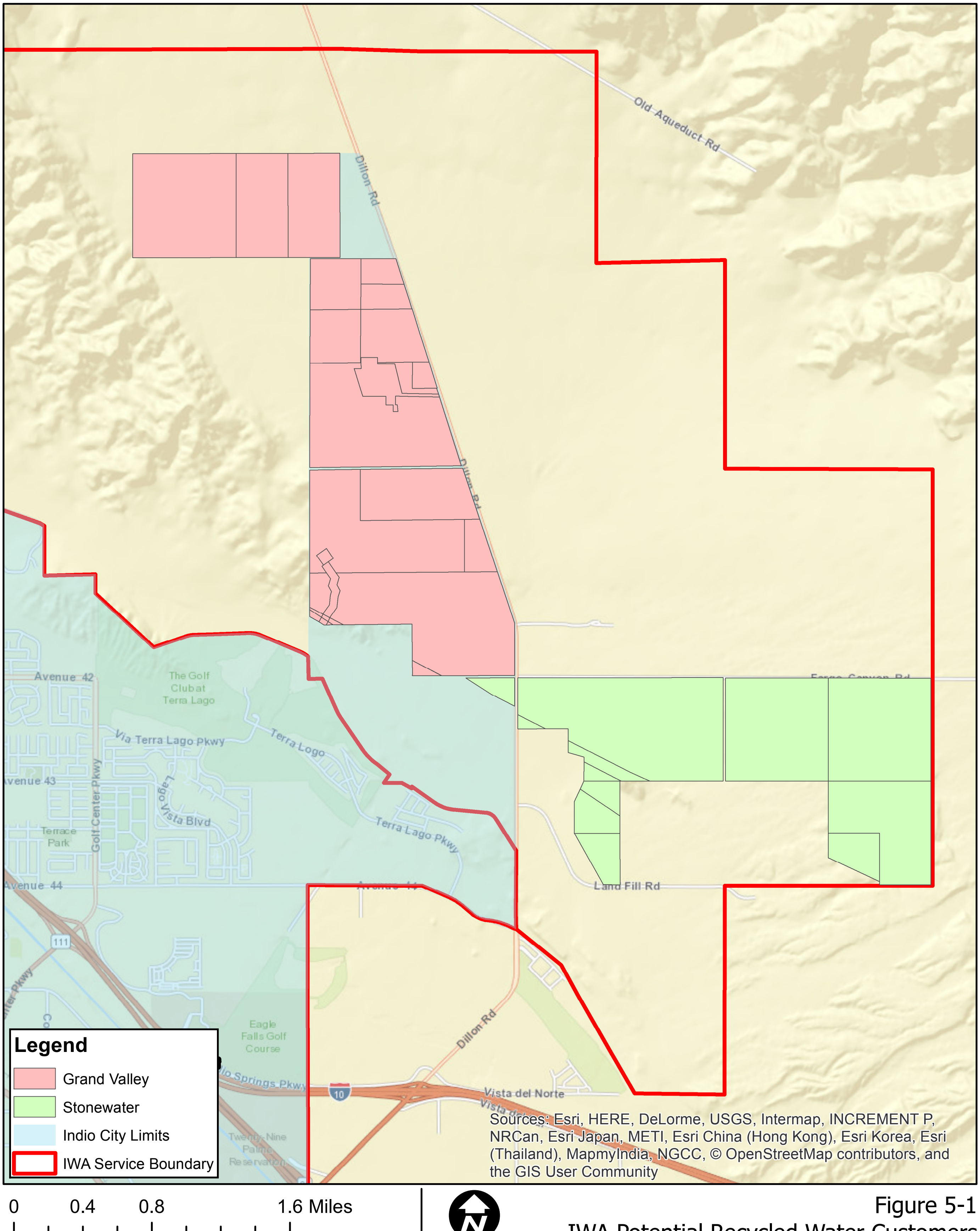

Figure 5-1
IWA Potential Recycled Water Customers

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Recycled Water Program Development Feasibility Study
Indio Water Authority / Valley Sanitary District

Table 5-1: Grand Valley Land Use

Land use	Acres
Residential	576.0
Boutique Hotel	5.4
Clubhouse	6.0
Community Center	5.0
Open Space	520.6
Undisturbed Open Space	*186.7*
Wilderness Trails	*3.0*
Community Parks	***6.1***
Neighborhood Parks	***9.3***
Citrus Grove Paseos	***11.3***
Recreation OS & Playfields	***56.2***
Dillon Road Landscape	***7.2***
Golf Course	***233.1***
SE Drainage Channel	*7.7*
Community Collector Streets	60.0
Dillon Road R.O.W.	3.9
Golf Course Maintenance Yard	1.6
Fire Station Site	2.0
Well Site	3.0
TOTAL	**1,183.5**

Source: Table 3-1 – Land Use of the 2007 Citrus Ranch Specific Plan.

Of the proposed land uses, it is estimated that approximately 323 acres consists of golf course, park, or otherwise landscaped areas that could potentially be irrigated with recycled water.

5.3.1.2 Stonewater

A Specific Plan for Stonewater was not available at the time of preparation of this memorandum. Based on brochure information, Stonewater is described as an 818 acre development that proposes 2,364 residential units, hotel/resort, commercial/retail, and motor coach resort. The project is located at the southeast corner of Dillon Road and Avenue 42 / Fargo Canyon Road in the Indio Hills two miles north of Interstate 10. The proposed land use breakdown is included in Table 5-2.

Table 5-2: Stonewater Land Use

Land use	Acres
Undevelopable	13.68
Restricted Use	59.66
Utility Easements	32.1
Reservoir Sites	6
R.O.W.	10.28
Hillside Areas / Open Space or Recreation Amenity	**19.46**
Drainage Facilities	50.3
Parks and Trails	**25**
Internal Collector Roads	36.36
Resort Hotel and Condominiums	25
Retail / Commercial	25.26
Motor Coach Resort / Commercial	62.04
Multi-Family Rental Condominiums	15
Single Family Residential	438.01
TOTAL	**818.15**

Source: RoBott Land Company Exclusive Offering Memorandum. Retrieved December 2, 2016.

Of the proposed land uses, it is estimated that approximately 44acres consists of open space, parks, or otherwise landscaped areas that could potentially be irrigated utilizing recycled water.

5.3.2 Potential Recycled Water Demands

Recycled water demands were established in previous studies for those potential customers previously identified. This Study focuses on the potential recycled water demands for the proposed Grand Valley and Stonewater developments. Recycled water demands are estimated by applying a water demand factor to the area of irrigable land. As Grand Valley and Stonewater are proposed developments without existing water usage records, a conservative planning factor of 4,000 gpd/acre was utilized similar to the 2012 IWA WMP for Park Irrigation. Demand calculations are provided in Table 5-3 and Table 5-4.

Table 5-3: Potential Recycled Water Demands – Grand Valley

Land Use	Area (ac)	Water Demand Factor (gpd/ac)[1]	Average Day Demand (gpm)
Community Parks	6.1	4,000	16.9
Neighborhood Parks	9.3	4,000	25.8
Citrus Grove Paseos	11.3	4,000	31.4
Recreation OS & Playfields	56.2	4,000	156.1
Dillon Road Landscape	7.2	4,000	20.0
Golf Course	233.1	4,000	647.5
TOTAL	**323.2**	**-**	**897.8**

[1] Park Irrigation factor from Table 2-6 of the 2012 IWA WMP.

Table 5-4: Potential Recycled Water Demands – Stonewater

Land Use	Area (ac)	Water Demand Factor (gpd/ac)[1]	Average Day Demand (gpm)
Hillside Areas / Open Space or Recreation Amenity	19.46	4,000	54.1
Parks and Trails	25	4,000	69.4
TOTAL	**44.46**	**-**	**123.5**

[1] Park Irrigation factor from Table 2-6 of the 2012 IWA WMP.

The potential average day recycled water demands for the proposed Citrus Ranch and Stonewater developments are estimated at 897.8 gpm and 123.5 gpm, respectively, for a total of 1,021.3 gpm. Average day demand represents the average demand over an entire year. Demands typically vary seasonally with the higher demands occurring in the hotter, drier months and lower demands occurring in the cooler, wetter months. Demands also vary throughout the day, typically set by the irrigation window. This Study utilizes those factors established in the 2011 IWA RWMP, listed in Table 5-5.

Table 5-5: Peaking Factors

Demand Condition	Peaking Factor
Minimum month	0.26 x ADD
Maximum month	1.87 x ADD
Maximum day	2.0 x ADD
Peak hour	MDD x 24 / irrigation period in hours

Source: 2011 IWA RWMP.

The peak hour demand factor, as mentioned previously, depends on the number of hours per day that irrigation is occurring. Irrigation periods can range anywhere from 5 hours to 15 hours; however, for the purpose of this analysis, an irrigation period of 10 hours has been used as it is the more common irrigation period of potential IWA and VSD customers and is consistent with the planning criteria of the 2011 IWA RWMP. An irrigation period of 10 hours equates to a peak hour factor of 2.4 times the maximum day demand. A summary of the demands for Citrus Ranch and Stonewater under the varying demand conditions is provided in Table 5-6.

Table 5-6: Potential Recycled Water Demands – Summary

Potential Customer	Minimum Month (gpm)	Average Day (gpm)	Maximum Month (gpm)	Maximum Day (gpm)	Peak Hour (gpm)[1]
Citrus Ranch	233.4	897.8	1,678.8	1,795.6	4,309.3
Stonewater	32.1	123.5	230.9	247.0	592.8
TOTAL	**265.5**	**1,021.3**	**1,909.8**	**2,042.6**	**4,902.1**

[1] Based on a 10-hour irrigation window.

It should be noted that demand conditions are applied on a per land use basis and the summarized demands presented in Table 5-6 may not be representative of the actual demands used for infrastructure sizing. Infrastructure sizing is discussed further in Section 7 of this TM. It should also be noted that delivery of recycled water to the customers identified in the previous study and the Citrus Ranch and Stonewater developments will not be possible due to a limitation of currently projected wastewater flows that will be available.

6. Wastewater Treatment Process Selection

6.1 Description of Existing Wastewater Treatment Plant

The VSD WRF is located on Van Buren Street in the City of Indio and provides wastewater treatment for approximately 98 percent of the City of Indio's population. The effluent from the VSD WRF is secondary quality effluent that is currently discharged to the CVSC.

In 2015 and 2016, the VSD WRF treated approximately 5.6 million gallons per day (mgd). With a minimum discharge of about 0.5 mgd required to the CVSC to maintain the existing riparian vegetation, this leaves approximately 5.1 mgd of average daily flow for recycled water use. As directed by VSD and IWA, the planning horizon for this study was to evaluate wastewater flows available through 2030. By 2030, the VSD WRF is expected to reach a total capacity of 12 mgd. Assuming the discharge of about 0.5 mgd to CVSC remains the same, approximately 11.5 mgd of average daily flow for recycled water will be available by 2030. The recycled water system has been sized to accommodate current flows with space allocated for secondary treatment for flows through the year 2030.

The existing WRF liquid handling system comprises influent pumps, screening, grit removal, primary sedimentation basins, secondary treatment, oxidation ponds, a biological treatment unit, and disinfection. The WRF effluent is treated to secondary quality via an activated sludge treatment process including aeration basin with selectors, and secondary clarifiers. Disinfection is achieved with chlorine through a Chlorine Contact Tank (CCT3). Disinfected water is dechlorinated with sodium bi-sulfate before being discharged to the CVSC. During peak events, flows can also be diverted through oxidation ponds. These ponds currently act as a parallel secondary treatment system with the activated sludge system. A second Chlorine Contact Tank, CCT2, allows disinfection of pond effluent before discharging to the CVSC.

A process flow diagram and site plan showing the existing facilities for the VSD WRF is provided and shown in Figure 6-1 and Figure 6-2, respectively.

Discharge flow and water quality data from the VSD WRF's effluent for the period between January 31, 2015 and May 31, 2016 is presented in **Appendix B**. The data shows average monthly flows at the facility range from 5.1 mgd in the dry season to 6.4 mgd during the wet weather months. Average monthly carbonaceous biochemical oxygen demand (CBOD) and total suspended solids (TSS) values from the plant effluent are 15.1 and 8.6 mg/L respectively. Additionally, bacteria monitoring yielded average monthly counts for E.coli of 2.5 MPN/100mL and Fecal Coliform of 3.1 MPN/100mL. Monthly total dissolved solids (TDS) averages were obtained from January through October of 2015. The average value recorded during that period was 449.0 mg/L.

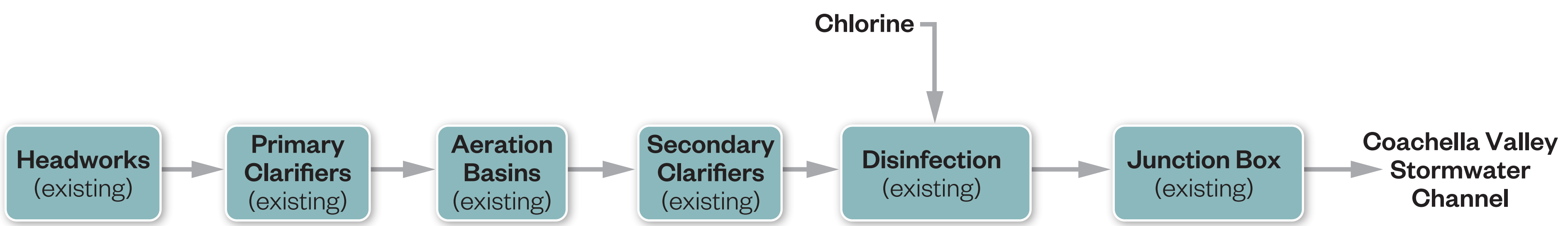

Figure 6-1
VSD WRF - Existing VSD WRF Process Treatment Schematic

Figure 6-2
VSD WRF Existing Facility Site Layout

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6.2 Recycled Water Treatment Alternatives

The recycled water treatment alternatives evaluated in this section include uses for irrigation, surface spreading, as well as groundwater injection. In order to produce recycled water that meets Title 22 requirements (for irrigation and surface spreading) at the VSD WRF, several treatment alternatives have been identified, which all include coagulation, tertiary filtration and disinfection. With the addition of tertiary level treatment, the VSD WRF would be able to provide recycled water to irrigation customers as well as recharge via spreading and percolation. In order to meet groundwater recharge requirements via injection, microfiltration and reverse osmosis followed by advanced oxidation processes is required.

For tertiary filtration, the alternatives evaluated include sand filters, cloth filters, microfiltration, and membrane bioreactors (MBR), while the groundwater injection alternative includes microfiltration/reverse osmosis (MF/RO) combination. All alternatives will require disinfection as the final treatment step. For tertiary treatment and groundwater recharge via spreading, chlorine disinfection is required. For ground water recharge via injection, advanced oxidation is required. The alternatives were developed based on conventional Title 22 treatment requirements as well as any potential future treatment plant effluent requirements. A brief description of each process and the recommended design criteria for these alternatives are further described in the following sections.

6.2.1 Tertiary Filtration

Tertiary filters remove suspended solids from secondary effluent by passing it through a filter media that can be fine sand, dual media (anthracite/sand), or cloth. These are discussed below in more detail in the following sections.

6.2.1.1 Sand Filtration

Sand bed filters work by providing the particulate solids with many opportunities to be captured on the surface of a sand grain. Sand filters are available either as standalone package units or in a modular concrete design. The backwash can be intermittent or continuous depending on the design. Most sand filters operate with an upflow, counter-current flow pattern. For planning purposes, the assumed design criteria for sand filtration are summarized in Table 6-1 to be verified during preliminary design.

Table 6-1: Sand Filtration Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flowrate	mgd	6	12
Filter media		Sand	Sand
Filtration rate	gpm/sq. ft	3.0	3.0
Total Sand Filtration surface area	Sq.ft	1,390	2,780
Cell Size	Sq.ft	400	400
Number of units		4	8
Backwash (continuous or intermittent)		Intermittent	Intermittent

6.2.1.2 Cloth Filtration

Cloth filters use a woven media to capture and filter out particles in the wastewater. A typical configuration is to have the cloth media on discs with an inside-out flow pattern. Cloth media filters are also available as standalone package units or in a modular concrete design and are typically low-head systems with automatic backwash capabilities. For planning purposes, the assumed design criteria for cloth filtration are summarized in Table 6-2.

Table 6-2: Cloth Filtration Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flow rate	mgd	6	12
Filter media		Cloth	Cloth
Average Filtration rate	gpm/sq. ft	3.0	3.0
Total Disk Filtration surface area	Sq.ft	1,390	2,780
Total Number of Disks	ft	30	60
Number of Disk Filtration Units		2	4

6.2.2 Micro Filtration

Micro filtration (MF) is a pressure-driven process that provides a near absolute barrier to suspended solids and microorganisms. MF membranes have a pore size ranging from 0.01 to 1.0 microns. Using MF for tertiary filtration also provides greater flexibility for future groundwater recharge since it is required as a pretreatment for reverse osmosis. The preliminary sizing of the MF system such that it can be used for either standalone tertiary treatment or as the pretreatment step before reverse osmosis. For planning purposes, the assumed design criteria are summarized in Table 6-3.

Table 6-3: Micro Filtration Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flow rate	mgd	6	12
Membrane Type		Hollow fiber	Hollow fiber
Membrane Material		Polyvinylidene fluoride (PVDF)	Polyvinylidene fluoride (PVDF)
Pore Size	Micron	0.04	0.04
Filtration flux rate	gallons/sq. ft day	28	28
Recovery	%	90	90
Number of duty trains		4	14
Total number of train		5	10
Flow per train	mgd	1.48	1.48

6.2.3 Membrane Bioreactor

The MBR process is a biological process that consists of membranes installed in membrane tanks and submerged in mixed liquor to separate solids and produce a high-quality effluent. The MBR process has the advantage of being able to achieve nutrient removal and also provides greater flexibility for future groundwater recharge since it is required as a pretreatment for reverse osmosis. Membranes used in this application have typical pore sizes in the range of 0.04 microns to 0.4 microns. While the MBR process is typically a higher cost alternative, it has advantages over tertiary filtration that include more flexibility for future groundwater recharge since it is considered pre-treatment for advanced treatment and any RO system downstream if an MBR would not require microfiltration. MBR would be a substitute for the existing activated sludge and secondary clarifier system, and new filters required for tertiary. For planning purposes, the assumed design criteria are summarized in Table 6-4.

Table 6-4: Membrane Bioreactor Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flow rate	mgd	6	12
Membrane Type		Hollow fiber	Hollow fiber
Membrane Material		Polyvinylidene fluoride (PVDF)	Polyvinylidene fluoride (PVDF)
Pore Size	Micron	0.04	0.04
Filtration flux rate	gallons/sq. ft day	30	30
Number of trains		4	8
Cassettes per train		5	5
Redundancy	%	25	25

6.2.4 Reverse Osmosis

High-pressure membrane processes such as RO are typically used for the removal of dissolved constituents including both inorganic and organic compounds. RO is considered a “high-pressure” process because it operates from 75 to 1,200 psig, depending upon the total dissolved solids (TDS) concentration of the feed water. During the RO process, the mass-transfer of ions through membranes is diffusion-controlled. The feed water is pressurized, forcing water through the membranes, concentrating the dissolved solids that cannot travel through the membrane. Consequently, these processes can remove salts, hardness, synthetic organic compounds, disinfection-by-product precursors, etc. Some of the major concerns with the RO process are the higher energy usage as well as the management of the concentrated brine stream, particularly for inland facilities such as VSD where a regional brine line for disposal has not yet been constructed. For this facility, there are limited options for brine disposal. Brine disposal would consist of on-site evaporation ponds or there may be potential for regional evaporation ponds. For either option, the brine could be further concentrated through secondary RO or thermal evaporative processes to increase finished water production and decrease brine volume, effectively reducing the size of the evaporation ponds. For planning purposes, the assumed design criteria is summarized in Table 6-5.

Table 6-5: Reverse Osmosis Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flow rate	mgd	6	12
Membrane Type		Hollow Fiber	Hollow Fiber
Membrane Material		Polyvinylidene fluoride (PVDF)	Polyvinylidene fluoride (PVDF)
Pore Size		Non-porous	Non-porous
Filtration flux rate	gallons/sq. ft day	11	11
Recovery	%	80	80
Number of Duty units		4	8
Total number of Units		5	10
Flow per unit	mgd	1.33	1.33

6.2.5 Disinfection Alternatives

This section outlines some of the disinfection alternatives that are used for tertiary and advanced treatment including chlorine, and advanced oxidation (UV and peroxide) respectively.

6.2.5.1 Chlorine Disinfection

Chlorine has been one of the more common methods for disinfection of wastewater effluent. The move from gaseous chlorine to liquid hypochlorite solutions has reduced the risk associated with chlorine disinfection. Currently the WRF uses chlorine disinfection and for the title 22 tertiary requirements, this would also be most cost effective. For planning purposes, the assumed design criteria for new disinfection facilities is summarized in Table 6-6.

Table 6-6: Chlorine Disinfection Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flow rate	mgd	6	12
Chemical name		Sodium Hypochlorite (NaOCl)	Sodium Hypochlorite (NaOCl)
Percent Active Chemical	%	10.25	10.25
Estimated Chlorine Dose	mg/L	5 - 10	5 - 10
Detention Time at peak flow	mins	90	90
Chlorine Contact Tank Dimensions	L(ft) x W(ft) x D(ft)	139 x 12 x 10	139 x 12 x 10
Number of Channels		2	4
Number of Passes per Channel		3	3

6.2.5.2 Advanced Oxidation

Advanced oxidation processes in a very broad sense refers to a set of chemical treatment procedures designed to remove organic (and sometimes inorganic) materials in water and wastewater by oxidation through reactions with hydroxyl radicals. These treatment procedures typically include ozone (O_3), hydrogen peroxide (H_2O_2) and/or UV light disinfection. The most common and cost effective is UV disinfection with hydrogen peroxide. When coupled, these provide an advanced oxidation system in which hydroxyl radicals are produced that attack and destroy many micro-constituents. For planning purposes, the assumed design criteria are summarized in Table 6-7.

Table 6-7: Advanced Oxidation Design Criteria

Criteria	Units	2017 Flowrate	2030 Flowrate
Flow rate	mgd	6	12
UV Dose	MJ/sq.cm	110	110
UVT	%	65	65
Estimated Hydrogen Peroxide Dose	mg/L	5 - 10	5 - 10

6.3 Wastewater Treatment Infrastructure Improvements

This section outlines the infrastructure improvements that are required for each alternative identified in Section 6.2 above. For each alternative, a process flow diagram and site layout is provided that identifies the space requirements for each treatment option. It should be noted that these layouts are at a preliminary concept level stage and could change based on further knowledge of the wastewater quality either through

FEEM testing or pilot testing which is discussed further in Section 6.4. These layouts show the general footprints based on recent vendor information. The footprints were developed for each unit operation based on an assumed existing system capacity of 6 mgd and 2030 flows which are projected to be approximately 12 mgd. Additionally, it should be noted that the site layouts presented, follow the phasing plan identified by the VSD Facility Master Plan completed by MWH in September 2015. Any improvements noted in the subsequent sections would be constructed upon the completion of all solids handling facility upgrades and the decommissioning of both North and South Cells, and Ponds 2 and 3.

6.3.1 Tertiary Filtration (Alternatives 2, 3, 5a, and 6)

Tertiary filtration facilities are associated with Alternatives 2, 3, 5a, 6, which could consist of either sand or cloth filters and would require the construction of several units based on the design criteria in Section 6.2.1 above. A secondary effluent pump station would be required to pump effluent to the new tertiary filters and disinfection system. A recycled water pump station and recycled water storage tank would also be required to provide irrigation water to customers. The new filtration facilities are proposed for construction on the southern side of the facility in the decommissioned South Cell, and the recycled water storage tank and pump station in decommissioned Pond 3. A preliminary process flow diagram and conceptual site layout of the tertiary filtration system is presented in Figure 6-3 and Figure 6-4, respectively.

6.3.2 Tertiary Microfiltration

The tertiary microfiltration system would be based on the design criteria in Section 6.2.2 above. A secondary effluent pump station would be required to pump effluent to the new tertiary microfilters. The permeate could then be pumped from the microfiltration tank to the disinfection system and recycled water storage tank. A recycled water pump station located on the south side of the facility in decommissioned Pond 3 would be required to provide irrigation water to customers. A preliminary process flow diagram and conceptual site layout of the microfiltration system is presented in Figure 6-5 and Figure 6-6 respectively.

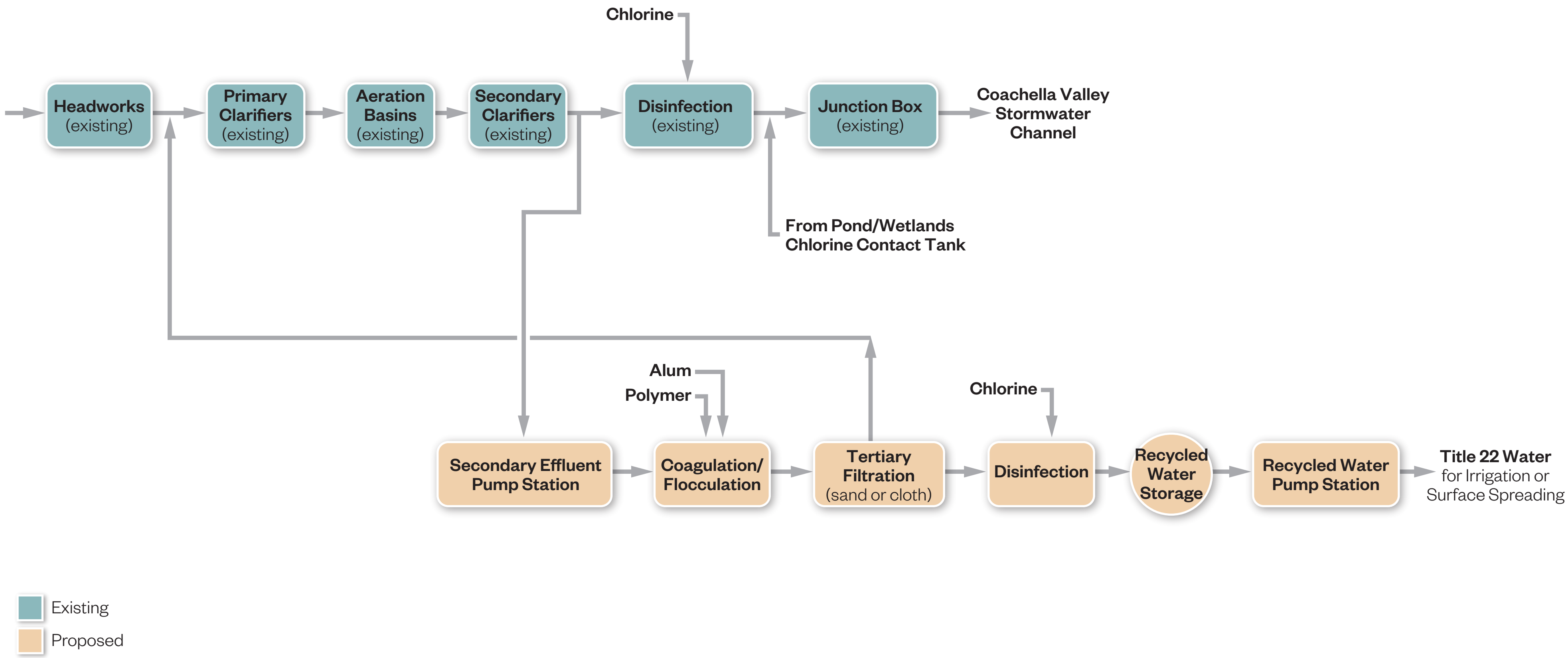

Figure 6-3
VSD WRF - Tertiary Filtration PFD

Figure 6-4
VSD WRF Preliminary Tertiary Filtration Site Layout

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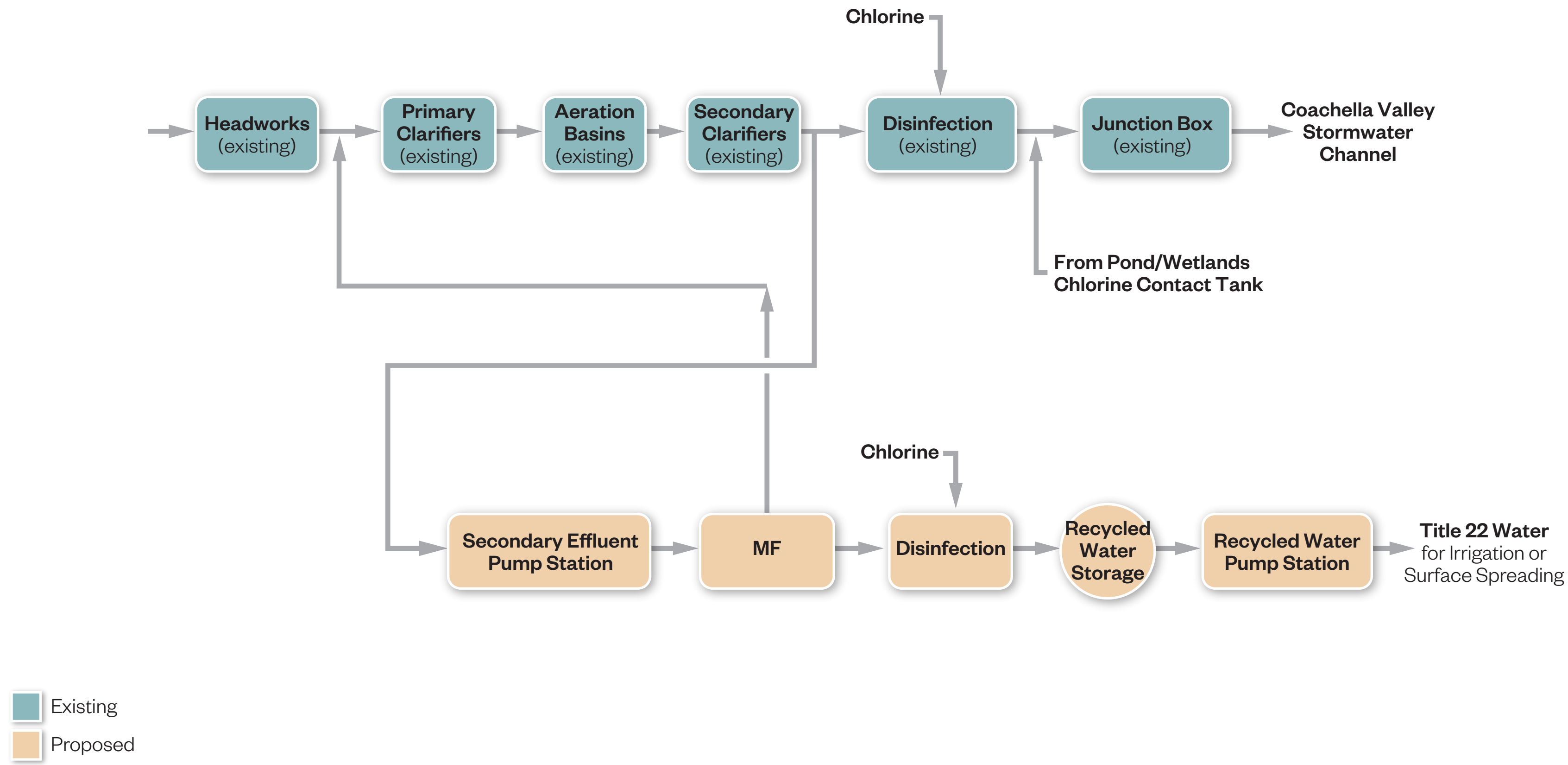

Figure 6-5
VSD WRF - Tertiary MicroFiltration PFD

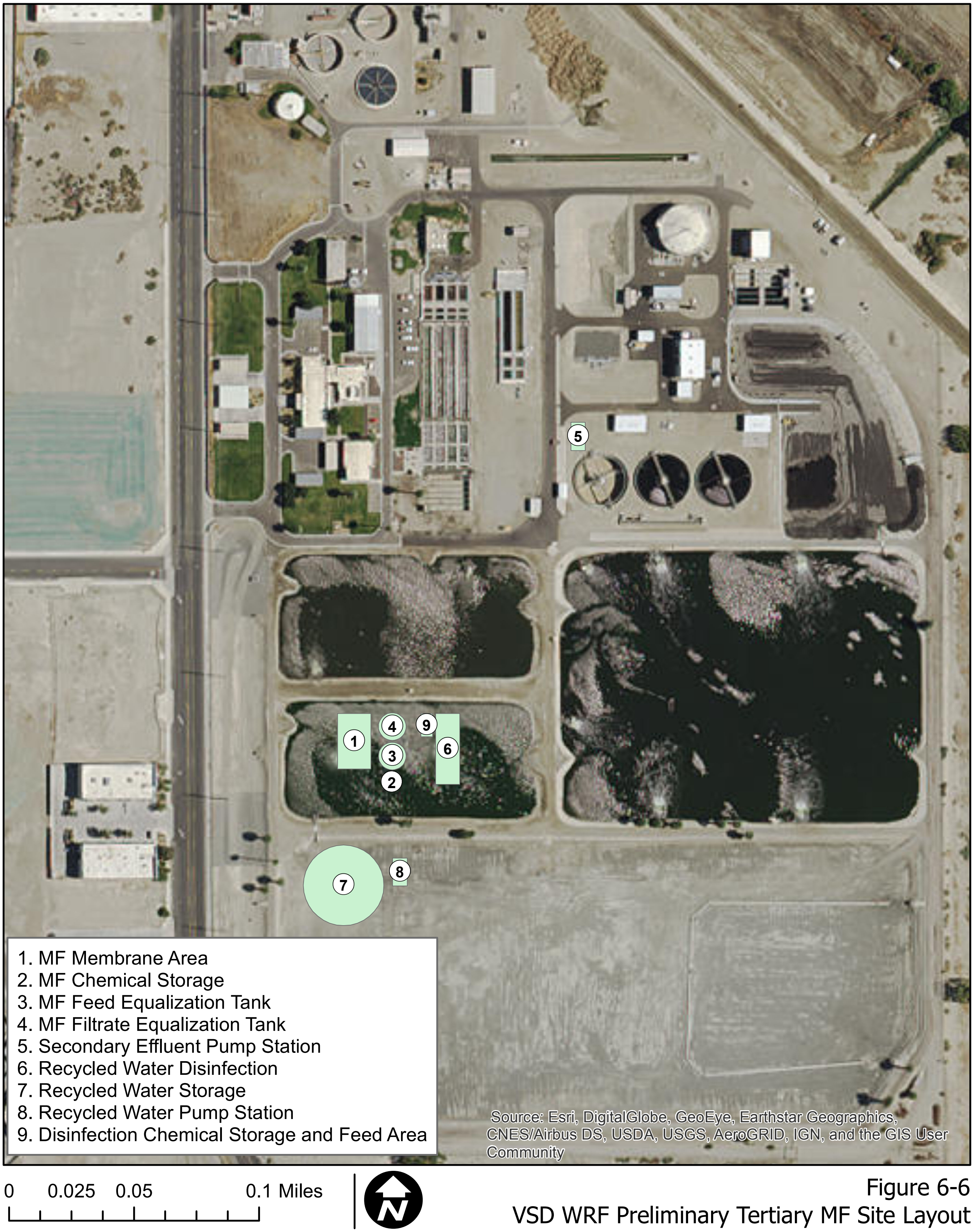

Figure 6-6
VSD WRF Preliminary Tertiary MF Site Layout

6.3.3 Membrane Bioreactor

The MBR system would be based on the design criteria presented in Section 6.2.3 above. If MBR were selected as the preferred treatment, the new MBR facilities would be constructed in the decommissioned South Cell. The membrane permeate would be pumped from the membrane tank to the disinfection system and recycled water pump station proposed in decommissioned Pond 3, also located on the south side of the facility. A preliminary process flow diagram and conceptual site layout of the membrane bioreactor system is presented in Figure 6-7 and Figure 6-8, respectively. Since the MBR process can also be a pre-treatment process to the RO system, it would be possible to use the MBR treatment if groundwater injection was being implemented at the plant or at Posse Park.

6.3.4 Advanced Treatment (Alternatives 4 and 5b)

Advanced water treatment (AWT) facilities are associated with Alternatives 4 and 5b and would be designed to treat wastewater for groundwater injection at the VSD WRF or Posse Park. This advanced treatment system would consist of the unit operations for MF/RO and UV/AOP as described previously. A break tank would be provided before the RO unit to ensure a stable influent flow. After RO treatment, the RO permeate would be pumped to the UV/AOP and stabilization processes. Then, the finished water would be pumped to storage or to injection wells at the plant or Posse Park. A preliminary process flow diagram and conceptual site layout of the advanced treatment system is presented in Figure 6-9 and Figure 6-10, respectively.

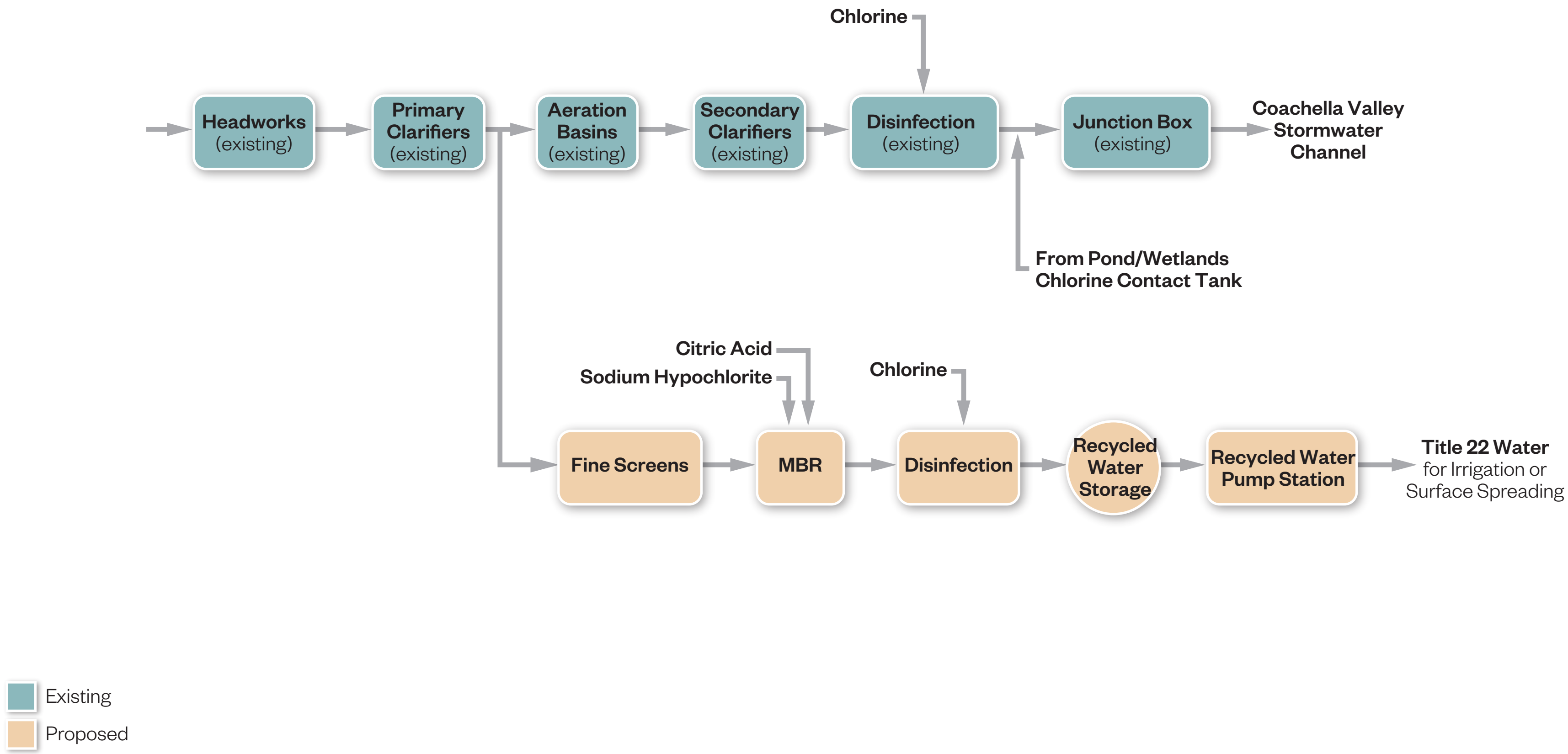

Figure 6-7
VSD WRF - MBR PFD

Figure 6-8
VSD WRF Preliminary Tertiary MBR Site Layout

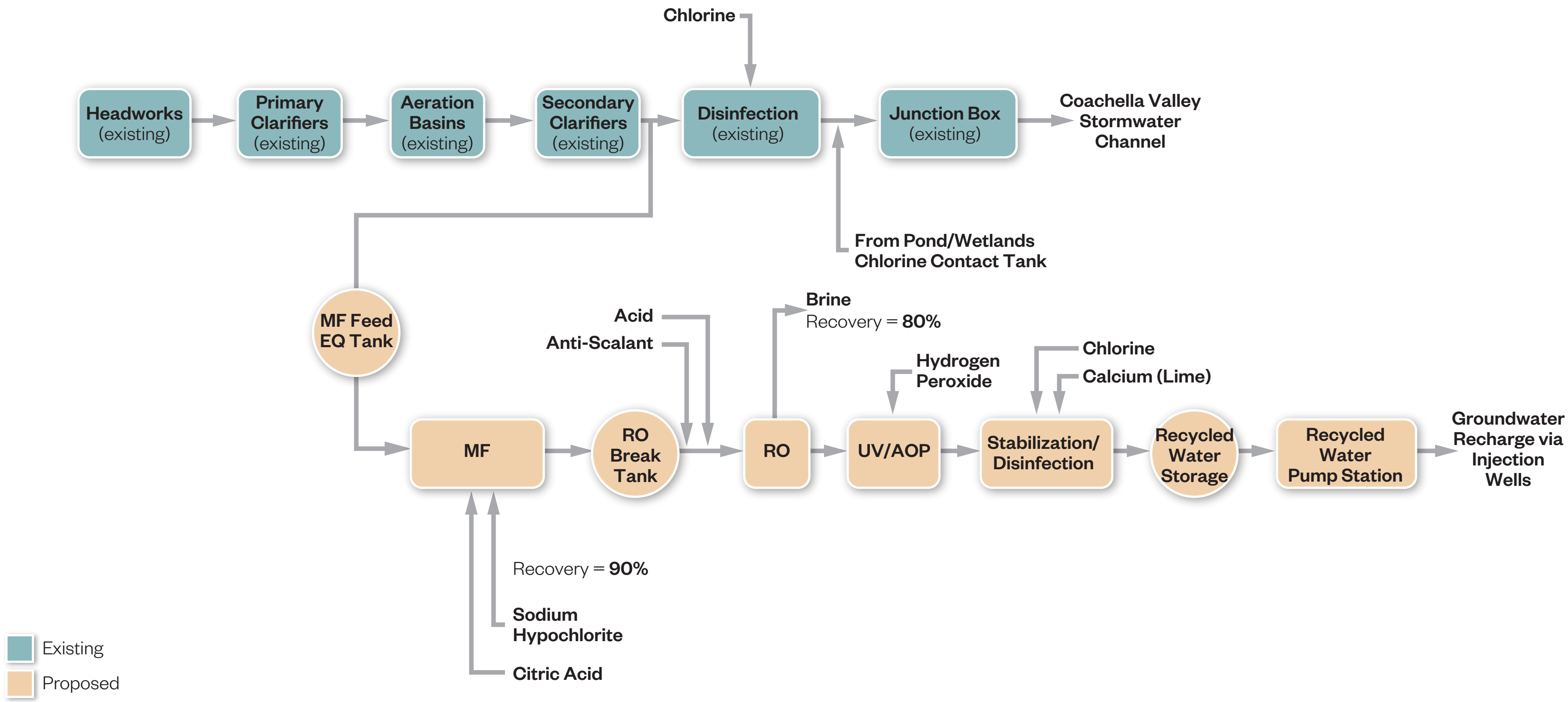

Figure 6-9
VSD WRF - Advanced Treatment System PFD

Figure 6-10
VSD WRF Preliminary Advanced Treatment Site Layout

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6.4 Further Analyses

One component of the scope of work for this feasibility study was to conduct a two month pilot study, which was to assist in getting the priority project(s) identified in this study closer to implementation. However, the pilot study was to be conducted only at the Coachella Sanitary District, which would not benefit all the agencies participating in the study, and there were not adequate funds budgeted to conduct multiple, long term pilot studies. As discussed in detail in Section 10 of this TM, in order to benefit all of the agencies and get each of the projects identified closer to implementation, a bench scale pilot study was conducted at each of the respective WWTP's which included Valley Sanitation District's Water Reclamation Facility. Through this study, groundwater recharge via spreading was identified as the most cost-effective alternative for IWA and VSD; however, percolation testing and soil borings will be needed in or near the existing evaporation ponds on the VSD site to confirm the hydrogeological findings and adequacy for percolation.

If the percolation tests show that groundwater recharge via spreading is not a viable alternative and IWA and VSD desires to implement the next most cost-effective alternative, which is groundwater recharge via injection, it is recommended that VSD/IWA consider conducting a full scale pilot study. This will help further determine if some or all of the filtration alternatives under consideration are indeed viable for this specific water quality and assist in establishing design criteria. Pilot testing typically should be conducted over a 6 month period for the information to be conclusive. This greatly effects the projected cost estimates for the advanced treatment processes, chemical storage, and feed systems as a more conservative approach must be taken without additional wastewater quality information. Assumptions were made in determining the design criteria presented herein.

7. Conveyance and Recharge

This section details the conveyance criteria and infrastructure requirements for each recycled water alternative presented in Section 2 above. Each of the alternatives have been evaluated independently for conveyance system requirements, each of which is described in further detail herein.

7.1 Recycled Water Infrastructure Criteria

The recycled water system infrastructure consists of the conveyance facilities necessary to deliver recycled water to its point of use. Main facilities may consist of pumps, pipelines, storage tanks, and valving, all which make up the recycled water distribution system. The criteria for establishing the size, hydraulic gradient, and redundancy for these facilities are presented in the following subsections. These criteria were utilized in the development of the proposed recycled water conveyance system alternatives.

7.1.1 Pipeline Sizing Criteria

Pipelines are typically sized to limit internal velocities in order to protect internal pipe linings, minimize hydraulic transients, and minimize head losses. Larger transmission mains, which typically span long distances, are typically subject to more stringent head loss criteria as any amount of head loss accumulated over long distances can have large impacts in terms of pumping requirements. Minimizing head loss results in lesser pumping requirements, which in turn results in lower energy consumption and operational cost savings. Pipelines are also sized based on industry standard diameters. The criteria utilized for sizing of pipelines is presented in Table 7-1. For the purpose of this feasibility study, it has been assumed that the minimum allowable pipe diameter is 8 inches.

Table 7-1: Pipeline Sizing Criteria

Item	Criteria[1]	Demand Condition
Maximum velocity (12” and smaller)	7 ft/s	Peak Hour Demand
Maximum velocity (16” and greater)	5 ft/s	Peak Hour Demand
Maximum Head loss	5 ft / 1,000 ft	Peak Hour Demand
Hazen-Williams Roughness Coefficient “C”	130	N/A

[1] Adapted from Table 5 – System Evaluation Criteria from the 2011 Recycled Water Master Plan, Carollo Engineers.

7.1.2 Distribution System Criteria

The recycled water distribution system must be capable of providing service pressures within certain minimum and maximum values as set forth by the California Plumbing Code (CPC), and as set forth by the governing agency. The 2011 Recycled Water Master Plan, prepared by Carollo Engineers (2011 RWMP) established service pressure ranges, as listed in Table 7-2. The minimum service pressure seeks to maintain service pressures as existing customers transition from the potable water system to the recycled water system and serves to supply existing and potential customers' sprinkler systems or other irrigation methods. The intent of the maximum service pressure is to limit or prevent over-pressurization, excessive pipe design, or requirement for pressure regulating valves on customer services, and to manage system energy. This range of service pressures forms the criteria for establishing the recycled water distribution system pressure zones.

Table 7-2: Distribution System Criteria

Item	Criteria[1]	Demand Condition
Minimum Service Pressure	60 psi	Peak Hour Demand
Maximum Service Pressure	125 psi[2]	Static

[1] Adapted from Table 5 – System Evaluation Criteria from the 2011 Recycled Water Master Plan, Carollo Engineers.

[2] Services must be equipped with pressure regulators as required by the California Plumbing Code, latest edition.

The option of operating the recycled water distribution system at a lower pressure that is only capable of delivering water into at-grade golf course lakes for the purposes of lowering distribution pumping energy requirements has been discussed in previous studies. However, this Study adheres to the requirements listed in Table 7-2 as a conservative approach to avoid requiring potential customers re-pump recycled water to a pressure suitable for their irrigation system needs.

7.1.3 Pumping Criteria

As recycled water from the VSD WRF will be stored in a reservoir at or near the existing ground surface elevation of the WRF, pumping will be required in order to deliver the recycled water to the customers. Pump stations are typically designed to be able to meet the design flow with the largest pump out of service, referred to as "firm" capacity, which allows for routine pump maintenance. There are two separate criteria for selecting firm capacity depending on whether or not the distribution system is "floated" by a gravity storage tank. The criteria are summarized in Table 7-3.

Table 7-3: Pump Sizing Criteria

Item	Criteria[1]
For Pressure Zones with Gravity Storage Firm Pump Capacity	Maximum Day Demand w/ Largest Pump Out of Service
For Pressure Zones without Gravity Storage Firm Pump Capacity	Peak Hour Demand w/ Largest Pump Out of Service
Emergency Back-up Power Requirements	Connection for Portable Generator

[1] Adapted from Table 5 – System Evaluation Criteria from the 2011 Recycled Water Master Plan, Carollo Engineers.

There is an exception to the peak hour demand criteria for golf courses as they typically have water stored in on-site lakes that they then pump to the irrigation system. In lieu of providing the full peak hour demand to the identified golf courses, which can be very large flow rates, the maximum day demand is provided throughout the day with on-site lakes serving as equalization. The need for variable frequency drive (VFD) pumps is indicated for pertinent alternatives in subsequent sections.

7.1.4 Storage Criteria

Recycled water storage components typically consist of operational storage only and it is assumed that temporary interruptions of the recycled water system will be tolerable. Operational storage serves to equalize the variation in recycled water customer demands with either the VSD WRF production capacity, or the treated water pump station capacity. This operational storage criteria was established in the 2011 RWMP based on a 10-hour irrigation window of 58 percent as listed in Table 7-4, also noting that this criteria could potentially be reduced if golf courses have on-site storage.

Table 7-4: Storage Criteria

Item	Criteria[1]
Operational Storage	58% of Maximum Day Demand

[1] Adapted from Table 5 – System Evaluation Criteria from the 2011 Recycled Water Master Plan, Carollo Engineers.

This storage criteria will be applied on a per-alternative basis since not all alternatives serve customers directly or require the operational storage for equalization purposes.

In the 2011 IWA RWMP, it was stated that due to the relatively flat terrain of the study area, gravity storage tanks were not planned as they could not provide adequate elevation head. The 2011 IWA RWMP recommended 10 MG of storage, split into 3.5 MG for Phase 1 and 6.5 MG for Phase 2 (based on a criteria of 67 percent of MDD). Pump stations were planned for each ground level tank to meet peak flows.

7.1.5 Surface Spreading Basin Sizing Criteria

Surface spreading basin area and gross area requirements are based on the soil infiltration rate and the actual utilizable spreading area. As the infiltration rate at the VSD WRF and Posse Park are currently unknown, it has been conservatively estimated at a rate of 1 foot per day, although actual values may be established with field investigations. Of the gross area of a site, a portion of it will be occupied for the construction of spreading basin berms, side slopes, ramps, and for freeboard requirements. Based on general construction and grading industry standards, it is estimated that 60 percent of the gross area will be considered as actual spreading area. See Table 7-5 for a summary of the spreading basin criteria.

Table 7-5: Spreading Basin Criteria

Item	Criteria
Infiltration Rate	1 foot per day[1]
% Utilizable Area[2]	60%

[1] Assumed.

[2] Percent of gross area available for spreading.

7.1.6 Groundwater Injection Criteria

Recharge via injection wells is often utilized when a confining unit prevents or inhibits recharge via spreading from reaching the production aquifer, or due to lack of available land for the construction of spreading basins. On a basic level, an injection well typically consists of a casing with screening, annular seal, inductor pipe, and some form of injection flow control and telemetry. Depending on the available driving head, injection pump stations may also be required if the available gravity head is insufficient. In addition, injection wells can have a tendency to foul prematurely due to undesired injection of air and the corrosive nature of recycled water. To combat this, above grade air valves and downhole flow control valves to hold the column of water can be used in addition to the provision of a submersible pump for back flushing. A summary of the injection well criteria is provided in Table 7-6.

Table 7-6: Injection Well Criteria

Item	Criteria
Injection Well Capacity (ea)[1]	1.5 MGD
Backflush Pump Capacity (ea)[2]	3 MGD
Downhole Flow Control Valve Driving Head Req'd (ft)[3]	50 ft

[1] Per Section 4 of this Technical Memorandum.

[2] Backflush pump capacity = 2 x Injection Well Capacity.

[3] Per Baski Medium Head InFlex FCV, 10-3/4" Housing O.D., 1,550 gpm injection capacity.

7.2 Conveyance Infrastructure Improvements

7.2.1 Surface Spreading at VSD (Alternatives 3 and 4)

Recharge via spreading basins is typically accomplished by delivering recharge water to land or impoundments where water can be spread to percolate into the ground to recharge the groundwater aquifer where it can be subsequently recovered by pumping. Major factors in determining a spreading system include the underlying aquifer characteristics, permeability of the soil, available area, topography, and water quality.

The approximate 20-acre area located to the south of the VSD WRF site where the former biological treatment ponds were located has been identified as a potential area for spreading in terms of percolation and in minimizing conveyance infrastructure. Based on conversations with VSD staff, VSD is currently exploring the option of abandoning the former biological treatment ponds in place. If the area is to be repurposed for spreading, it will require excavation and disposal of any accumulated solids. This area is triangular shaped, generally flat, gently sloping down from west to east and from north to south, and conducive to spreading via the basin method, provided that recommended field explorations confirm adequate infiltration.

Assuming field investigations confirm an infiltration rate of 1.5 foot per day and estimating a 60 percent utilizable area, the actual available spreading area equates to 12 acres and an infiltration rate of approximately 5.9 MGD, which would be approximately equal to the existing VSD WRF flow. For phasing considerations, the entire southern area would need to be developed into spreading basins for current conditions, and any additional recharge would require acquiring additional land. If percolation tests prove that the soil supports a higher percolation rate than assumed, the spreading basins could accommodate higher flow rates as listed in Table 7-7. A range of 1.5 to 3 feet per day has been presented based on infiltration requirements for existing and 2030 flows.

Table 7-7: Potential Spreading Percolation Rates

Gross Area (ac)	Perc Rate (ft/d)	Flow (ft^3/d)[1]	Flow (MGD)
20	1.5	784,080	5.9
20	3	1,568,160	11.7

[1] Based on 60% utilization of the gross area for surface spreading.

Key spreading basin considerations include ensuring that the impoundment is not classified as a dam per the Division of Safety of Dams (DSOD), berm roads parallel to natural contour lines, equipment access ramps to harrow basin bottoms and/or remove accumulated sediment to increase basin floor permeability (scarification), bank stabilization, ability to take basins offline or rotate basins for drying or other maintenance purposes, freeboard for wind and rainwater, flow control and metering, and an outfall for basin overflows. To maximize infiltration rates in basin-type facilities, shallower basins are preferred (Bouwer, 2002). Although deeper basins provide more head on the basin floor, this has been shown to actually reduce infiltration rates due to compressibility of the clogging layer and other processes. Shallow basins also facilitate drying of basins for maintenance. Spreading the majority of the flow during the cooler months also naturally helps reduce the impact from evaporation. A spreading basin conceptual layout has been prepared (see Figure 7-1) with these considerations in mind. Major infrastructure includes the spreading basins, gravity pipeline system from the recycled water reservoir to the spreading basins with two separate outfalls for basin operation flexibility. In addition, an overflow pipeline that can send flow directly from the recycled water reservoir to the stormwater channel will be needed in order to bypass the spreading basins or if VSD WRF effluent exceeds spreading basin capacity. To achieve gravity flow, it is assumed that a new deeper outfall will need to be constructed at the stormwater channel. Spreading basin outfall pipelines have been sized based on a nominal flow of 12 MGD due to the uncertainty of the percolation rates, while the overflow pipeline has been sized based on the Plant year 2030 capacity of 12 MGD, summarized in Table 7-8.

Table 7-8: Spreading Basin Pipeline Sizing

Component	Design Flow (MGD)	Design Flow (cfs)	Max Allowable Velocity (ft/s)	Req'd Min. Dia. (in)	Selected Dia (in)
Outfall to Recharge Basins	12	18.6	7	22.1	24
Overflow Line to Stormwater Channel	12	18.6	7	22.1	24

Recharge via spreading basins is generally the simplest recharge method and least intensive from a capital and operations and maintenance (O&M) standpoint, although it occupies the largest footprint.

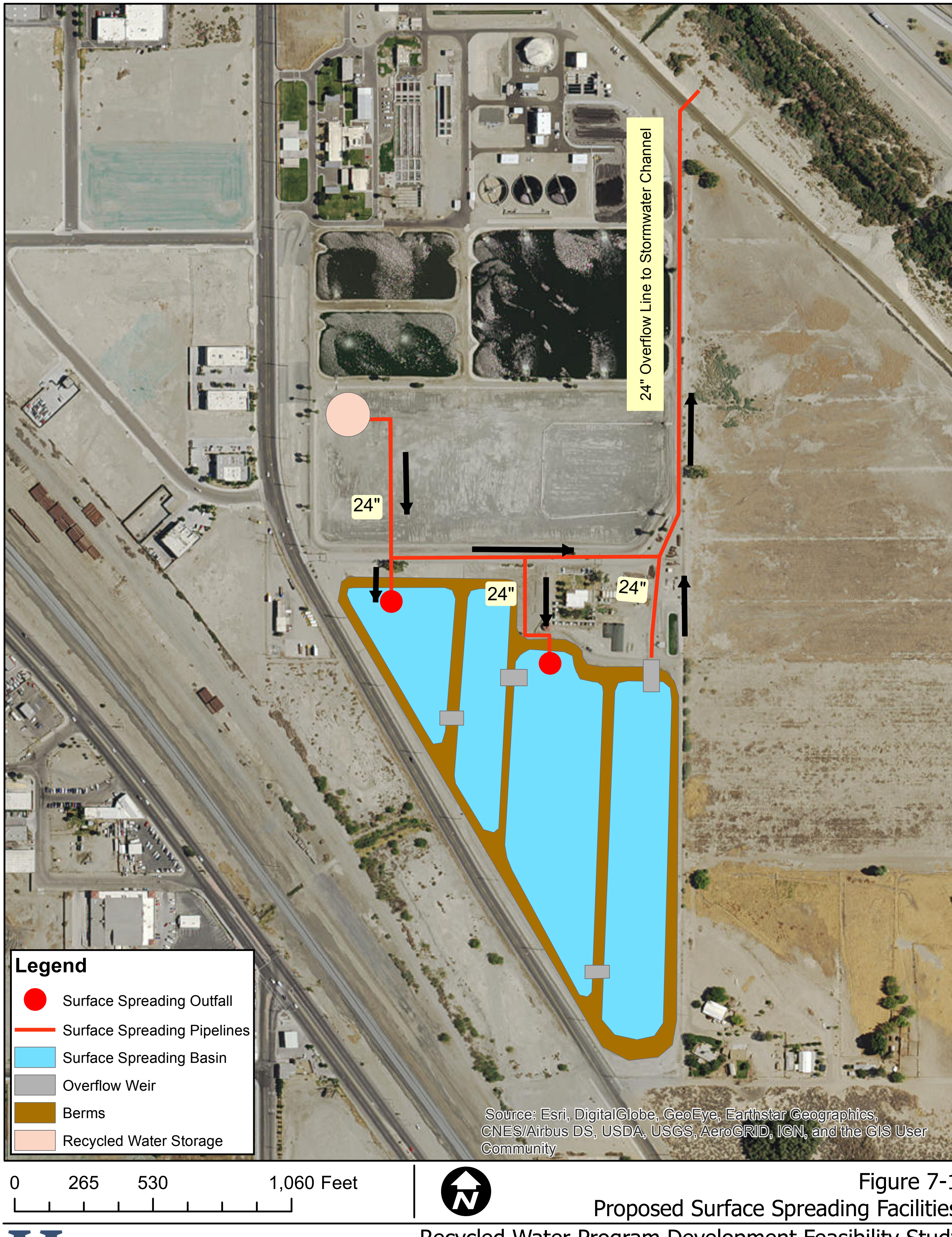

Figure 7-1
Proposed Surface Spreading Facilities

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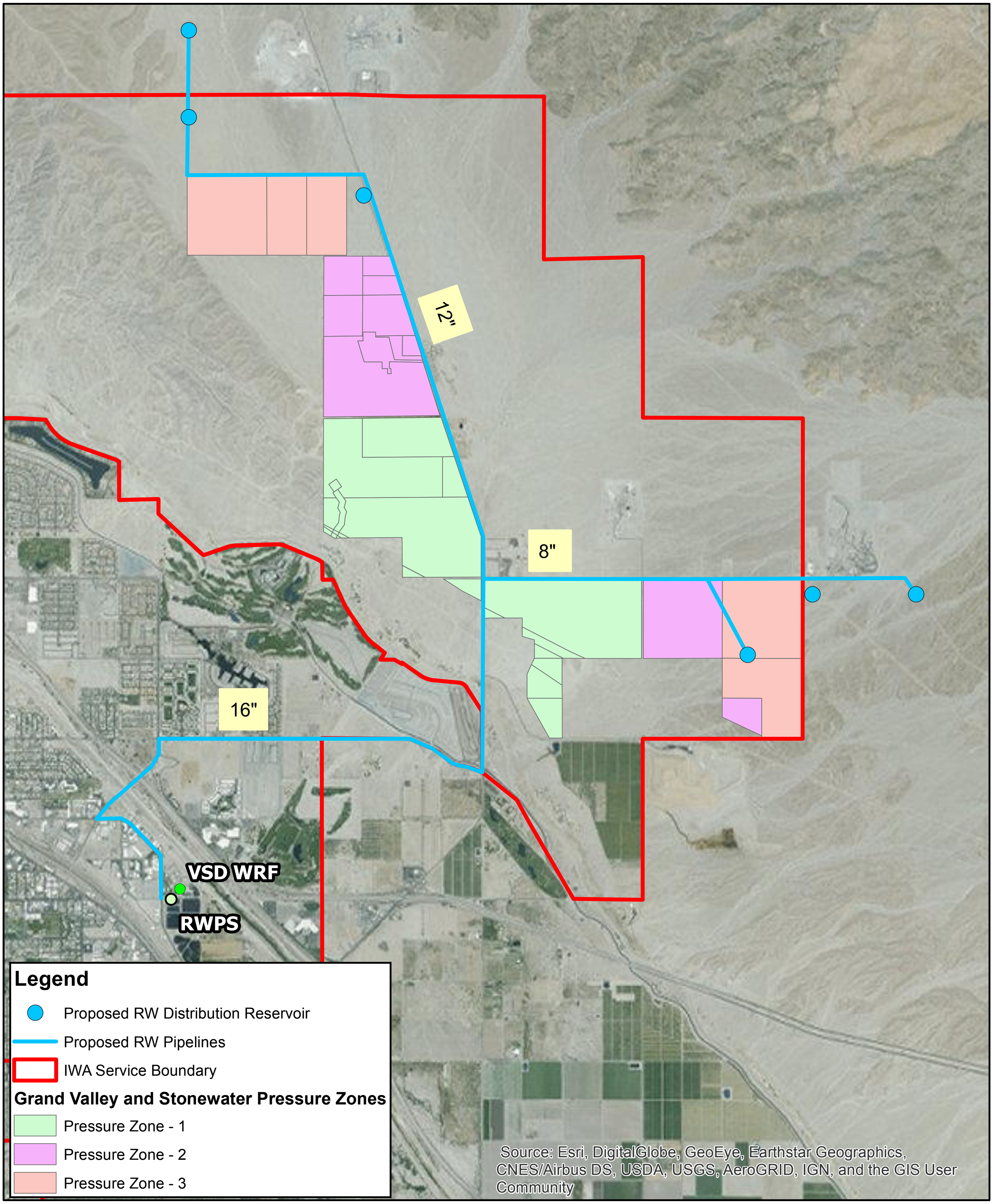
7.2.2 Conveyance to Recycled Water Customers (Alternatives 3, 5a, 5b, 6)

Alternative 3 includes the same spreading basin infrastructure as described in Alternative 2 with the addition of the Phase 1 and Phase 2 recycled water distribution system as proposed in the latest Recycled Water Feasibility Study (Carollo, 2016). While there would, on average, be less available flow to spread when combined with serving recycled water customers, flows available for spreading could still be as high as 4.5 MGD during the low demand months.

Direct delivery of recycled water to customers is achieved via a pressurized distribution system consisting primarily of pumps, pipelines, and storage reservoir(s). A recycled water distribution system was originally laid out for the customers identified in the TM No. 1 Market and Demand Assessment, which was most recently updated to a scaled-back phased system in the 2016 IWA RW Feasibility Study (Carollo, 2016). The study herein establishes the RW distribution system requirements needed to support the proposed Grand Valley and Stonewater developments and only re-evaluates what has already been proposed to the extent of determining the impact of the addition of the two developments and identifying any potential optimization. If these two developments are to be served recycled water, Phases 1 and 2 proposed in the previous feasibility study (Carollo, 2016) may need to be further scaled back, but will be dependent on the wastewater generated by the two proposed developments.

7.2.2.1 Pressure Zone Mapping

The study area and customers identified in the previous studies were generally limited to within the City of Indio limits, noted as having a relatively flat terrain with customer elevations ranging from -30 feet to 20 feet above mean sea level (AMSL). The RWPS proposed therein was noted as adding approximately 280 feet of head, which given a WRF elevation of -30 feet AMSL would correspond to a hydraulic grade line (HGL) of approximately 250 feet. The proposed Grand Valley and Stonewater developments are located outside the current City limits to the northeast with elevations higher than the previously identified customers, from 90 feet AMSL to 475 feet AMSL. To serve the lowest pressure zone for each of these developments would require an HGL of approximately 365 feet AMSL (115 feet higher than previously proposed). For the purposes of this Study, it is assumed that a separate series of pumps and pipelines would be dedicated to serve Grand Valley and Stonewater due to the differing gradient requirement. A summary of the estimated pressure zones required are presented in Table 7-9, Table 7-10, and Figure 7-2. It is assumed that each pressure zone will be floated by a gravity storage tank similar to the domestic water systems proposed by each development.



0 0.5 1 2 Miles

Figure 7-2
Proposed Recycled Water Distribution

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Table 7-9: Grand Valley Pressure Zones

Pressure Zone	Min. Elev. (ft AMSL)	Max. PZ HGL (ft AMSL)[1]	Max. Service Elev (ft AMSL)	Min. PZ HGL (ft AMSL)[2]	Proposed Tank HW Elev (ft AMSL)
1	90	378	200	339	360
2	200	488	310	449	470
3	310	598	420	559	580

[1] Based on a maximum allowable static pressure of 150 psi.

[2] Based on a minimum allowable static pressure of 60 psi.

Table 7-10: Stonewater Pressure Zones

Pressure Zone	Min. Elev. (ft AMSL)	Max. PZ HGL (ft AMSL)[1]	Max. Service Elev (ft AMSL)	Min. PZ HGL (ft AMSL)[2]	Proposed Tank HW Elev (ft AMSL)
1	90	378	218	357	365
2	218	506	347	486	495
3	347	635	475	614	625

[1] Based on a maximum allowable static pressure of 150 psi.

[2] Based on a minimum allowable static pressure of 60 psi.

7.2.2.2 Pump Station Sizing

Given the assumption that the recycled water system serving these two developments will be floated by gravity storage, pump sizing will be based on a firm capacity capable of delivering maximum day demand. The required pump station parameters are summarized in Table 7-11.

Table 7-11: Pump Station Sizing

Firm Capacity Req'd (gpm)[1]	No. of Duty Pumps	No. of Stand-by Pumps	Capacity per Pump (gpm)	TDH Req'd (ft)	Min. HP Req'd	VFD?	Emer. Back-up Power
2,042.6	2	1	1,050	395	150	No	Connection for portable generator

[1] Maximum day demand of Grand Valley and Stonewater given pressure zones with gravity storage.

7.2.2.3 Pipeline Sizing and Alignment

Demands used for pipeline sizing are summarized in Table 7-12. As listed in Table 7-1, pipelines are typically sized based on peak hour demand. However, in the case of golf courses, it is assumed that the proposed golf courses that are part of the Grand Valley development will include lakes and their own private on-site distribution system capable of delivering the required peak flows. Therefore, the distribution system improvements to accommodate the golf course will only require maximum day demand flows from the recycled water distribution system. For all other irrigation flows, the peak hour demand has been used.

Table 7-12: Pipeline Sizing

Development	ADD (gpm)	MDD (gpm)	PHD (gpm)	Flow Used for Pipe Sizing (gpm)[1]	Min. Pipe Dia. Req'd (in)	Length (ft)
Grand Valley						
Golf Course Demand	648	1,295	2,823	1,295	-	-
Non-Golf Course Demand	250	501	1,091	1,091	-	-
Subtotals	**898**	**1,796**	**3,914**	**2,386**	**12**	**12,000**
Stonewater						
Golf Course Demand	0	0	0	0	-	-
Non-Golf Course Demand	124	247	538	538	-	-
Subtotals	**124**	**247**	**538**	**538**	**8**	**10,000**
TOTALS	**1,021**	**2,043**	**4,453**	**2,925**	**16**	**27,000**

[1] For pipe sizing purposes, maximum day demand is utilized for golf course demands assuming on-site lakes are available for peaking, while peak hour demand is utilized for all other irrigation demands.

As mentioned previously, it is assumed that a separate pressure zone will be required to serve Grand Valley and Stonewater. In order to serve this area, a separate pipeline will parallel the pipeline that was originally proposed as part of the 2016 RW Feasibility Study from the VSD WRF to the intersection of Golf Center Parkway and Avenue 44. The pipeline will continue east down Avenue 44 turning north at Dillon Road where it will then split to serve each of the two developments. The main transmission line will require a minimum diameter of 16 inches, while the Citrus Ranch and Stonewater transmission lines will require minimum diameters of 12 inches and 8 inches, respectively. Four special crossings would be required:

1. CVSC at Golf Center Parkway
2. I-10 Freeway at Golf Center Parkway
3. Concrete lined stormwater channel at Avenue 44
4. Coachella Canal at Dillon Road

It is assumed that these crossings will be constructed via the jack and bore method each with a minimum casing diameter of 30 inches, although alternative construction methods may be considered during detailed design, such as installing a pipeline in the existing Golf Center Parkway bridge, horizontal directional drilling (HDD), or microtunneling.

7.2.2.4 Storage

Due to the Grand Valley's and Stonewater's proximity to the hills, and based on proposed development information, it is assumed that recycled water storage will be provided adjacent to the developments via gravity storage tanks that will float the system. A summary of the total storage requirements is provided in Table 7-13. Due to the sloping terrain, it is anticipated that a series of tanks would need to be constructed in order to serve each pressure zone, although the total storage requirement would remain unchanged.

Table 7-13: Storage Requirements

Development	ADD (gpm)	MDD (gpm)	Total Storage Req'd (MG)[1]
Citrus Ranch	897.78	1,795.56	2.59
Stonewater	123.50	247.00	0.36
TOTALS	**1,021.28**	**2,042.56**	**2.94**

[1] Storage required = 58% of MDD.

7.2.2.5 Optimization

This Study has independently evaluated the recycled water distribution system improvements required to serve the proposed Grand Valley and Stonewater developments. If serving recycled water directly to customers via a recycled water distribution system is ultimately selected as the preferred alternative, there may be several areas of optimization that may be explored further in detailed design, as listed below:

- Combine the lower Grand Valley / Stonewater pressure zone with the rest of the network to eliminate parallel piping in Golf Center Parkway. The increase in hydraulic gradients may require a pressure reducing station for the lower service area.

- If pressure zones are combined, consider eliminating peaking tanks and pump stations. Floating the recycled water system may also eliminate the need for variable frequency drive pumps.

- Utilize existing on-site golf course lakes for peaking to eliminate peaking tanks and pump stations, and to optimize pipeline diameters.

7.2.3 Recharge via injection wells at VSD WRF (Alternative 4)

Recharge via injection wells is often utilized when a confining unit prevents or inhibits recharge via spreading from reaching the production aquifer, or due to lack of available land for the construction of spreading basins. On a basic level, an injection well typically consists of a casing with screening, annular seal, inductor pipe, and some form of injection flow control and telemetry. Depending on the available driving head, injection pump stations may also be required if the available gravity head is insufficient. In addition, injection wells can have a tendency to foul prematurely due to undesired injection of air and the corrosive nature of recycled water. To combat this, above grade air valves and downhole flow control valves to hold the column of water can be used in addition to the provision of a submersible pump for back flushing.

To limit conveyance infrastructure, an injection system network has been developed on-site at the VSD WRF where the former biological treatment ponds are located. The system would be developed in two phases as follows:

- Phase 1, Existing Conditions – 6 MGD design capacity, 4 injection wells @ 1.5 MGD each
- Phase 2, Year 2030 – 12 MGD design capacity, 8 injection wells @ 1.5 MGD each

To optimize injection performance, the injection wells are spread out along the site perimeter. This would require constructing the recycled water distribution system to accommodate the 2030 proposed flows of 12 MGD. The injection system also includes a bypass line to the stormwater channel to deliver excess flows or in the event that the injection system becomes inactive. It is assumed that the existing stormwater channel outfall would be utilized for the injection system bypass discharge. This system is depicted in Figure 7-3 with a summary of pipeline sizing in Table 7-14.

Figure 7-3
Proposed Injection Well Facilities

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Table 7-14: Injection Transmission System Sizing

Component	Design Flow (MGD)	Design Flow (cfs)	Max Allowable Velocity (ft/s)	Req'd Min. Dia. (in)	Selected Dia (in)
Transmission Piping[1]	6	9.3	7	15.6	16
Bypass Line to Stormwater Channel	12	18.6	7	22.1	24

[1] Note that the 6 MGD design flow accommodates a total flow of 12 MGD due to the looped piping network.

Based on the groundwater mounding information provided by Todd Groundwater, available head provided by the effluent reservoir, and the estimated headlosses for piping, fittings, and valving including the downhole flow control valve, it is estimated that a low-head injection pump station will be required in order to achieve well injection rates and handle periodic injection well fouling. This injection pump station could be phased in as VSD WRF capacity and injection water increases over time. A summary of the injection pump station parameters is provided in Table 7-15.

Table 7-15: Injection Pump Station Parameters

Condition	No. Duty Pumps	No. Stand-by Pumps	Pump Capacity per Ea (gpm)	Min HP Req'd Per Pump	PS Firm Capacity (gpm)	VFD?	Back-up Power Req'd
Existing	2	1	2,100	30	4,200	Yes	Connection for Emergency generator
Year 2030	4	1	2,100	30	8,400	Yes	Connection for Emergency generator

Due to the propensity of injection wells to foul, a submersible backflushing pump will also be included for each injection well, capable of backflushing at least two times the injection rate. The backflush pump parameters are as listed in Table 7-16.

Table 7-16: Backflush Pump Parameters

Type	Pump Capacity (gpm)	VFD?	Min HP Req'd Per Pump
Submersible	2,100	No	100

A separate backflushing piping system will be required to dispose of the backflush water. It is assumed that the backflush piping will connect to the bypass line that discharges to the stormwater channel, although the backflush could potentially be routed to the head of the VSD WRF if the flows and water quality can be accomodated. A summary of the backflush transmission system sizing assuming only one injection is backflushed at a time is provided in Table 7-17.

Table 7-17: Backflush Transmission System Sizing

Component	Design Flow (gpm)	Design Flow (cfs)	Max Allowable Velocity (ft/s)	Req'd Min. Dia. (in)	Selected Dia (in)
Backflush Piping	2,100	4.7	7	11.1	12

As injection in the southern WRF area is hydrogeologically limited to approximately 12 MGD, if any additional injection is to be performed, additional sites will need to be identified either in the northern WRF area, or by acquiring additional land. While recharge via injection wells is generally capital and O&M intensive, it provides a higher recharge capacity with a smaller footprint when compared to spreading basins.

7.2.4 Surface Spreading at Posse Park (Alternative 5a)

Alternative 5a includes a tertiary treated recycled water transmission main to convey flows from the VSD WRF to Posse Park for spreading (see Figure 7-4). This transmission main is sized for the year 2030 WRF peak dry weather flow of 12 MGD (see Table 7-18).

Table 7-18: RW Transmission Main Sizing

Component	Design Flow (MGD)	Design Flow (cfs)	Max Allowable Velocity (ft/s)	Req'd Min. Dia. (in)	Selected Dia (in)
RWTM	12	18.6	5	26.1	30

Alternative 5a also includes spreading basins sized very similarly to Alternative 2 as Posse Park has an available area comparable to the area where the former biological ponds are located; however, Posse Park does not have close access to the CVSC for overflow provisions; therefore, any overflow must be routed off-site via sewer or storm drain. In terms of recycled water customer service, it is assumed that Phase 1 from the Recycled Water Feasibility Study (Carollo, 2016) will be constructed, offset as necessary to account for service to Grand Valley and Stonewater.

Pumping will be required to convey the flows from the VSD WRF to Posse Park. Since customers will also be served off of the RWTM, the RW pump station must add additional head that would otherwise not be required in order to pressurize the RWTM up to service pressure. A summary of the pump station requirements is provided in Table 7-19.

Table 7-19: RW Pump Station Parameters

Condition	No. Duty Pumps	No. Stand-by Pumps	Pump Capacity per Ea (gpm)	Min HP Req'd Per Pump	PS Firm Capacity (gpm)	VFD?	Back-up Power Req'd
Existing	2	1	2,100	175	4,200	No	Connection for Emergency Generator
Year 2030	4	1	2,100	175	8,400	No	Connection for Emergency Generator

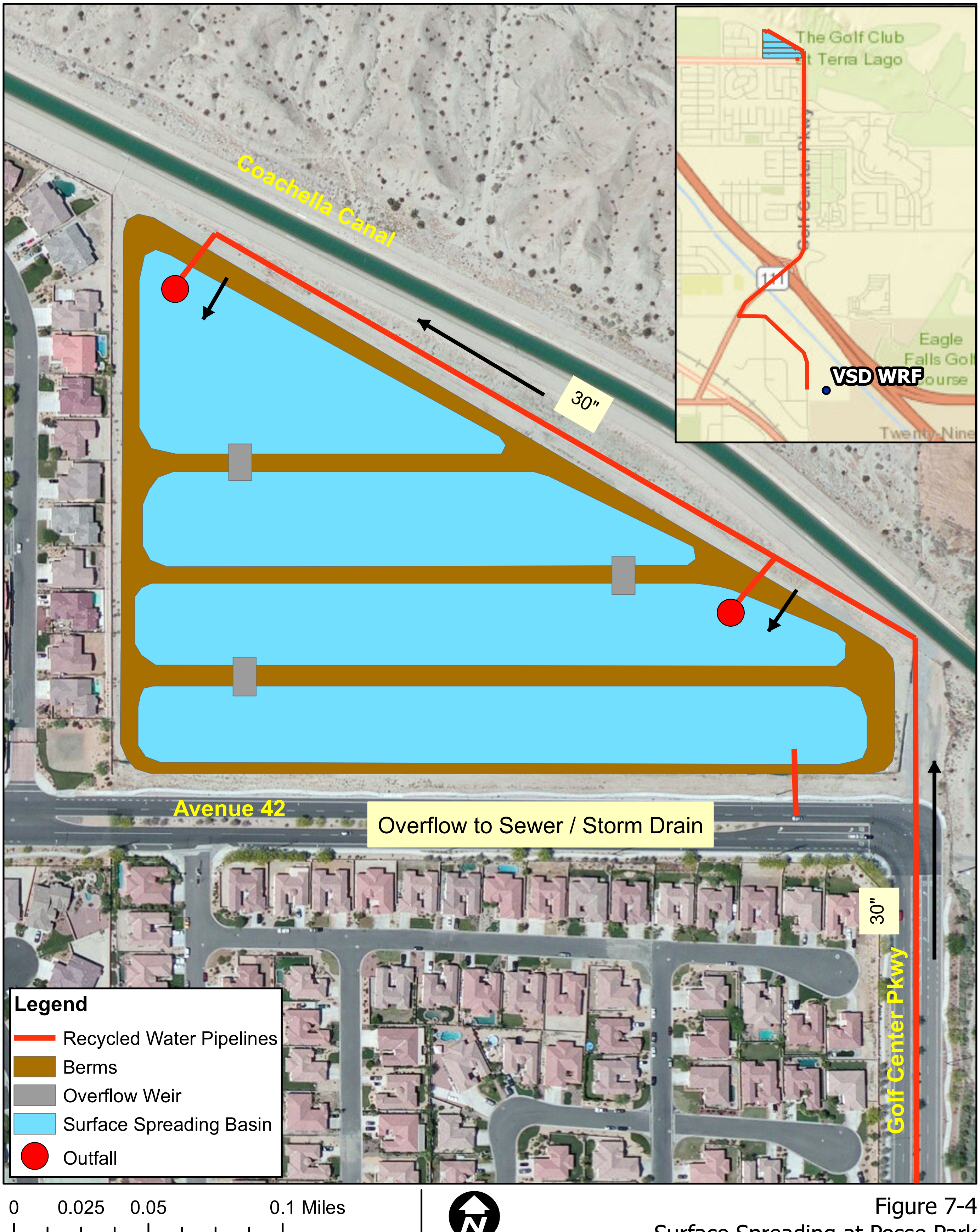

Figure 7-4
Surface Spreading at Posse Park

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7.2.5 Groundwater Injection at Posse Park (Alternative 5b)

Alternative 5b includes a tertiary treated recycled water transmission main to convey flows from the VSD WRF to Posse Park for advanced treatment and injection (see Figure 7-5). This transmission main is sized for the year 2030 WRF peak dry weather flow of 12 MGD (see Table 7-16).

Table 7-20: RW Transmission Main Sizing

Component	Design Flow (MGD)	Design Flow (cfs)	Max Allowable Velocity (ft/s)	Req'd Min. Dia. (in)	Selected Dia (in)
RWTM	12	18.6	5	26.1	30

Since Posse Park does not have close access to the CVSC, an on-site impoundment must be provided to capture injection well backflushing flows. Alternatively, the backflush flows could be piped off-site via sewer or storm drain. In terms of recycled water customer service, it is assumed that Phase 1 from the Recycled Water Feasibility Study (Carollo, 2016) will be constructed, offset as necessary to account for service to Grand Valley and Stonewater. Due to the close proximity to the Coachella Canal, there is the potential to connect the RWTM to the Canal for exchanges or supplemental flows to recycled water customers during peak seasonal demands to increase the baseline injection rate, although this was not specifically included in this evaluation.

Pumping will be required to convey the flows from the VSD WRF to Posse Park. Since customers will also be served off of the RWTM, the RW pump station must add additional head in order to pressurize the RWTM up to service pressure that would otherwise not be required if only serving to fill the RO feed tank. A summary of the pump station requirements is provided in Table 7-21.

Table 7-21: RW Pump Station Parameters

Condition	No. Duty Pumps	No. Stand-by Pumps	Pump Capacity per Ea (gpm)	Min HP Req'd Per Pump	PS Firm Capacity (gpm)	VFD?	Back-up Power Req'd
Existing	2	1	2,100	250	4,200	Yes	Connection for Emergency Generator
Year 2030	4	1	2,100	250	8,400	Yes	Connection for Emergency Generator

Figure 7-5
Alternative 5b

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7.2.6 Deliver to Recycled Water Customers and Excess to CVSC (Alternative 6)

Alternative 6 includes the same infrastructure as described in Alternative 3 excluding the spreading basins. Excess flow would be discharged as secondary treated effluent to the CVSC, which is similar to current operations.

8. Economic Analysis

8.1 Opinion of Probable Costs

This section presents the opinions of probable cost for the alternatives including the capital and associated O&M costs. These costs reflect the alternatives at the study-level stage, which can be used to evaluate project feasibility and for cost-comparative purposes. In general, the probable costs are based on previous experience, current available information from trusted sources, project location, and project-specific conditions. It should be noted that costs presented herein may differ from previous studies potentially due to changes in cost over time, assumptions, and contingency factors. Detailed cost breakdowns are included in **Appendix C**.

8.1.1 Capital Costs

Conceptual costs were developed for each of the alternatives. The Cost Estimate Classification System guidelines published by the Association for the Advancement of Cost Engineering International (AACEI) is used to define the level of accuracy of these estimates. Costs are considered Class 4 for study or feasibility use and 1-15% level of project definition. The accuracy range is normally considered plus 50% and minus 30% for this level of estimate

The probable costs have been prepared for guidance in project evaluation and comparison from the information available at the time of the estimates. Actual project costs will depend on criteria such as actual labor and material costs, competitive market conditions, actual site conditions, final project scope, and other variables. As a result, actual project costs will vary from this estimate. The proximity to actual costs will depend on how close the assumptions of this estimate match final project conditions. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help assure proper project evaluation and adequate funding.

Probable construction costs for the alternatives were developed using quantity take-offs and a material unit cost approach when possible. In some cases, facility capacity or footprints were used to obtain costs. In the case of the recycled water distribution system infrastructure, costs from the Recycled Water Feasibility Study (Carollo, 2016) were utilized by escalating in accordance with the Engineering News-Record (ENR) Construction Cost Indices (CCI). The direct and indirect markups and additional project costs presented below are applied to all alternatives. Project assumptions are provided in Table 8-1.

Table 8-1: Process Assumptions for Cost Development

Alternative	Cost Assumptions
Tertiary Treatment	• Conventional treatment consisting of a secondary effluent pump station, coagulation, sand filters, chlorine contact tank and storage. • Total capacity is assumed 6 mgd.
Advanced Treatment	• Advanced treatment assumes effluent pump station, microfiltration, reverse osmosis, UV advanced oxidation processes, electric service upgrade and storage. • Total capacity for Alternative 4 is assumed as 6 mgd. • Total capacity for Alternative 5b is assumed as 4.5 mgd (average of the low of 1.5 MGD and high of 7.5 MGD) taking into account customer demands.
Recycled Water Distribution/Conveyance	• Recycled Water Feasibility Study (Carollo, 2016) costs escalated from January 2014 (ENR CCI of 10736) to December 2016 (ENR CCI of 11555). • Any service to Grand Valley and/or Stonewater will be a direct offset in costs from the Recycled Water Feasibility Study (Carollo, 2016).
Spreading Basins	• Surface spreading at VSD considers using existing basins with limited rework of existing soils. • Surface spreading at Posse Park considers installing new basins. • Overflow can be accommodated by the existing storm drain or sewer.
Groundwater Injection	• Involves groundwater injection wells only (no recovery). • Injection requires pressurization. • Existing production wells will be used for recovery.

A contingency has been included in these cost estimates based on the level of project definition and as a provision for unforeseeable, additional costs within the reasonable bounds of a similar project scope. Other project cost factors, and construction cost markups used in the estimates are noted in Table 8-2. Indirect costs associated with engineering design, environmental, permitting, and construction management have not been included.

Table 8-2: Project Cost Factors

Component	Cost Factor
Other Project Cost Factors[1]	
Equipment Installation	D
Process Mechanical (Piping, valves, appurtenances, etc.)	10 - 25%
Overall Site Work	5 - 10%
Structural/Building Systems	5 - 60%
HVAC/Plumbing	0 - 5 %
Instrumentation and Control	10 - 20%
Electrical	15 - 30%
Construction Cost Markups	
Escalation	9%
Overhead	10%
Profit	10%
Bond/Insurance	3%
General Conditions	10%
Scope Contingency	35%

[1] "Other Project Cost Factors" for conveyance facilities set at 0 as unit cost represents installed cost.

Additional cost adjustments were considered, as follows:

- Cost estimates are for the project location in the Coachella Valley, California to be consistent with current market prices (i.e., labor) in the area.
- The cost estimates were escalated to February 2019 dollars (assumed earliest reasonable start of construction).
- A Market Adjustment Factor normally would be applied to compensate for fluctuations in material and labor prices driven by the national and global market. Since the market is currently generally stable this factor was not included in the cost estimates.
- Land and/or right-of-way costs were not included in the cost estimates for this screening.

Table 8-3 summarizes the capital costs for each project cost component. Figure 8-1 shows these costs graphically. Other than Alternative 1 – "Status Quo" alternative, Alternative 2 has the lowest capital cost of the alternatives considered.

Table 8-3: Capital Cost Estimates by Alternative and Component

Alternative	Tertiary Treatment ($M)	Advanced Treatment ($M)	Recycled Water Distribution ($M)	Spreading Basins ($M)	Groundwater Injection ($M)	Total ($M)
1 – Status Quo	-	-	-	-	-	**-**
2 – Spread at VSD	37.0	-	-	6.7	-	**43.8**
3 – RW Distribution and Spread at VSD	37.0	-	82.9	6.5	-	**126.5**
4 – Inject at VSD	-	49.3	-	-	21.0	**70.4**
5a – RW Distribution and Spread at Posse Park	37.0	-	33.9	18.4	-	**89.4**
5b – RW Distribution and Inject at Posse Park	37.0	44.3	46.5	-	16.5	**144.4**
6 – RW Distribution and Excess to CVSC	37.0	-	82.7	-	-	**119.7**

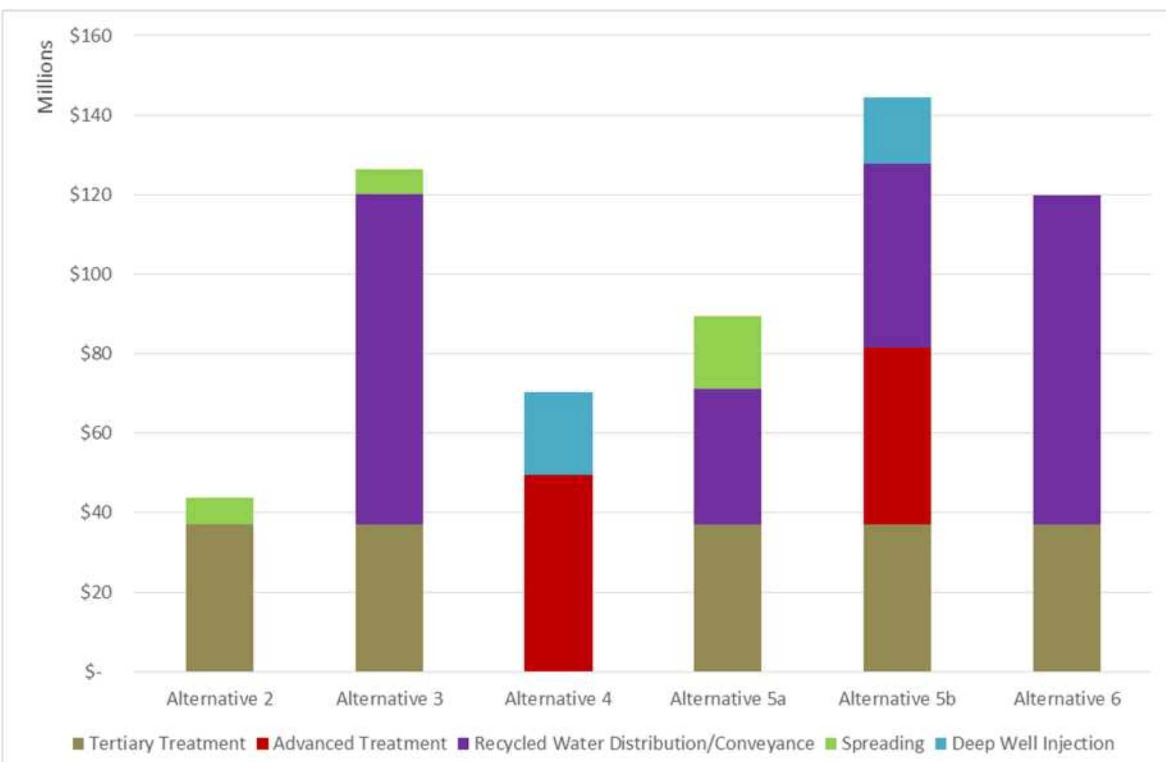


Figure 8-1: Capital Cost Graphical Comparisons

8.1.2 O&M and Lifecycle Estimates

Assumptions in developing the estimated annual O&M costs including power cost, chemical costs, labor, and annual maintenance are presented in Table 8-4. These values are discretionary and are based on review of estimates at similar facilities and engineering judgement.

The whole or partial number of additional full time equivalents (FTE) plant staff required to operate and maintain a treatment process was specific for each alternative. This does not constitute a staffing plan and should be reviewed by VSD and IWA based on agency policies and resources prior to finalizing. Salary estimates were based on the U.S. Bureau of Labor Statistics average salary for a Water Operator in the State of California and an assumed burdened rate of 1.6 ($65,500*1.6 = $105,000). The power cost is assumed as 11.41 cents per kilowatt-hour (kWh) based on the current energy rate sheet published by Imperial Irrigation District for Municipal Services.

Table 8-4: Annual O&M Cost Basis Assumptions

O&M Function	Tertiary Treatment	Advanced Treatment	Recycled Water Distribution	Spreading Basins	Groundwater Injection
Staffing (FTE)	2	2	2	1	1
Power	$0.1141/kWh				
Annual Maintenance (Plant)	2%				
Annual Maintenance (Non-plant Infrastructure)	0.05%				
Chemicals	Annual chemical demand plus deliveries				

A life cycle analysis was developed based on the capital and O&M estimates. The annualized capital cost assumes a 30-year term at an interest rate of 1.6 percent. A contingency of 35-percent is included with the O&M costs. The life cycle costs for each alternative are based on a maximum plant flow of 6 mgd at VSD and 4.5 mgd at Posse Park (after customer demands). To assess Alternative 1 – "Status Quo" alternative, the cost of water is assumed at $5,321 per acre foot, equal to the CVWD-adjusted cost for the State Water Project (SWP) purchase deal presented in IWA's Supplemental Water Supply Program and Fee Study. Table 8-5 lists the life cycle estimates developed at a conceptual level.

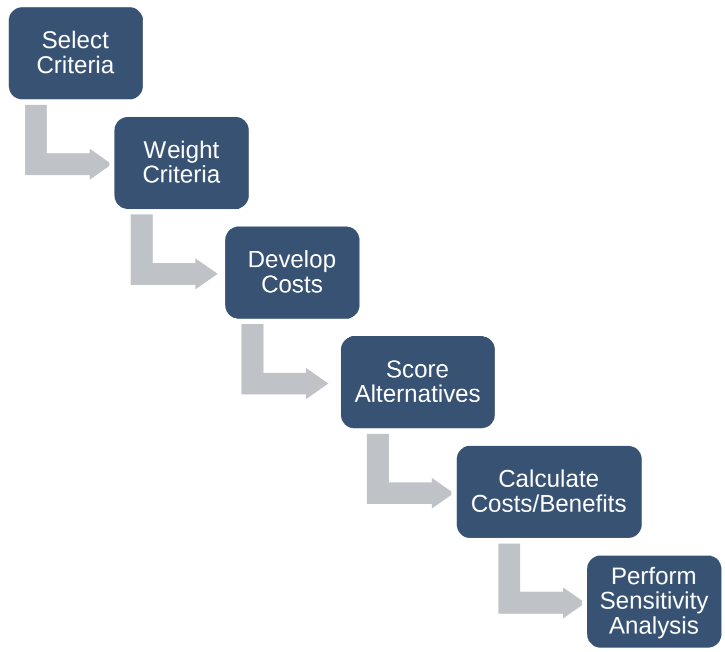
Table 8-5: Lifecycle Estimates

Alternative	Annualized Capital Cost ($M)	Annual O&M Cost ($M)	Annualized Lifecycle Cost ($M)	Cost Per Acre-foot ($)
Alt 1	-	-	-	5,321
Alt 2	1.85	1.67	3.52	524
Alt 3	5.34	2.75	8.10	1,205
Alt 4	2.97	4.60	7.57	1,127
Alt 5a	3.78	2.27	6.05	900
Alt 5b	6.10	4.22	10.31	1,535
Alt 6	5.06	2.62	7.67	1,141

9. Alternatives Analysis

A decision model was created to evaluate the costs and non-monetary benefits of each alternative. The objective is to identify the preferred approach that meets the goals and objectives of the feasibility study. The evaluation process included continuous engagement with the project team consisting of correspondence, workshops, and review between the stakeholders to define and select the alternatives, determine selection criteria, assign weightings of the criteria, review scoring methodologies and scores for each criterion of each alternative, and review the costs and decision model results. The decision process included the following steps:

1. Select decision criteria representing important non-monetary benefits or attributes of an alternative that are independent, provide differentiation, and are measurable.
2. Weight the decision criteria to prioritize importance of the individual criterion to the decision process.
3. Develop cost estimates (capital, O&M, and life cycle) for each alternative.
4. Develop a quantitative or qualitative score for each alternative with respect to each decision criterion.
5. Calculate the cumulative scores of each alternative based on the product of the weighting assigned to the criterion and the score/costs.



6. Perform sensitivity analyses to evaluate the impact of criteria weighting relative to the scores for each alternative.

9.1 Selection Criteria

Selection criteria was initially established by IWA and VSD in a workshop to represent factors of importance to these utilities, provide differentiation among alternatives, and avoid redundancy in definition that could lead to double counting of benefits. Note that other selection criteria were identified and discussed, but were ultimately eliminated because they were either duplicative with other criteria, or did not offer differentiation among the potential alternatives under consideration. The criteria was again discussed and finalized in a subsequent workshop.

Once selection criteria was set, IWA and VSD were asked to complete weighting sheets separately to distribute points relative to the primary criteria's importance. An average of these weightings is used for the decision analysis. Table 9-1 provides the actual weightings submitted by VSD, IWA, and the average.

Table 9-1: VSD and IWA Criteria Weightings

Criteria	VSD	IWA	Average
Costs	25%	20%	22.5%
Operability	18%	3%	10.5%
Project Implementation	12%	5%	8.5%
Groundwater Benefits	15%	2%	8.5%
Funding Opportunities	10%	30%	20%
Agency Benefits	20%	40%	30%
TOTAL	**100%**	**100%**	**100%**

In addition, subcriteria were determined to better define the criteria and aide in the scoring. Initially, all subcriteria within a criteria category were considered to have equal weighting and could be adjusted during the sensitivity analysis if preferred. Table 9-2 lists the selected primary criteria, subcriteria, definitions of the criteria as it relates to IWA and VSD, and the scoring methodology used for this analysis.

Table 9-2: Criteria Definitions and Scoring Methodologies

Selection Criteria	Subcriteria	Definitions	Scoring Methodology
Operability	Staffing	Staffing levels to operate and maintain	Additional full-time equivalent (FTE) staff required for each alternative component
	Operations Certification	Qualifications required to operate the alternative components	Expected level of operator certification required in the operating permit
	Ease of Operations	O&M complexity and risk for failures / loss of service	The number of process and infrastructure components that must be controlled at all times to achieve consistent operations
Project Implementation	Ease of Implementing	Constructability considerations	Complexity of construction including sequencing, external factors, permits, public involvement, etc.
	Timelines	Time required to implement an alternative	Factors include permitting, piloting, public participation, size and complexity.
Public Benefits	Water Quality Improvements	Ability to improve the quality of the drinking water supply	Likeliness that recharge will improve water quality (e.g., chromium, nitrates, etc.) at IWA production wells
	Groundwater Protection	Ability to recharge aquifer and prevent overdrafting	Likeliness that recharge will prevent need to utilize more costly imported water
Funding Opportunities	Grants	Available funding of the capital program through grants	Potential that project will qualify for current grant programs in California
Agency Benefits	Groundwater Credits	Ability to recharge aquifer and potentially reduce costs paid to the RAC	Flow rates for injection or surface spreading
	Independence	Reliance on other agencies for water resources, operations, and waste management	Number of agencies required to construct, operate, or maintain the project components. This includes waste hauling or disposal to off-site facilities.
	Resilience	Diversification of the water portfolio	Will this alternative provide another long-term water resource that augments current supplies
Costs	Capital	Capital costs	Normalized capital costs not accounting for grants
	O&M	O&M costs	Normalized annual O&M costs
	Life Cycle	Life cycle costs	Normalized 20-year life cycle costs

9.2 Alternative Scoring

A benefit score was generated for each alternative relative to the primary selection criteria and subcriteria. Criteria for each alternative were scored in a similar manner. Scores were generated using engineering analysis and judgement and, when possible, quantifiable scoring methodologies were used to impart objectivity to the analysis. Alternatives were scored based on a 1 to 5 scale, with 1 being the worst and 5 being the best. Higher scores are considered more favorable. See Table 9-3 and Table 9-4 for a summary of the scoring results.

Table 9-3: Criteria Weighting and Scoring Table

Criteria	Weight	Subcriteria	Weight	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5a	Alt 5b	Alt 6
Operability	10.5%	Staffing	33%	5	4	3	1.5	2	1	3
		Operations Certification	33%	5	4	3	1.5	2	1	3
		Ease of Operations	34%	5	4	2.5	1.5	2.5	1	3
		Weighted Subtotal	**100%**	**11**	**8.4**	**5.9**	**3.2**	**4.6**	**2.1**	**6.3**
Project Implementation	8.5%	Ease of Implementing	50%	5	3.5	2.75	3	2	1	2.75
		Timelines	50%	5	3.5	2.75	2.5	2	1	3.5
		Weighted Subtotal	**100%**	**8.5**	**6.0**	**4.7**	**4.7**	**3.4**	**1.7**	**5.3**
Public Benefits	8.5%	Water Quality Improvements	50%	1	4.5	4	4	3	2.5	1.25
		Protection	50%	1	4.5	4	4.5	4	3	2
		Weighted Subtotal	**100%**	**1.7**	**7.7**	**6.8**	**7.3**	**6.0**	**4.7**	**2.8**
Funding Opportunities	20.0%	Grant Priorities	100%	1	3.5	3.5	3.5	3	3.5	3
		Weighted Subtotal	**100%**	**4**	**14**	**14**	**14**	**12**	**14**	**12**
Agency Benefits	30.0%	Groundwater Credits	33%	1	5	3	5	3	3	1
		Independence	33%	1	5	4	4.5	4	3	2
		Resilience	34%	1	5	4	4	4	3.75	2.5
		Weighted Subtotal	**100%**	**6**	**30**	**22**	**27**	**22**	**20**	**11**
Costs	22.5%	Capital	33%	5	4	2	3	3	1	2.5
		O&M	33%	5	4	3	3	2.5	1	3
		Life Cycle	34%	5	4	3	3	2.75	1	3.5
		Weighted Subtotal	**100%**	**23**	**18**	**12**	**14**	**12**	**5**	**14**
		WEIGHTED TOTALS	**100%**	**53**	**84**	**65**	**70**	**60**	**47**	**51**

Table 9-4: Criteria Weighting and Scoring Summary

Rank	Score	Alternative
1	84	2 – Spread at VSD
2	70	4 – Inject at VSD
3	65	3 – RW Distribution and Spread at VSD
4	60	5a – RW Distribution and Spread at Posse Park
5	53	1 – Status Quo
6	51	6 – RW Distribution and Excess to CVSC
7	47	5b – RW Distribution and Inject at Posse Park

9.3 Conclusions

As shown in in Table 9-4, on-site recharging generally ranks the most favorably as it limits conveyance infrastructure and costs, and allows for recharging of the aquifer, which can be utilized for any demand by pumping from the groundwater basin. Recycled water distribution ranks slightly less favorably as it requires more extensive conveyance infrastructure, is limited to only serving recycled water demand, and recycled water demands by nature are more variable, which can result in unutilized recycled water during low irrigation periods. Off-site facility alternatives were lower ranked even though they may potentially improve groundwater quality for some IWA production wells over time but, come at a much higher cost and complexity. The lowest ranking alternative was Alternative 1 – Status Quo, due to the potentially high costs of securing alternative water rights and the lack of agency benefits. It should be noted that Alternatives 2, 3, and 5a are dependent upon field investigations confirming the ability to percolate water at a reasonable rate, hydrogeological modeling confirming that the percolated water will reach the aquifer, and the ability to acquire property of adequate area.

10. Bench Scale Pilot Study

One component of the scope of work for this feasibility study was to conduct a pilot study at the Coachella Sanitation District's WWTP. However, so that the pilot study brought value to all the agencies participating in the study, the pilot was conducted at their respective WWTP's which included Coachella Sanitation District (CSD), Valley Sanitation District's Water Reclamation Facility (VSD WRF) and Horton Wastewater Treatment Plant operated by Mission Springs Water District (MSWD). The focus of this write-up is on the pilot conducted at VSD WRF. The purpose of the pilot was to ultimately assist in getting the priority projects identified as part of this study closer to implementation by providing information on the filterability of the secondary effluent that allows for a better estimate of pretreatment needs and a better estimate of the types of filters needed. Having this information in turn, assists in better estimating the capital and operations and maintenance costs. To determine the filterability of the secondary effluent at each of the WWTP's a bench scale ultrafiltration membrane (UF) pilot as a pretreatment to reverse osmosis treatment was utilized. In addition, fluorescence characterization of dissolved organic matter in the raw and filtered wastewater was evaluated to understand the dissolved organic matters effect on filterability and pretreatment.

10.1 Goals and Objectives

The bench scale pilot test will verify filter parameters and filter performance on the respective wastewater effluent. This testing will provide a comparison of filter performance to compare the fouling characteristics of the different wastewater processes used at the three different wastewater treatment plants. The following are the main objectives of the membrane bench scale pilot testing including:

A. Verify the filterability of the effluent from the respective WWTP by PVDF UF membrane.

B. Analyze permeability (i.e., specific flux) to show the true fouling of the respective effluent on the membrane.

C. Evaluate fluorescence Excitation Emissions Matrix (EEMs) as a means of comparing/correlating fouling propensity of the respective wastewater process and the effective removal of the membranes before and after filtration.

10.2 Methods

This section summarizes the methods and parameters used for the bench scale Ultrafiltration (UF) membrane pilot study. The detailed Pilot Test Protocol is included in **Appendix D**.

10.2.1 Sample Preparation and Field Measurement

At VSD WRF, secondary effluent samples were collected from the secondary clarifier prior to chlorination dosing as shown in Figure 10-1. Grab samples of secondary effluent were collected to test for biological oxygen demand (BOD), total suspended solids (TSS), particle size and Excitation Emissions Matrix (EEMS) for organic matter characterization. Electrical Conductivity (EC), turbidity, and pH of the raw secondary effluent were measured at the field site. Near the completion of the third 30-minute filtration run cycle, two filtrate samples for the BOD, TSS, particle size and EEM's samples were collected. EC, turbidity and pH of the filtrate were measured at the field site.

Figure 10-1
VSD WRF Existing Facility - Sample Location

Recycled Water Program Development Feasibility Study
Indio Water Authority / Valley Sanitation District

Hazen

10.2.2 Bench Scale UF Membrane Set-up

The UF membrane parameters used in this pilot study are summarized in Table 10-1. The bench scale UF membrane included feed and filtrate pressure gauges, an 8 GPM pump, a manual flow control valve, sample batch basin, and the UF membrane module.

Table 10-1: Bench Scale Toray Ultrafiltration Membrane Parameters

Parameters	UF Membrane
Manufacturer/Model	Toray/HFS-LAB 018/HFS-LAB 018
Membrane Surface Area	0.18 m^2
Membrane Material	PVDF Fiber
Pump	8 GPM 60 lbs per square inch (PSI)

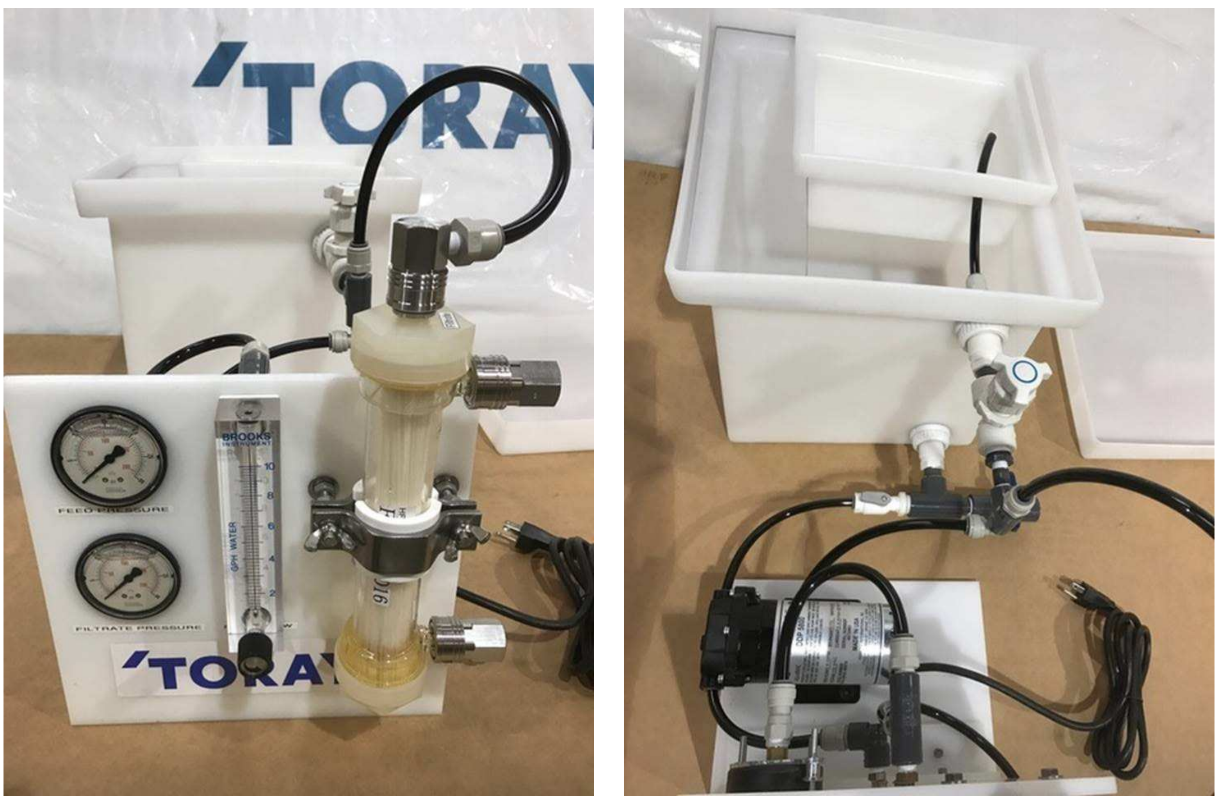


Figure 10-2: Bench Scale UF Membrane Set-Up

10.2.3 Membrane Filtration Procedure

The secondary effluent batch samples were pre-filtered through a #40 sieve mesh (0.0165 inch sieve opening). The filtrate pressure was kept constant at 1.0 psi and the flow at 4.0 gallons per hour (GPH) for three 30-minute filtration run cycles. After each 30-minute run, the membrane was removed and filled half way with tap water and shaken for 1 minute and 30 seconds to mimic the backwash cycle. Table 10-2 summarizes the UF membrane run cycle parameters used for the pilot study.

Table 10-2: UF Membrane Filtration Pilot Test Parameters

Pilot Test Parameters	Field Conditions
Sample	Secondary Effluent
Initial Filtration	#40 sieve mesh (1/64 nominal sieve mesh size)
Run Time	30 min
Flow	4 GPH
Flux	49.5 gallons per day per square foot (GFD)
Backwash	Manual Shake for 1.5 minutes to mimic backwash cycle
Chemical Cleaning	1,000 ppm Sodium Hypochlorite Hydrochloric Acid

10.3 Results

The raw data for the pilot study is included in **Appendix E**.

10.3.1 Membrane Performance

One of the goals of the bench-scale pilot study was to verify filterability. The filterability of the secondary effluent at VSD WRF was confirmed and the results are shown in Figure 10-3 and Figure 10-4. Figure 10-3 shows particle sizes ranging from 0.95 microns to 373.10 microns in the secondary effluent. The filtrate particle size distribution in Figure 10-4 shows a narrow range of 40 microns to 121.80 microns which indicates that the filterable particles are being removed through the membrane.

In addition, the differential pressure and specific flux are indicative of the filterability of the feed water through the membrane. Specific flux is the amount of filtrate produced per surface unit area over a differential pressure. In general, differential pressure exceeding the threshold value prompts the backwash cycle of the membrane. Excessive backwash cycles denote poor feed water quality. Membrane design flux and threshold values for differential pressure may be determined during full scale pilot tests studies.

The backwash cycle for this bench scale pilot study was kept constant at 30-minute intervals to simply compare three different wastewater qualities. The comparison analysis is discussed in the Recycled Water Program Development Feasibility Study Report that was prepared as part of this project. The differential pressure trend that was witnessed is shown in Figure 10-5. As anticipated, the differential pressure (Figure 10-5) shows an increasing trend at each filtration run cycle and recovers after each simulated backwash cycle. The specific flux shows a typical decreasing trend (Figure 10-6) after each filtration run cycle and recovers after each backwash. Although the results show filterability of the VSD WRF effluent, it is important to conduct a full scale pilot test to determine design values.

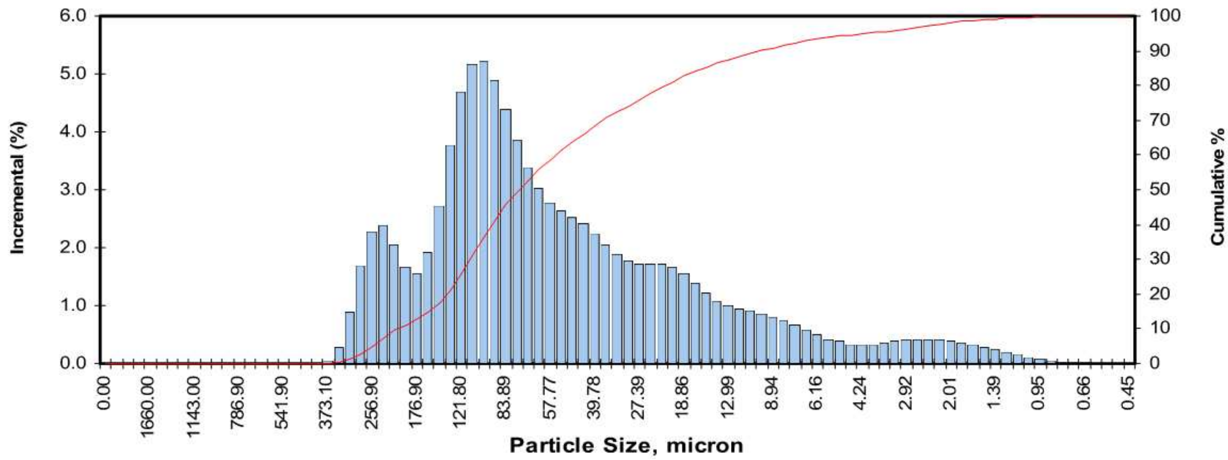


Figure 10-3 VSD Raw Secondary Effluent Particle Size

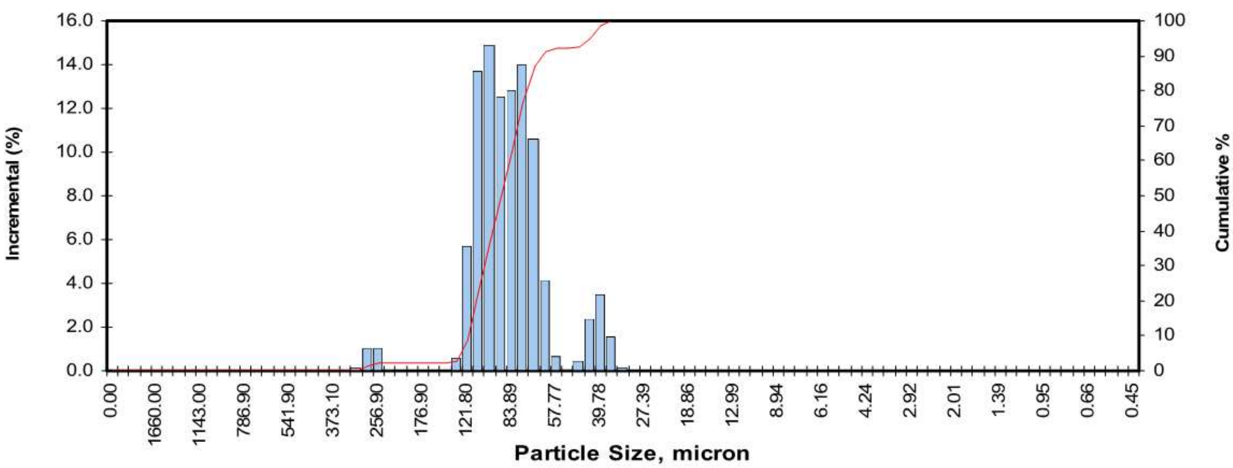


Figure 10-4 VSD Filtrate Particle Size

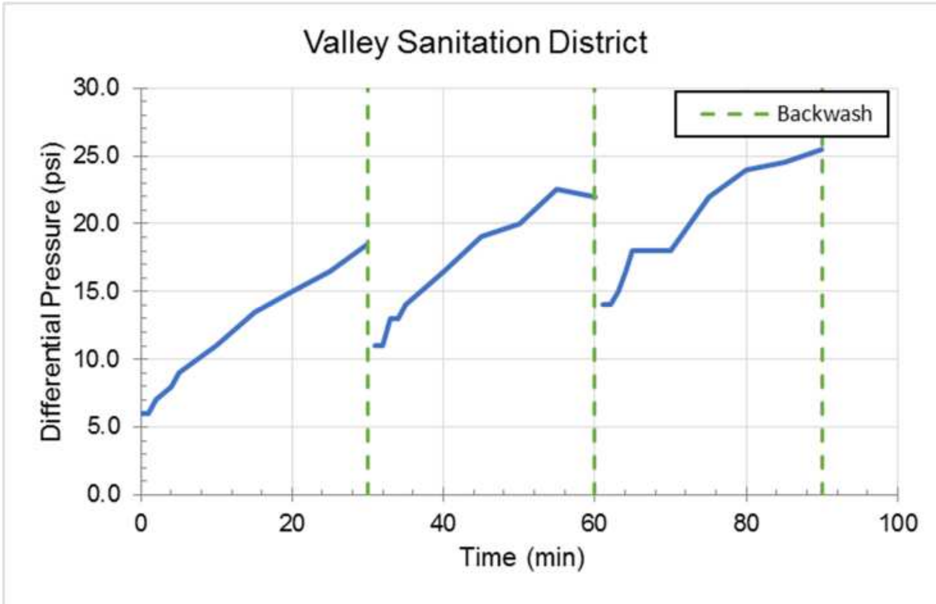


Figure 10-5 Differential Pressure through the UF Membrane

Accumulation of deposits and cake formation on the membrane appears to be the main cause of decreased specific flux in the UF membrane resulting in reduced membrane capacity. Adsorption of organic matter, particularly humic substances, to membrane pores is often the controlling factor in membrane performance. As shown in Figure 10-6, there was a decline in specific flux after the backwash process. The decline in specific flux after backwash could be associated with organic matter adsorption to the UF membrane pores.

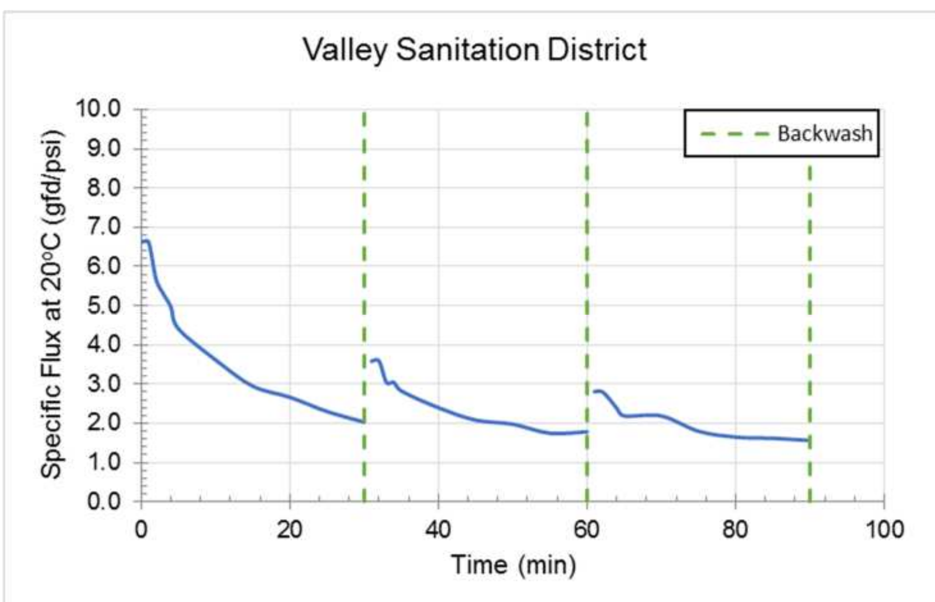


Figure 10-6 Specific Flux at 20°C through the UF Membrane

10.3.2 Water Quality

The conventional chemical parameters in wastewater treatment were measured for the secondary effluent and UF membrane filtrate. As expected, the TSS and turbidity were reduced in the filtrate. The UF membrane was effective in removing suspended and colloidal solids.

Table 10-3: Water Quality Results

Water Quality	Unit	Results	
		Raw Secondary Effluent	Pilot Filtrate
Total Suspended Solids (TSS)	mg/L	2	ND
Biological Oxygen Demand (BOD)	mg/L	ND	ND
Turbidity	NTU	2.2	0.15
Conductivity	µS/cm	842	859
pH	-	7.65	7.7
Temperature	°C	29.5	30.5

10.3.3 Fluorescence Excitation and Emission Matrix (FEEM)

Fluorescence spectroscopy provides reliable information on characterization of fluorescing dissolved organic matter (DOM) in wastewater effluent. The FEEM spectra (Figure 10-7) is a three-dimensional representation of the fluorescence intensities over a range of excitation and emission wavelengths. In a FEEM spectrum, the intensity of peak regions is indicative of various DOM sources. In wastewater, the main sources of DOM are soluble microbial products from activated sludge treatment and trace organic compounds (Region I) and humic substances (Region II and III). Table 10-4 summarizes the potential fouling of each peak region of DOM.

Table 10-4: Peak of Interest and Fouling Tendency of each FEEM Region

Peaks of Interest	Fouling Tendency	Excitation/Emission Wavelength
Region I	Moderate Fouling	280/330 nm
Region II	High Fouling	254/450 nm
Region III	Non- Fouling (good)	330/440 nm

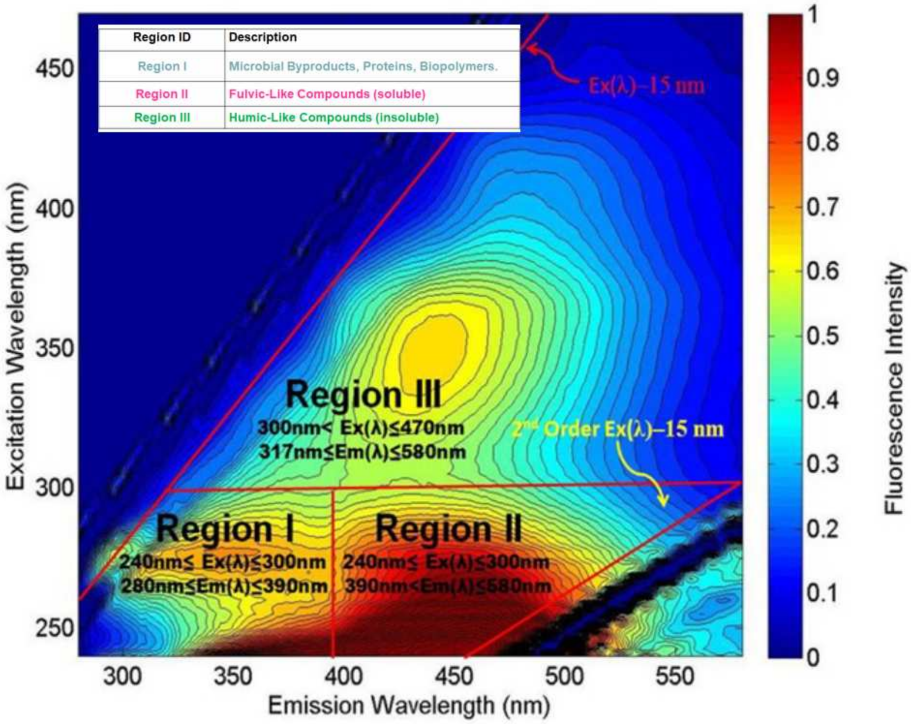


Figure 10-7 Excitation Emission Matrix Spectroscopy

In membrane treatment processes, UF membranes are effective in reducing viruses and humic substances in the filtrate. However, effluent organic matter could induce the formation of a biofouling layer, resulting in an unacceptable degree of system performance loss. The FEEM spectra for each sample is shown in Figure 10-8. A 49 percent reduction of total organic carbon (TOC) was observed in comparing the raw secondary effluent to the filtrate samples. The relatively high concentration of TOC in the UF feed water would potentially increase biofouling in the membrane.

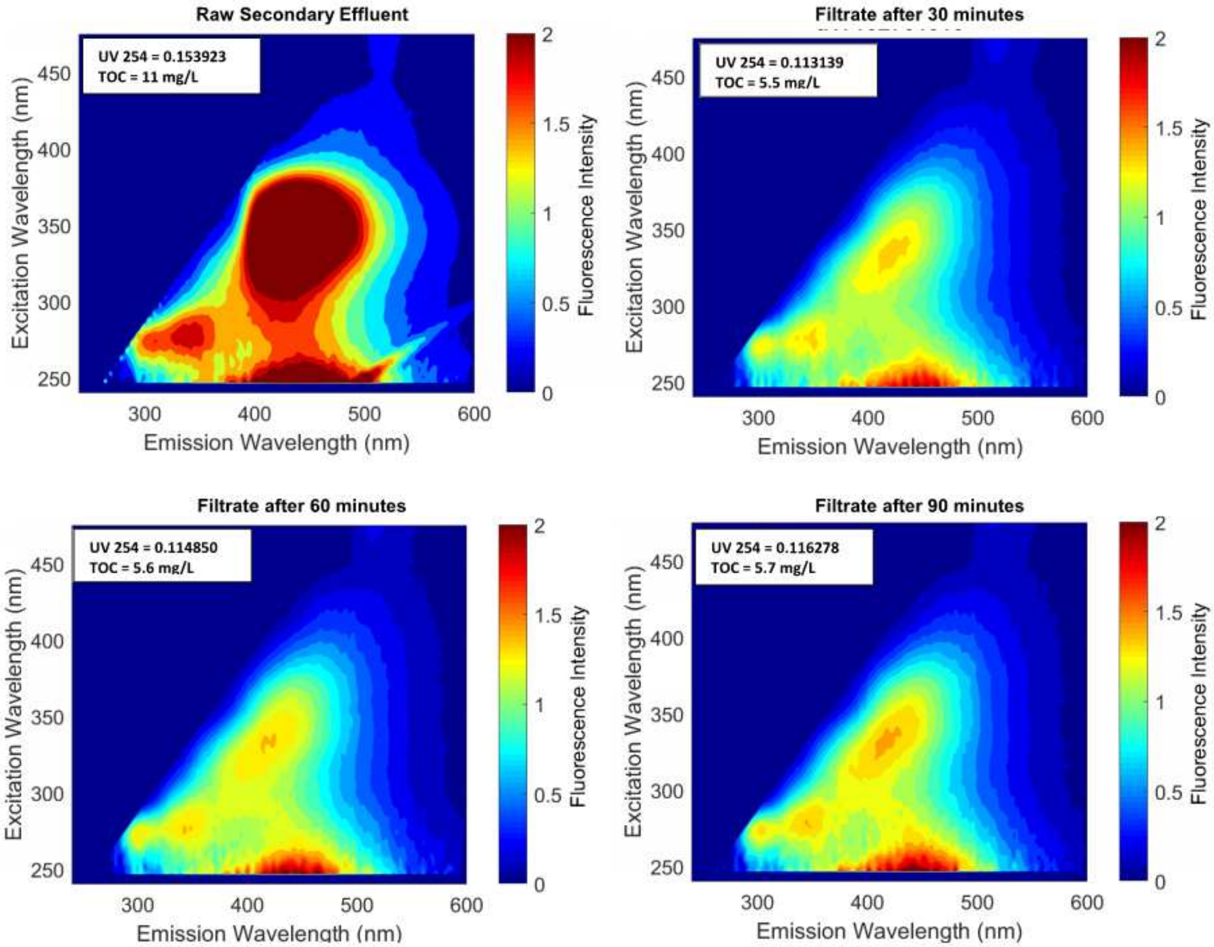


Figure 10-8 Fluoresce EEMS for Secondary Effluent and Filtrate

10.4 Conclusion

The VSD WRF secondary effluent, without additional treatment, has the potential of moderate to high membrane fouling based on the observed FEEM spectra and TOC concentration. This observation is validated by the high differential pressure after the 90-minute membrane run cycle and decline in specific flux. Additional pre-treatment (i.e., tertiary filtration and/or granular activated carbon filters) could be required prior to the membrane filtration. A more comprehensive study is necessary to determine pre-treatment and conducting a full scale pilot study for the advance water treatment facility. A full evaluation of the planned advanced water treatment system is recommended to determine optimal operational parameters including flux rate (typically 20-30 gfd), threshold value, backwash cycle feed water quality (i.e., TOC), runtime, and CIP procedures. The full evaluation would include conducting a full-scale pilot study over a six-month period to provide the information necessary for design.

11. Grant Opportunities and Funding Options

One component of this feasibility study was to identify the available grants and funding options for the recycled water alternative projects identified. The challenge with grant and loans are the uncertainty due to meeting qualifications, timing and their fluidity and availability. Briefly summarized below, are the grants and loans that are currently available for recycled water projects. This is not intended to be a comprehensive list but a snapshot in time as to what is currently available that is relevant to the alternatives identified. Due to the volume of applications received and awarded, the amount of monies available changes and we cannot predict if these monies will be available when the alternatives discussed herein are ready for implementation. Further evaluation will be needed as IWA and VSD make decisions on the project to pursue and schedule for design and construction. A description of the funding opportunities available are briefly described below.

11.1 California State Water Resources Control Board

The California State Water Resources Control Board (SWRCB) provides funding for planning, design and construction of recycled water projects that augment or offset fresh water supplies. The Division of Financial Assistance administers the Water Recycling Funding Program (WRFP). The primary sources of funding for water recycling projects are as follows:

1. Proposition 1 is the Water Quality, Supply, and Infrastructure Improvement Act of 2014. Proposition 1 funding authorized $7.545 billion in general obligation bonds for water projects and is administered under five programs including Small Community Wastewater ($260M), Water Recycling ($625M), Drinking Water ($260M), Stormwater ($200M) and Groundwater Sustainability ($800M). Of most relevance to the recycled water project alternatives presented herein, and explained in more detail below, are the Water Recycling, Small Community Wastewater, and Groundwater Sustainability Programs.

    a. Water Recycling – Provides grants and loans for the planning and construction of water recycling projects. Grants may be provided for studies to determine the feasibility of using recycled water and selecting a preferred alternative to augment or offset potable water from local or State supplies. Grants for planning will cover 50 percent of eligible costs up to a maximum of $75,000 and a 50 percent match from the agency is required. Grants for construction of recycled water projects are available and projects may receive funds up to 35 percent of construction costs up to a maximum of $15 Million. Low interest loans may be obtained for the balance not covered by the construction grants and they are funded under the Clean Water State Revolving Fund (CWSRF), discussed below, or State bond funded. As of October 2017, there were executed agreements to fund 28 recycled water projects with project costs totaling more than $1.69 billion of which $222M in grants will be dispersed and $945M will be funded utilizing low interest loans.

       As of January 2018, on line applications are still being accepted by the State Water Resources Control Board for Planning Grants under the Water Recycling Funding

Program for planning, Clean Water State Revolving Fund for planning, construction and implementation and the Water Recycling Funding Program for construction.

b. Small Community Wastewater – The small community wastewater program includes an annual appropriation of $8M. Under this program, planning grants for recycled water projects are available to communities that serve a population less than 20,000 where the average median household income (MHI) is less than 80 percent of the Statewide MHI. The maximum grant amount can be 100 percent of the total project cost up to a maximum of $500,000 per project. Construction grants are also available under this program to fund recycled water projects up to a maximum of $6M per project. Qualifying under this construction grant program is dependent on the average MHI and it must be shown that the wastewater rates are at least 1.5 to 2 percent of the average MHI. This would need further evaluation to determine if IWA and VSD would qualify under this program.

2. Clean Water State Revolving Fund (CWSRF) Program provides low interest financing for planning, design and construction of recycled water projects. Generally, the loan rate is one half of the State of California's most recent general obligation bond rate and the terms of the loan are for the lesser of 30 years or the expected useful life of the asset. In many cases, agencies may utilize a combination of funding sources to complete projects. As of March 2017, the interest rate being offered by DFA was 1.8%.

11.2 United States Department of the Interior - Bureau of Reclamation

1. WaterSMART Water and Energy Efficiency Grants program provides a 50/50 cost share to water and irrigation districts, Tribes, States and other entities that deliver water or power. Awards are through a competitive process with focus on projects that can be completed in 24 months and will help sustain water supplies in the western United States. These grants may be leveraged with other non-Federal funding sources. Funding opportunities for fiscal year 2018 are currently being developed.

2. Title XVI Water Reclamation and Reuse grants provide funding for planning, design and construction of water recycling and reuse projects on a project specific basis. New funding opportunities are released annually. For a project to be funded for design and/or construction, a feasibility study that meets the requirements under Title XVI Directives and Standards WTR 11-01 must be completed. The Federal cost share for Title XVI projects is typically limited by law to not more than 25 percent of the total cost of planning, design, and construction up to a maximum of $20 million.

11.3 Public-Private Partnerships

Traditionally public agencies have utilized available funding methods such as grants, loans, user fees, taxes and municipal bonds. However, some state and local agencies are turning to innovative financing programs such as public-private partnerships (PPPs or P3s) to help fund and manage infrastructure that has traditionally been provided by the public sector. Under PPP's, a government entity contracts with a private firm to design, finance, construct, operate and maintain an infrastructure asset on behalf of the public sector. The advantages of a PPP is that it provides a source of cash flow for the public agency and access to capital that may not otherwise be available. There are a number of standard models for private participation in the water sector including management contracts, leases and concession as well as hybrid models. However, careful consideration needs to be taken when developing the agreements such that they reflect acceptable risk to both parties. Several articles (U.S. Department of the Treasury, April 2015 and KPMG, 2011) that discuss the details and risks associated with utilizing private financing are included in **Appendix F**.

11.4 Conclusions

Grant and loans are currently available to fund planning, design and construction of the alternatives discussed herein. It is anticipated that there is enough detail developed for the alternatives described herein that IWA and VSD can and should apply for a combination of grant funding under both State and Federal Proposition 1 and Title XVI respectively and, if necessary, apply for low interest loans under the CWSRF. When reviewing grant applications, State and Federal agencies look favorably on agencies that partner to implement recycled water programs. One of the most important items in qualifying for grants is the ability to show a well-defined project and that the agency(ies) have the means and the dedication to implement the project.

Appendix A: References

References

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7. Indio Water Authority Recycled Water Feasibility Study, Carollo Engineers, January 2016.
8. Indio Water Authority Supplemental Water Supply Program and Fee Study

Valley Sanitary District

1. Valley Sanitary District Collection System Master Plan Draft Report, MWH Global, June 2013.
2. Valley Sanitary District Water Reclamation Facility Final Master Plan, MWH Global, September 2015.
3. Deactivation of Biological Treatment Ponds Technical Memorandum, MWH Global a part of Stantec, January 24, 2017.

Appendix B: Effluent Flow and Water Quality Data Tables and Graphs

Effluent Flow and Water Quality Data Tables and Graphs

Table B-1: Effluent Flow and Water Quality Data – Summary

Date	Flow[1] (MGD)	CBOD[1] (mg/L)	TSS[1] (mg/L)	TDS[2] (mg/L)	E.coli[2] (MPN/100mL)	Fecal Coliform[2] (MPN/100mL)
Jan-15	6.39	13.64	7.97	450.00	2.35	1.66
Feb-15	6.36	14.97	5.69	488.00	1.52	1.00
Mar-15	6.38	15.65	6.75	444.00	1.00	1.52
Apr-15	5.88	13.98	7.08	458.00	2.41	1.97
May-15	5.16	14.52	8.05	420.00	2.38	3.97
Jun-15	5.11	12.09	8.71	418.00	4.13	3.73
Jul-15	5.18	11.80	8.11	456.00	2.90	5.80
Aug-15	5.08	13.57	4.78	-	4.65	5.30
Sep-15	5.56	17.54	5.38	-	6.70	10.30
Oct-15	5.51	17.17	9.64	460.00	3.90	4.30
Nov-15	5.54	18.76	11.94	-	1.40	2.10
Dec-15	5.70	16.25	9.76	-	1.10	1.10
Jan-16	6.16	16.23	7.82	456.00	1.30	1.70
Feb-16	5.83	14.57	7.20	-	1.00	1.00
Mar-16	5.57	15.56	11.90	-	2.10	3.30
Apr-16	5.61	20.36	13.76	440.00	2.20	1.30
May-16	5.15	10.19	11.59	-	1.80	2.10
Minimum	**5.08**	**10.19**	**4.78**	**418.00**	**1.00**	**1.00**
Maximum	**6.39**	**20.36**	**13.67**	**488.00**	**6.70**	**10.30**
AVERAGE	**5.65**	**15.11**	**8.60**	**449.00**	**2.52**	**3.07**

(1) Values calculated from samples taken at locations EFF-001A and EFF-001B

(2) Results from samples taken at location EFF-001C

Figure B-1: Average Monthly Effluent Flows

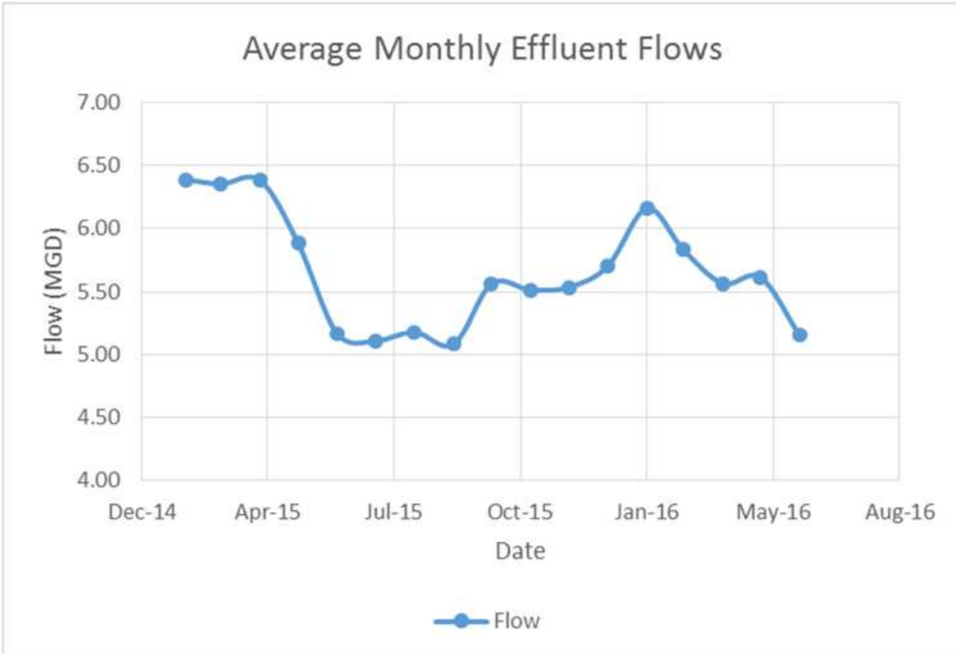


Figure B-2: Water Quality Data – TSS and CBOD

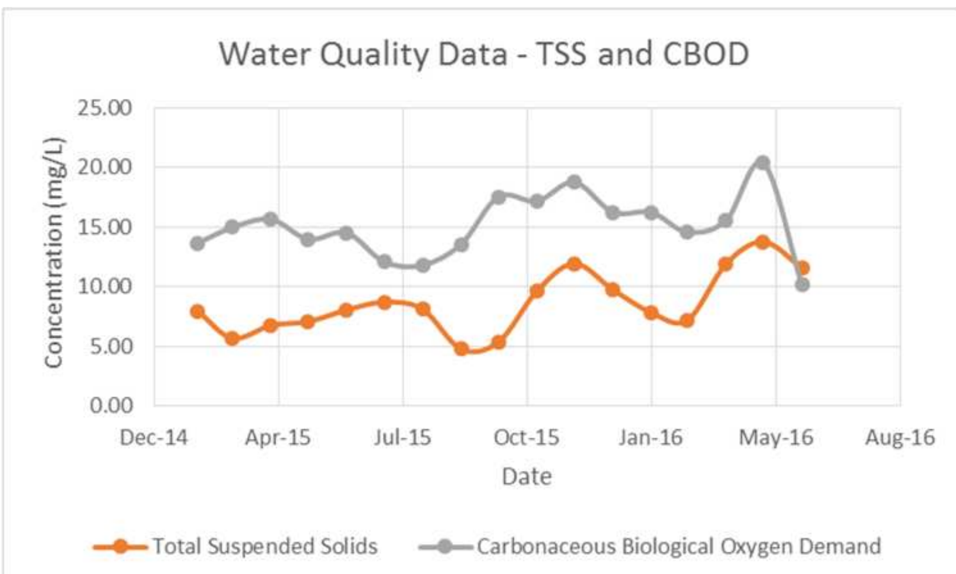


Figure B-3: Water Quality Data – TDS

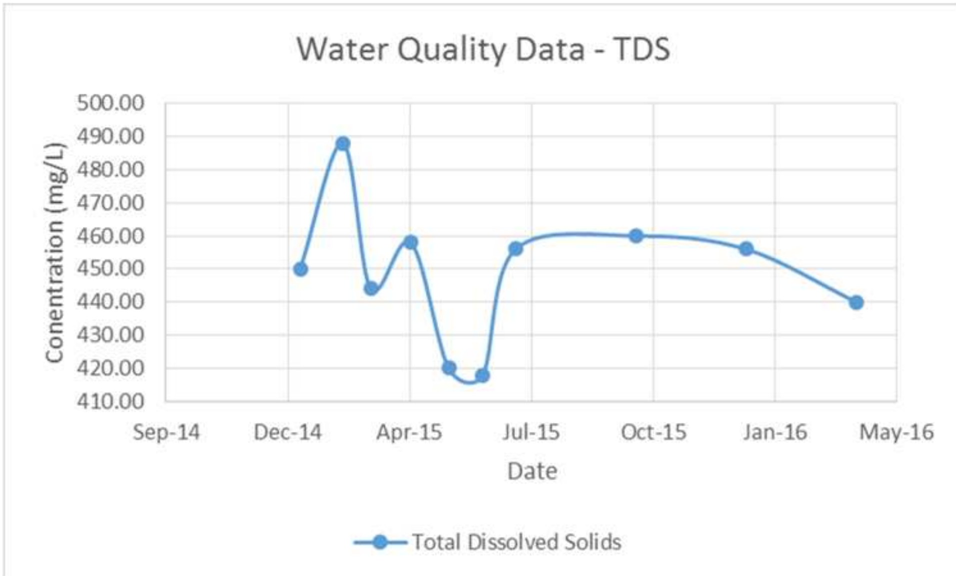
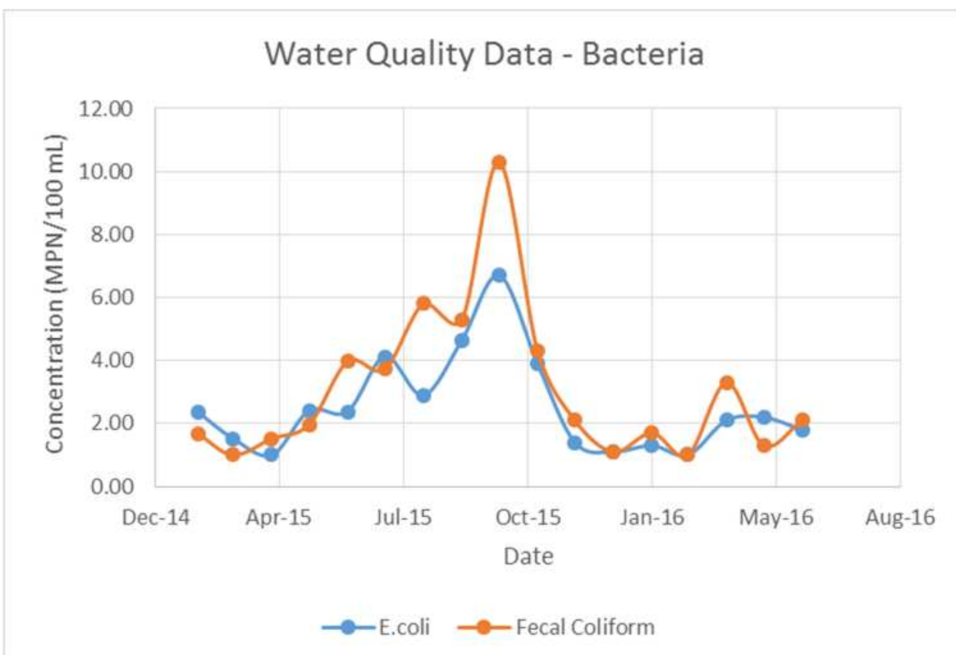


Figure B-4: Water Quality Data – Bacteria



Appendix C: Cost Breakdown

Recycled Water at VSD/IWA (6 mgd)

	Alternative 2	Alternative 3	Alternative 4	Alternative 5a	Alternative 5b	Alternative 6
Tertiary Treatment	$ 37,019,000	$ 37,019,000		$ 37,019,000	$ 37,019,000	$ 37,019,000
Advanced Treatment			$ 49,331,000		$ 44,302,207	
Recycled Water Distribution/Conveyance		$ 82,923,375		$ 33,903,717	$ 46,490,086	$ 82,668,000
Spreading	$ 6,762,000	$ 6,506,625		$ 18,443,283		
Deep Well Injection			$ 21,030,000		$ 16,511,914	
Total Construction Cost	***$ 43,800,000***	***$ 126,500,000***	***$ 70,400,000***	***$ 89,400,000***	***$ 144,400,000***	***$ 119,700,000***
Annualized capital cost (1.6%, 30 years)	***$ 1,849,755***	***$ 5,342,328***	***$ 2,973,122***	***$ 3,775,527***	***$ 6,098,278***	***$ 5,055,151***
Cost per Acre-foot	$ 524	$ 1,205	$ 1,127	$ 900	$ 1,535	$ 1,141

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
1	*6 MGD Secondary Effluent Pump Station*	*6*	*EA*	*$ 376,600*	*$ 2,259,600*	
		Subtotal:			**$ 2,259,600**	
	Other Indirect Factors:					
	Equipment Installation Cost	0%			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	0%			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	0%			$ -	As percent of total cost. Including site preparation and improvements
	Structural	0%			$ -	As percent of total cost
	HVAC/Plumbing	0%			$ -	As percent of total cost
	Electrical	0%			$ -	As percent of total cost
	Instrumentation and Controls	0%			$ -	As percent of total cost
	General Conditions (Div01)	10%			*$ 225,960*	
		Subtotal:			**$ 2,485,560**	
	Escalation at 3.5% annually	9%			*$ 223,229*	
		Subtotal:			**$ 2,708,789**	
	Contractor Overhead	10%			*$ 270,878.87*	
		Subtotal:			**$ 2,979,668**	
	Contractor Profit	10%			*$ 297,966.75*	
		Subtotal:			**$ 3,277,634**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 3,277,634**	
	Bond and Insurance	3%			*$ 98,329.03*	
		Subtotal:			**$ 3,375,963**	
	Design Contingency	35%			*$ 1,181,587.17*	
		Subtotal:			**$ 4,557,550**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 4,558,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
Coagulation						
1	*Polymer Metering Pump Skid (2 pumps per skid)*	*1.00*	*EA*	*7,200*	*9,360*	*Includes installation factor of 30%*
2	*PE Polymer Storage Tank (2750 gallons)*	*1.00*	*EA*	*7,150*	*9,295*	*Includes installation factor of 30%*
3	*Concrete Slab (18-inches thick)*	*43.00*	*CY*	*550*	*23,650*	*Includes underlay, formwork, rebar, concrete*
4	*Concrete Containment Walls(12-inches thick)*	*20.00*	*CY*	*1,150*	*23,000*	*Includes underlay, formwork, rebar, concrete*
	Subtotal:				**$ 65,305**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*25%*			$ 16,326	As percent of total cost. If not included in the unit cost above
	Site Civil	*10%*			$ 6,531	As percent of total cost. Including site preparation and improvements
	Structural	*30%*			$ 19,592	As percent of total cost
	HVAC/Plumbing	*5%*			$ 3,265	As percent of total cost
	Electrical	*20%*			$ 13,061	As percent of total cost
	Instrumentation and Controls	*15%*			$ 9,796	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 13,388*	
	Subtotal:				**$ 147,263**	
	Escalation at 3.5% annually	*9%*			*$ 13,226*	
	Subtotal:				**$ 160,488**	
	Contractor Overhead	*10%*			*$ 16,048.85*	
	Subtotal:				**$ 176,537**	
	Contractor Profit	*10%*			*$ 17,653.73*	
	Subtotal:				**$ 194,191**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 194,191**	
	Bond and Insurance	*3%*			*$ 5,825.73*	
	Subtotal:				**$ 200,017**	
	Design Contingency	*35%*			*$ 70,005.88*	
	Subtotal:				**$ 270,023**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 271,000**	

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RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
Sand Filtration						
1	*Parkson Continuous Upflow - 6mgd*	*1*	*LS*	*$ 1,600,000*	*$ 2,080,000*	*Includes installation factor of 30%*
	Subtotal:				**$ 2,080,000**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*25%*			$ 520,000	As percent of total cost. If not included in the unit cost above
	Site Civil	*10%*			$ 208,000	As percent of total cost. Including site preparation and improvements
	Structural	*40%*			$ 832,000	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*15%*			$ 312,000	As percent of total cost
	Instrumentation and Controls	*15%*			$ 312,000	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 426,400*	
	Subtotal:				**$ 4,690,400**	
	Escalation at 3.5% annually	*9%*			*$ 421,246*	
	Subtotal:				**$ 5,111,646**	
	Contractor Overhead	*10%*			*$ 511,164.58*	
	Subtotal:				**$ 5,622,810**	
	Contractor Profit	*10%*			*$ 562,281.04*	
	Subtotal:				**$ 6,185,091**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 6,185,091**	
	Bond and Insurance	*3%*			*$ 185,552.74*	
	Subtotal:				**$ 6,370,644**	
	Design Contingency	*35%*			*$ 2,229,725.47*	
	Subtotal:				**$ 8,600,370**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 8,601,000**	

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RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
1	*Microfiltration 3 mgd*	*1*	*LS*	*$ 1,820,000*	*$ 2,366,000*	*Includes installation factor of 30%*
		Subtotal:			**$ 2,366,000**	
	Other Indirect Factors:					
	Architectural	*0%*			$ 1,275,000	Building Cost
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*20%*			$ 473,200	As percent of total cost. If not included in the unit cost above
	Site Civil	*5%*			$ 118,300	As percent of total cost. Including site preparation and improvements
	Structural	*5%*			$ 118,300	As percent of total cost
	HVAC/Plumbing	*5%*			$ 118,300	As percent of total cost
	Electrical	*15%*			$ 354,900	As percent of total cost
	Instrumentation and Controls	*15%*			$ 354,900	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 517,890*	
		Subtotal:			**$ 5,696,790**	
	Escalation at 3.5% annually	*9%*			*$ 511,630*	
		Subtotal:			**$ 6,208,420**	
	Contractor Overhead	*10%*			*$ 620,841.99*	
		Subtotal:			**$ 6,829,262**	
	Contractor Profit	*10%*			*$ 682,926.19*	
		Subtotal:			**$ 7,512,188**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 7,512,188**	
	Bond and Insurance	*3%*			*$ 225,365.64*	
		Subtotal:			**$ 7,737,554**	
	Design Contingency	*35%*			*$ 2,708,143.82*	
		Subtotal:			**$ 10,445,698**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 10,446,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
Chlorine Contact Time						
1	*Excavation*	*2720*	*CY*	*$ 60*	*$ 163,200*	*Includes excavation, backfill (imported fill), disposal, shallow excavation, no shoring, no dewatering*
2	*Concrete Slabs*	*2499*	*CY*	*$ 550*	*$ 1,374,450*	*Includes underlay, formwork, rebar, concrete*
3	*Concrete Walls*	*1545*	*CY*	*$ 1,150*	*$ 1,776,750*	*Includes underlay, formwork, rebar, concrete*
4	*Tank Coating*	*33158*	*SF*	*$ 20*	*$ 663,160*	*Interior surface area only. Cost assumes two coats*
5	*Handrail*	*458*	*LF*	*$ 150*	*$ 68,700*	*Aluminum, 3 bar with toeboard*
6	*Weir gate*	*4*	*EA*	*$ 20,000*	*$ 80,000*	
7	*Sodium Hypochlorite Metering Pump Skid (2 pumps per skid)*	*1*	*EA*	*$ 10,000*	*$ 10,000*	
8	*PE Sodium Hypochlorite Storage Tank (5200 gallons)*	*1*	*EA*	*$ 12,090*	*$ 12,090*	
9	*Recycled Water Distribution*	*52*	*CY*	*$ 550*	*$ 28,600*	*Includes underlay, formwork, rebar, concrete*
10	*Chemical Storage Area: Concrete Containment Walls(12-inches thick)*	*21*	*CY*	*$ 1,150*	*$ 24,150*	*Includes underlay, formwork, rebar, concrete*
		Subtotal:			**$ 4,037,900**	
	Other Indirect Factors:					
	Equipment Installation Cost	20%			$ 807,580	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	10%			$ 403,790	As percent of total cost. If not included in the unit cost above
	Site Civil	10%			$ 403,790	As percent of total cost. Including site preparation and improvements
	Structural	10%			$ 403,790	As percent of total cost
	HVAC/Plumbing	0%			$ -	As percent of total cost
	Electrical	10%			$ 403,790	As percent of total cost
	Instrumentation and Controls	10%			$ 403,790	As percent of total cost
	General Conditions (Div01)	10%			*$ 686,443*	
		Subtotal:			**$ 7,550,873**	
	Escalation at 3.5% annually	5%			*$ 399,870*	
		Subtotal:			**$ 7,950,743**	
	Contractor Overhead	10%			*$ 795,074.25*	
		Subtotal:			**$ 8,745,817**	
	Contractor Profit	10%			*$ 874,581.68*	
		Subtotal:			**$ 9,620,398**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 9,620,398**	
	Bond and Insurance	3%			*$ 288,611.95*	
		Subtotal:			**$ 9,909,010**	
	Design Contingency	35%			*$ 3,468,153.65*	
		Subtotal:			**$ 13,377,164**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 13,378,000**	

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RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
Reverse Osmosis						
1	*RO System - 4.24 mgd flow based on a 6 mgd Tertiary Facility*	*1*	*LS*	*$ 3,600,000*	*$ 4,680,000*	*Includes installation factor of 30%*
2	*Sulfuric Acid Metering Pump Skid (2 pumps per skid)*	*1*	*EA*	*$ 9,700*	*$ 12,610*	*Includes installation factor of 30%*
3	*PE Sulfuric Acid Storage Tank (7400 gallons)*	*1*	*EA*	*$ 17,680*	*$ 22,984*	*Includes installation factor of 30%*
4	*Concrete Slab (18-inches thick)*	*42*	*CY*	*$ 550*	*$ 23,100*	*Includes underlay, formwork, rebar, concrete*
5	*Concrete Containment Walls(12-inches thick)*	*19*	*CY*	*$ 1,150*	*$ 21,850*	*Includes underlay, formwork, rebar, concrete*
	Subtotal:				**$ 4,760,544**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ 1,300,000	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*20%*			$ 952,109	As percent of total cost. If not included in the unit cost above
	Site Civil	*10%*			$ 476,054	As percent of total cost. Including site preparation and improvements
	Structural	*5%*			$ 238,027	As percent of total cost
	HVAC/Plumbing	*5%*			$ 238,027	As percent of total cost
	Electrical	*20%*			$ 952,109	As percent of total cost
	Instrumentation and Controls	*15%*			$ 714,082	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 963,095*	
	Subtotal:				**$ 10,594,047**	
	Escalation at 3.5% annually	*9%*			*$ 951,454*	
	Subtotal:				**$ 11,545,501**	
	Contractor Overhead	*10%*			*$1,154,550.09*	
	Subtotal:				**$ 12,700,051**	
	Contractor Profit	*10%*			*$1,270,005.09*	
	Subtotal:				**$ 13,970,056**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 13,970,056**	
	Bond and Insurance	*3%*			*$ 419,101.68*	
	Subtotal:				**$ 14,389,158**	
	Design Contingency	*35%*			*$5,036,205.20*	
	Subtotal:				**$ 19,425,363**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 19,426,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
UV Peroxide System						
1	*In Channel UV Disinfection System - 6mgd*	*1*	*LS*	*$ 525,000*	*$ 682,500*	*Includes installation factor of 30%*
	Peroxide Dosing and Storage (inluded in the cost above)				*$ -*	
		Subtotal:			**$ 682,500**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*25%*			$ 170,625	As percent of total cost. If not included in the unit cost above
	Site Civil	*20%*			$ 136,500	As percent of total cost. Including site preparation and improvements
	Structural	*60%*			$ 409,500	As percent of total cost
	HVAC/Plumbing	*5%*			$ 34,125	As percent of total cost
	Electrical	*30%*			$ 204,750	As percent of total cost
	Instrumentation and Controls	*20%*			$ 136,500	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 177,450*	
		Subtotal:			**$ 1,951,950**	
	Escalation at 3.5% annually	*9%*			*$ 175,305*	
		Subtotal:			**$ 2,127,255**	
	Contractor Overhead	*10%*			*$ 212,725.51*	
		Subtotal:			**$ 2,339,981**	
	Contractor Profit	*10%*			*$ 233,998.06*	
		Subtotal:			**$ 2,573,979**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 2,573,979**	
	Bond and Insurance	*3%*			*$ 77,219.36*	
		Subtotal:			**$ 2,651,198**	
	Design Contingency	*35%*			*$ 927,919.29*	
		Subtotal:			**$ 3,579,117**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 3,580,000**	

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RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
1	*Recycled Water Storage Tank - 6 mgd*	*1*	*LS*	*$ 3,750,000*	*$ 3,750,000*	
		Subtotal:			**$ 3,750,000**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*10%*			$ 375,000	As percent of total cost. If not included in the unit cost above
	Site Civil	*10%*			$ 375,000	As percent of total cost. Including site preparation and improvements
	Structural	*5%*			$ 187,500	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*5%*			$ 187,500	As percent of total cost
	Instrumentation and Controls	*5%*			$ 187,500	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 506,250*	
		Subtotal:			**$ 5,568,750**	
	Escalation at 3.5% annually	*9%*			*$ 500,131*	
		Subtotal:			**$ 6,068,881**	
	Contractor Overhead	*10%*			*$ 606,888.06*	
		Subtotal:			**$ 6,675,769**	
	Contractor Profit	*10%*			*$ 667,576.87*	
		Subtotal:			**$ 7,343,346**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 7,343,346**	
	Bond and Insurance	*3%*			*$ 220,300.37*	
		Subtotal:			**$ 7,563,646**	
	Design Contingency	*35%*			*$ 2,647,276.08*	
		Subtotal:			**$ 10,210,922**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 10,211,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA, VSD

20050-002

Conceptual Level Estimate

Estimator:	*A. Briggs*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
1	*Evaporation Ponds*	*1*	*AC*	*$ 500,000*	*$ 500,000*	*Includes installation factor of 30%*
	Subtotal:				**$ 500,000**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	*5%*			$ 25,000	As percent of total cost. Including site preparation and improvements
	Structural	*5%*			$ 25,000	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*0%*			$ -	As percent of total cost
	Instrumentation and Controls	*0%*			$ -	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 55,000*	
	Subtotal:				**$ 605,000**	
	Escalation at 3.5% annually	*9%*			*$ 54,335*	
	Subtotal:				**$ 659,335**	
	Contractor Overhead	*10%*			*$ 65,933.52*	
	Subtotal:				**$ 725,269**	
	Contractor Profit	*10%*			*$ 72,526.87*	
	Subtotal:				**$ 797,796**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 797,796**	
	Bond and Insurance	*3%*			*$ 23,933.87*	
	Subtotal:				**$ 821,729**	
	Design Contingency	*35%*			*$ 287,605.30*	
	Subtotal:				**$ 1,109,335**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 1,110,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA/VSD

20050-002

ALTERNATIVE 2 - TERTIARY TREATMENT AND SPREADING AT VSD

Estimator:	*S. Valdez*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
	Spreading Basins	*580,800*	*CY*	*$ 5*	*$ 2,904,000*	
	24" Outfall piping to spreading basins	*600*	*LF*	*$ 345*	*$ 207,000*	
	24" Overflow to Stormwater Channel	*700*	*LF*	*$ 345*	*$ 241,500*	
	Subtotal:				**$ 3,352,500**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	*0%*			$ -	As percent of total cost. Including site preparation and improvements
	Structural	*0%*			$ -	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*0%*			$ -	As percent of total cost
	Instrumentation and Controls	*0%*			$ -	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 335,250*	
	Subtotal:				**$ 3,687,750**	
	Escalation at 3.5% annually	*9%*			*$ 331,198*	
	Subtotal:				**$ 4,018,948**	
	Contractor Overhead	*10%*			*$ 401,894.76*	
	Subtotal:				**$ 4,420,842**	
	Contractor Profit	*10%*			*$ 442,084.24*	
	Subtotal:				**$ 4,862,927**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 4,862,927**	
	Bond and Insurance	*3%*			*$ 145,887.80*	
	Subtotal:				**$ 5,008,814**	
	Design Contingency	*35%*			*$ 1,753,085.05*	
	Subtotal:				**$ 6,761,899**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 6,762,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA/VSD

20050-002

ALTERNATIVE 3 - TERTIARY TREATMENT, SERVE CUSTOMERS, AND SPREADING AT VSD

Estimator: *S. Valdez* *Date:* *3/23/2018*

Reviewer: *C. Portner* *Date:* *3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
	Spreading Basins	*580,800*	*CY*	*$ 5*	*$ 2,904,000*	
	24" Outfall piping to spreading basins	*600*	*LF*	*$ 345*	*$ 207,000*	
	24" Overflow to Stormwater Channel	*700*	*LF*	*$ 345*	*$ 241,500*	
	RW Distribution System	*1*	*EA*	*$ 40,986,161*	*$ 40,986,161*	*Per 2016 RW Feasibility Study.*
	Subtotal:				**$ 44,338,661**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	*0%*			$ -	As percent of total cost. Including site preparation and improvements
	Structural	*0%*			$ -	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*0%*			$ -	As percent of total cost
	Instrumentation and Controls	*0%*			$ -	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 4,433,866*	
	Subtotal:				**$ 48,772,527**	
	Escalation at 3.5% annually	*9%*			*$ 4,380,271*	
	Subtotal:				**$ 53,152,798**	
	Contractor Overhead	*10%*			*$ 5,315,279.81*	
	Subtotal:				**$ 58,468,078**	
	Contractor Profit	*10%*			*$ 5,846,807.79*	
	Subtotal:				**$ 64,314,886**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 64,314,886**	
	Bond and Insurance	*3%*			*$ 1,929,446.57*	
	Subtotal:				**$ 66,244,332**	
	Design Contingency	*35%*			*$ 23,185,516.31*	
	Subtotal:				**$ 89,429,849**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 89,430,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA/VSD

20050-002

ALTERNATIVE 4 - ADVANCED TREATMENT AND INJECTION AT VSD

Estimator:	*S. Valdez*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
	1.5 MGD Injection Well	*4*	*EA*	*$ 1,500,000*	*$ 6,000,000*	
	Backflush Pump	*4*	*EA*	*$ 100,000*	*$ 400,000*	
	Monitoring Well	*2*	*EA*	*$ 250,000*	*$ 500,000*	
	12" Injection Piping	*4800*	*LF*	*$ 165*	*$ 792,000*	
	16" Injection Piping	*5700*	*LF*	*$ 205*	*$ 1,168,500*	
	24" Overflow Piping	*2800*	*LF*	*$ 345*	*$ 966,000*	
	Low-head Injection Pump Station	*6*	*MGD*	*$ 100,000*	*$ 600,000*	
		Subtotal:			**$ 10,426,500**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	*0%*			$ -	As percent of total cost. Including site preparation and improvements
	Structural	*0%*			$ -	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*0%*			$ -	As percent of total cost
	Instrumentation and Controls	*0%*			$ -	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 1,042,650*	
		Subtotal:			**$ 11,469,150**	
	Escalation at 3.5% annually	*9%*			*$ 1,030,047*	
		Subtotal:			**$ 12,499,197**	
	Contractor Overhead	*10%*			*$ 1,249,919.68*	
		Subtotal:			**$ 13,749,117**	
	Contractor Profit	*10%*			*$ 1,374,911.65*	
		Subtotal:			**$ 15,124,028**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 15,124,028**	
	Bond and Insurance	*3%*			*$ 453,720.85*	
		Subtotal:			**$ 15,577,749**	
	Design Contingency	*35%*			*$ 5,452,212.15*	
		Subtotal:			**$ 21,029,961**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 21,030,000**	

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RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA/VSD

20050-002

ALTERNATIVE 5a - TERTIARY TREATMENT AND SPREADING AT POSSE PARK

Estimator:	*S. Valdez*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	
	30" Pipeline to Posse Park	*16,000*	*LF*	*$ 390*	*$ 6,240,000*	
	Spreading Basins	*580,800*	*CY*	*$ 5*	*$ 2,904,000*	
	RW Distribution System	*1*	*EA*	*$ 16,809,132*	*$ 16,809,132*	*Per 2016 RW Feasibility Study.*
	Subtotal:				**$ 25,953,132**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	*0%*			$ -	As percent of total cost. Including site preparation and improvements
	Structural	*0%*			$ -	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*0%*			$ -	As percent of total cost
	Instrumentation and Controls	*0%*			$ -	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 2,595,313*	
	Subtotal:				**$ 28,548,445**	
	Escalation at 3.5% annually	*9%*			*$ 2,563,942*	
	Subtotal:				**$ 31,112,387**	
	Contractor Overhead	*10%*			*$ 3,111,238.71*	
	Subtotal:				**$ 34,223,626**	
	Contractor Profit	*10%*			*$ 3,422,362.58*	
	Subtotal:				**$ 37,645,988**	
	Contract Allowances/Unit Price Items				*$ -*	
	Subtotal:				**$ 37,645,988**	
	Bond and Insurance	*3%*			*$ 1,129,379.65*	
	Subtotal:				**$ 38,775,368**	
	Design Contingency	*35%*			*$ 13,571,378.82*	
	Subtotal:				**$ 52,346,747**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 52,347,000**	

RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA/VSD

20050-002

ALTERNATIVE 5b - ADVANCED TREATMENT AND INJECTION AT POSSE PARK

Estimator:	*S. Valdez*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
	30" Pipeline to Posse Park	*16,000*	*LF*	*$ 390*	*$ 6,240,000*	
	1.5 MGD Injection Well	*3*	*EA*	*$ 1,500,000*	*$ 4,500,000*	*Total of 4.5 MGD injection*
	Backflush Pump	*3*	*EA*	*$ 100,000*	*$ 300,000*	*Total of 4.5 MGD injection*
	Monitoring Well	*2*	*EA*	*$ 250,000*	*$ 500,000*	
	12" Injection Piping	*3,600*	*LF*	*$ 165*	*$ 594,000*	
	16" Injection Piping	*4,275*	*LF*	*$ 205*	*$ 876,375*	
	30" Overflow Piping	*2,800*	*LF*	*$ 345*	*$ 966,000*	
	Low-head Injection Pump Station	*4.5*	*MGD*	*$ 100,000*	*$ 450,000*	
	RW Distribution System	*1*	*EA*	*$ 16,809,132*	*$ 16,809,132*	*Per 2016 RW Feasibility Study.*
		Subtotal:			**$ 31,235,507**	
	Other Indirect Factors:					
	Equipment Installation Cost	0%			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	0%			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	0%			$ -	As percent of total cost. Including site preparation and improvements
	Structural	0%			$ -	As percent of total cost
	HVAC/Plumbing	0%			$ -	As percent of total cost
	Electrical	0%			$ -	As percent of total cost
	Instrumentation and Controls	0%			$ -	As percent of total cost
	General Conditions (Div01)	10%			*$ 3,123,551*	
		Subtotal:			**$ 34,359,058**	
	Escalation at 3.5% annually	9%			*$ 3,085,794*	
		Subtotal:			**$ 37,444,852**	
	Contractor Overhead	10%			*$ 3,744,485.20*	
		Subtotal:			**$ 41,189,337**	
	Contractor Profit	10%			*$ 4,118,933.72*	
		Subtotal:			**$ 45,308,271**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 45,308,271**	
	Bond and Insurance	3%			*$ 1,359,248.13*	
		Subtotal:			**$ 46,667,519**	
	Design Contingency	35%			*$ 16,333,631.66*	
		Subtotal:			**$ 63,001,151**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 63,002,000**	

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RECYCLED WATER PROGRAM DEVELOPMENT FEASIBILITY STUDY

IWA/VSD

20050-002

ALTERNATIVE 6 - TERTIARY TREATMENT AND SERVE CUSTOMERS

Estimator:	*S. Valdez*	*Date:*	*3/23/2018*
Reviewer:	*C. Portner*	*Date:*	*3/23/2018*

#	Description	QTY	UNIT	UNIT COST	TOTAL COST	NOTES
	RW Distribution System	*1*	*EA*	*$ 40,986,161*	*$ 40,986,161*	*Per 2016 RW Feasibility Study.*
		Subtotal:			**$ 40,986,161**	
	Other Indirect Factors:					
	Equipment Installation Cost	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Process Mechanical (Piping, Valves, Appurtenances, etc)	*0%*			$ -	As percent of total cost. If not included in the unit cost above
	Site Civil	*0%*			$ -	As percent of total cost. Including site preparation and improvements
	Structural	*0%*			$ -	As percent of total cost
	HVAC/Plumbing	*0%*			$ -	As percent of total cost
	Electrical	*0%*			$ -	As percent of total cost
	Instrumentation and Controls	*0%*			$ -	As percent of total cost
	General Conditions (Div01)	*10%*			*$ 4,098,616*	
		Subtotal:			**$ 45,084,777**	
	Escalation at 3.5% annually	*9%*			*$ 4,049,074*	
		Subtotal:			**$ 49,133,851**	
	Contractor Overhead	*10%*			*$ 4,913,385.05*	
		Subtotal:			**$ 54,047,236**	
	Contractor Profit	*10%*			*$ 5,404,723.56*	
		Subtotal:			**$ 59,451,959**	
	Contract Allowances/Unit Price Items				*$ -*	
		Subtotal:			**$ 59,451,959**	
	Bond and Insurance	*3%*			*$ 1,783,558.77*	
		Subtotal:			**$ 61,235,518**	
	Design Contingency	*35%*			*$ 21,432,431.26*	
		Subtotal:			**$ 82,667,949**	
	TOTAL PROBABLE CONSTRUCTION COST:				**$ 82,668,000**	

O&M Categories	**Factor**
Pump Station / Treatment Plant O&M	2%
Non-plant infrastructure O&M	0.5%

Alternative 2 – Surface Spreading at VSD WRF	
Tertiary Treatment Capital Cost ($)	37,019,000
Treatment Plant O&M	*740,380*
Remaining Non-plant Capital Cost ($)	6,762,000
Non-Plant O&M	*33,810*
Power	
Tertiary Process Pump HP	50
Tertiary Process Pump Runtime per day (hrs)	24
Tertiary Process Pump kWh/yr	326,617
Number of Chemical Pumps	2
Chemical Feed Pump HP	0.5
Chemical Feed Pump Runtime per day (hrs)	24
Chemical Feed Pump kWh/yr	6,532
Electricity Cost ($/kWh)	0.1141
Total Electricity Cost ($/yr)	38,012
Chemical	
NaOCl (gal/yr)	187,667
NaOCl Cost ($/gal)	2.26
PACl (lb/yr)	365,292
PACl Cost ($/lb)	0.33
Polymer (gal/yr)	
Polymer Cost ($/gal)	
Total Chemical Cost ($/yr)	544,674
Labor	
No. of FTE	3
Annual Salary ($/yr/FTE)	104800
Total Labor Cost ($/yr)	314,400
TOTAL	**1,671,276**

Alternative 3 – Deliver to Recycled Water Customers and Surface Spreading at VSD WRF

Tertiary Treatment Capital Cost ($)	37,019,000
Treatment Plant O&M	*740,380*
Remaining Non-plant Capital Cost ($)	89,430,000
Non-Plant O&M	*447,150*
Power	
Tertiary Process Pump HP	50
Tertiary Process Pump Runtime per day (hrs)	24
Number of Chemical Pumps	2
Chemical Feed Pump HP	0.5
Chemical Feed Pump Runtime per day (hrs)	24
Chemical Feed Pump kWh/yr	6,532
RW Pump Station Total HP	1,850
RW Pump Station Runtime per day (hrs)	8
Total Pump kWh/yr	4,361,420
Electricity Cost ($/kWh)	0.1141
Total Electricity Cost ($/yr)	497,638
Chemical	
NaOCl (gal/yr)	187,667
NaOCl Cost ($/gal)	2.26
PACl (lb/yr)	365,292
PACl Cost ($/lb)	0.33
Polymer (gal/yr)	
Polymer Cost ($/gal)	
Total Chemical Cost ($/yr)	544,674
Labor	
No. of FTE	5
Annual Salary ($/yr/FTE)	104800
Total Labor Cost ($/yr)	524,000
Consumables	
Filtration Media - Sand (ton./yr)	3.33
Sand Cost ($/ton)	300
Total Consumable Cost ($/yr)	999
TOTAL	**2,754,841**

Alternative 4 – Groundwater Injection at VSD WRF

Advanced Treatment Capital Cost ($)	48,221,000
Treatment Plant O&M	*964,420*
Remaining Non-plant Capital Cost ($)	21,030,000
Non-Plant O&M	*105,150*
Power	
Advanced Process MF/RO (kWh/yr)	12,179,320
UV (kWh/yr)	630,720
Low-head Injection Pump HP	60
Low-head Injection Pump Runtime per day (hrs)	23.95
Backflush Pump HP	100
Backflush Pump Runtime per day (hrs)	0.05
Total Energy (kWh/yr)	13,202,524
Electricity Cost ($/kWh)	0.1141
Total Electricity Cost ($/yr)	1,506,408
Chemical	
NaOCl (gal/yr)	187,667
NaOCl Cost ($/gal)	2.26
PACl (lb/yr)	365,292
PACl Cost ($/lb)	0.33
Citric Acid (gal/yr)	3,551
Citric Acid Cost ($/gal)	4.53
Anti-scalant (gal/yr)	9,137
Anti-scalant Cost ($/gal)	10
H2SO4 (lb/yr)	12
H2SO4 Cost ($/lb)	0.50
Hydrogen peroxide (gal/yr)	36,670
Hydrogen peroxide Cost ($/gal)	3.78
Lime (gal/yr)	374,853
Lime Cost ($/gal)	0.51
Total Chemical Cost ($/yr)	981,925
Consumables	
Filtration Media - Sand (ton./yr)	3.33
Sand Cost ($/ton)	300
Strainers (no./yr)	2
Strainer Cost ($/ea)	2,000
Microfilters (no./yr)	69
Microfilters Cost ($/ea)	800
RO Membranes (no./yr)	202
RO Membranes Cost ($/ea)	500
UV Lamps (no./yr)	206
UV Lamp Cost ($/ea)	352
Total Consumable Cost ($/yr)	233,711
Evaporation Ponds	
Evaporation Ponds OM ($/yr)	809,303
TOTAL	**4,600,917**

Alternative 5a – Deliver to Recycled Water Customers then Surface Spreading at Posse Park

Tertiary Treatment Capital Cost ($)	37,019,000
Treatment Plant O&M	*740,380*
Remaining Non-plant Capital Cost ($)	52,347,000
Non-Plant O&M	*261,735*
Power	
Tertiary Process Pump HP	50
Tertiary Process Pump Runtime per day (hrs)	24
Number of Chemical Pumps	2
Chemical Feed Pump HP	0.5
Chemical Feed Pump Runtime per day (hrs)	24
Chemical Feed Pump kWh/yr	6,532
RW Pump Station Total HP	650
RW Pump Station Runtime per day (hrs)	8
Total Pump kWh/yr	1,748,488
Electricity Cost ($/kWh)	0.1141
Electricity Cost ($/yr)	199,502
Chemical	
NaOCl (gal/yr)	187,667
NaOCl Cost ($/gal)	2.26
PACl (lb/yr)	365,292
PACl Cost ($/lb)	0.33
Polymer (gal/yr)	
Polymer Cost ($/gal)	
Total Chemical Cost ($/yr)	544,674
Labor	
No. of FTE	5
Annual Salary ($/yr/FTE)	104800
Total Labor Cost ($/yr)	524,000
Consumables	
Filtration Media - Sand (ton./yr)	3.33
Sand Cost ($/ton)	300
Total Consumable Cost ($/yr)	999
TOTAL	**2,271,290**

Alternative 5b – Deliver to Recycled Water Customers then Groundwater Injection at Posse Park

Advanced Treatment Capital Cost ($)	80,211,207
Treatment Plant O&M	*1,604,224*
Remaining Non-plant Capital Cost ($)	63,002,000
Treatment Plant O&M	*315,010*
Power	
Advanced Process MF/RO (kWh/yr)	6,089,660
UV (kWh/yr)	315,360
RW Pump Station Total HP	650
RW Pump Station Runtime per day (hrs)	8
Low-head Injection Pump HP	60
Low-head Injection Pump Runtime per day (hrs)	23.95
Backflush Pump HP	100
Backflush Pump Runtime per day (hrs)	0.05
Total Energy (kWh/yr)	6,584,046
Electricity Cost ($/kWh)	0.1141
Electricity Cost ($/yr)	751,240
Chemical	
NaOCl (gal/yr)	93,834
NaOCl Cost ($/gal)	2.26
PACl (lb/yr)	182,646
PACl Cost ($/lb)	0.33
Citric Acid (gal/yr)	1,776
Citric Acid Cost ($/gal)	4.53
Anti-scalant (gal/yr)	4,569
Anti-scalant Cost ($/gal)	12.00
H2SO4 (lb/yr)	6
H2SO4 Cost ($/lb)	0.50
Hydrogen peroxide (gal/yr)	18,335
Hydrogen peroxide Cost ($/gal)	3.78
Lime (gal/yr)	187,427
Lime Cost ($/gal)	0.51
Total Chemical Cost ($/yr)	500,100
Consumables	
Filtration Media - Sand (ton./yr)	1.67
Sand Cost ($/ton)	300
Strainers (no./yr)	1
Strainer Cost ($/ea)	2,000
Microfilters (no./yr)	35
Microfilters Cost ($/ea)	800
RO Membranes (no./yr)	101
RO Membranes Cost ($/ea)	500
UV Lamps (no./yr)	103
UV Lamp Cost ($/ea)	352
Total Consumable Cost ($/yr)	117,257
Labor	
No. of FTE	5
Annual Salary ($/yr/FTE)	104800
Total Labor Cost ($/yr)	524,000
Evaporation Ponds	
Evaporation Ponds OM ($/yr)	404,652
TOTAL	**4,216,482**

Alternative 6 – Deliver to Recycled Water Customers and Excess to CVSC

Tertiary Treatment Capital Cost ($)	37,019,000
Treatment Plant O&M	*740,380*
Remaining Non-plant Capital Cost ($)	82,668,000
Treatment Plant O&M	*413,340*
Power	
Tertiary Process Pump HP	50
Tertiary Process Pump Runtime per day (hrs)	24
Number of Chemical Pumps	2
Chemical Feed Pump HP	0.5
Chemical Feed Pump Runtime per day (hrs)	24
Chemical Feed Pump kWh/yr	6,532
RW Pump Station Total HP	1,850
RW Pump Station Runtime per day (hrs)	8
Total Pump kWh/yr	4,361,420
Electricity Cost ($/kWh)	0.1141
Electricity Cost ($/yr)	497,638
Chemical	
NaOCl (gal/yr)	187,667
NaOCl Cost ($/gal)	2.26
PACl (lb/yr)	365,292
PACl Cost ($/lb)	0.33
Polymer (gal/yr)	
Polymer Cost ($/gal)	
Total Chemical Cost ($/yr)	544,674
Labor	
No. of FTE	4
Annual Salary ($/yr/FTE)	104800
Total Labor Cost ($/yr)	419,200
Consumables	
Filtration Media - Sand (ton./yr)	3.33
Sand Cost ($/ton)	300
Total Consumable Cost ($/yr)	999
TOTAL	**2,616,231**

Appendix D: Pilot Study Protocol

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Recycled Water Program Development Feasibility Study

Pilot Test Protocol

October 2017

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List of Acronyms

Abbreviation	Definition
BOD	Biological Oxygen Demand
°C	Degrees Celsius
CWA	Coachella Water Authority
CSD	Coachella Sanitation District
FEEM	Fluorescence Excitation Emissions Matrix
IRWM	Integrated Regional Water Management
IWA	Indio Water Authority
MF	Microfiltration
MSWD	Mission Springs Water District
NaOCl	Sodium Chloride
NAOH	Sodium Hypochlorite
PSI	Pounds per square inch, lb/in^2
PVDF	Polyvinylidene Fluoride
RO	Reverse Osmosis
TM	Technical Memorandum
TSS	Total Suspended Solids
UF	Ultrafiltration
VSD	Valley Sanitation District
WWTP	Wastewater Treatment Plant

1. Introduction

As severe droughts in California continue and imported and local groundwater supplies are becoming taxed, water utilities are seeking alternative water supplies to meet growing water demands. Recycled water is a significant local resource that, depending on the level of treatment, may be utilized for landscape irrigation, industrial applications, and strengthening groundwater recharge.

Coachella Water Authority (CWA) / Coachella Sanitation District (CSD), Mission Springs Water District (MSWD), and Indio Water Authority (IWA) / Valley Sanitary District (VSD) collectively received a Proposition 84, Integrated Regional Water Management (IRWM) Grant to complete a recycled water study to evaluate the use of recycled water throughout the Coachella Valley. One component of the grant requirement was to complete a pilot study at the Coachella Sanitation District's wastewater treatment. Presented in the following pages is the project background, goals and objectives, operating procedures, safety and data collection.

1.1 Project Background

The project scope for the Recycled Water Feasibility Study included identifying distribution system requirements (transmission mains, pumping and storage), a broad hydrogeologic analysis to identify opportunities for groundwater spreading and/or injection at the most effective locations within the participating agencies service areas, evaluating water quality to determine the appropriate treatment technology(ies) for each identified recycled water use and, based on the water quality evaluation and recycled water use, a pilot study to determine the effectiveness of the identified technology to meet Title 22 Regulations. A summary report was prepared that identified and evaluated regional alternatives and individual technical memoranda were completed for IWA/VSD, MSWD and CWA/CSD, TM-1, TM-2, and TM-3 respectively that identified the alternatives for each participating agency. The primary recycled water applications that were evaluated included landscape irrigation and groundwater replenishment via spreading and/or injection.

At the time of this writing, there are three active wastewater treatment plants (WWTP) as part of the Recycled Water Feasibility Study in which wastewater could be produced for reuse. These WWTP's include Avenue 54 WWTP managed by the Coachella Sanitary District, Valley Sanitary District Water Reclamation Facility, and Horton Wastewater Treatment Plant owned and operated by Mission Springs Water District.

This pilot intends to verify the performance of an ultrafiltration membrane (UF) as a pretreatment to reverse osmosis treatment. This document outlines the requirements and objectives for the proposed pilot tests.

1.2 Goals and Objectives

The bench scale pilot test will verify filter parameters and filter performance on the respective wastewater effluent. This testing will provide a comparison of filter performance to compare the fouling characteristics of the different wastewater processes used at the three different wastewater treatment plants. The following are the main objectives of the membrane bench scale pilot testing including:

A. Filterability – Test to verify the filterability of the effluent from the respective WWTP by PVDF membrane.

B. Permeability – As part of filterability, parameters will be measured to calculate permeability to show the true fouling of the respective effluent on the membrane.

C. Fluorescence Excitation Emissions Matrix (FEEMs) as a means of comparing/correlating fouling propensity of the respective wastewater process and the effective removal of the membranes before and after filtration.

D. Temperature, pH, Conductivity, BOD, TSS, Particle Size, Turbidity before and after filtration to verify differences in the wastewater effluents and as a function of filtration.

1.3 Test Approach

This document summarizes the test approach and delineates the responsibilities of each party. The City of Coachella has retained Hazen and Sawyer (Hazen) to serve as the pilot test engineer during this study. Hazen has purchased and will provide the bench scale pilot system, Toray Industries, Inc. (HFU-LAB 018). Tama Snow is the Project Manager for the Recycled Water Feasibility Study and will be responsible for coordinating with CWA and Hazen Staff operating the pilot and collecting the data.

2. Wastewater Quality Sampling and Membrane Filtration Protocol

Described below are the procedures for collecting wastewater samples, procedures to operate a bench scale, ultrafiltration (UF) membrane system as well as collecting the operational data from the pilot.

2.1 Equipment and Supplies

The additional equipment/supplies and responsible party to provide are listed in Table 2-1 below:

Table 2-1: Equipment and Supplies

Equipment/Supplies	Responsible Party	Notes
Chlorine in the form of NaOCl (1000 ppm)	Hazen	Utilized for cleaning following final testing at each WWTP location
Hydrochloric Acid	Hazen	Utilized for cleaning following final testing at each WWTP location (if required)
Gloves	Hazen	
Safety Goggles	Hazen	
Lab Coats	Hazen	
Filter Screen (1/64")	Hazen	Used for filtering the effluent prior to the filter testing
Sample Bucket	Hazen	
Handheld Conductivity/pH Meter	Hazen	Rented from Pine Environmental
Handheld Turbidity Analyzer	Hazen	Provided by each agency
Access to potable water	Owner	Used to operate pilot to establish baseline; Used to clean equipment following operating pilot at each WWTP
Access to 120V electrical supply	Owner	Needed to operate pilot
Glycerin	Hazen	Fill UF membrane following testing to protect membrane
Ice Chests (6)	Hazen	For shipping samples to labs
Ice Packs	Hazen	To preserve samples shipped to labs
Sterilized Glass Sample Bottles (50 mL for FEEM's)	Hazen	For BOD, TSS, Turbidity, particle size and FEEM's Testing

2.2 Testing Schedule

Testing will begin the week of **October 16, 2017**. The schedule will be as follows:

- CSD – October 16, 2017
- VSD – October 17, 2017
- MSWD – October 18, 2017

2.3 Sampling Location

A secondary effluent wastewater sample (secondary effluent) shall be collected by the Owner's operator in a clean, five-gallon bucket.

2.4 Testing Protocol

Described below is the testing protocol to collect samples for the wastewater quality analyses, FEEM's testing and operating the bench scale UF filtration system and the data collection and sampling procedures.

2.4.1 Effluent and Filtrate Quality Testing

a) Raw Effluent - BOD, TSS, Turbidity, Particle Size **-** One sample of each of the secondary effluent (feed) shall be placed in a 500 mL plastic bottles provided by each agency and immediately placed on ice in a cooler. Bottles shall be labeled with the following information:

Name of WWTP
Sample ID: Raw Water
Date, Time of Sampling
Sampled By:
Type of Water: Secondary effluent

Note: These tests will be run in the Laboratory selected by CWA/CSD

b) Filtered Effluent **-** BOD, TSS, Turbidity, Particle Size **-** One sample of each of the secondary effluent (feed) shall be placed in a 500 mL plastic bottles provided by each agency and immediately placed on ice in a cooler and immediately placed on ice in cooler. Bottles shall be labeled with the following information:

Name of WWTP
Sample ID: UF Filtrate
Date, Time of Sampling
Type of Water: Filtered Secondary effluent

Note: These tests will be run in the Laboratory selected by CWA/CSD

2.4.2 Effluent and Filtrate FEEM Testing

a) Raw Effluent - FEEM – One sample of each secondary effluent (feed) shall be placed in 25 mL amber glass bottle(s) and immediately placed on ice in cooler. Bottles shall be labeled with the following information:

Name of WWTP
Sample ID: Raw Water
Date, Time of Sampling
Sampled By:
Type of Water: Secondary effluent

Note: These tests will be run in Hazen's Lab in Florida

b) Filtered Effluent - FEEM – One sample of each secondary effluent (feed) shall be placed in 25 mL amber glass bottle(s) and immediately placed on ice in cooler. Bottles shall be labeled with the following information:

Name of WWTP
Sample ID: Raw Water
Date, Time of Sampling
Sampled By:
Type of Water:

Note: These tests will be run in Hazen's Lab in Florida

2.4.3 Permeability

a) Clean Water Filtration Test – This is a test to measure the base line permeability of the membrane under a controlled water quality. Utilizing clean water (tap water) and operating the pilot at constant flow and pressure (P_2), record temperature (T) and filtrate pressure (P_1).

Table 2-2: Baseline Permeability

Flow (gpm)	Flux (gfd)	Pressure (Feed)	Pressure (Filtrate)	TMP	Permeability (GFD/PSI)
Calc	20				
Calc.	30				
Calc.	40				
Calc.	50				

Note: Need temperature. Area of the membrane module is 0.18 m^2. Each flow test shall be run for 3-5 minutes or until flow is stable.

b) Wastewater Test – Utilizing secondary effluent and operating the pilot at constant flow, record feed pressure (P_2) and filtrate pressure (P_1) at the time intervals on **Table 2-2.**

Note:

1. After each 30 minute run, the membrane shall be removed and filled half way with tap water and shaken for 1 minute and 30 seconds. This is to mimic a backwash cycle. The filter element is to be reinstalled and then operated again. This procedure shall be repeated after each 30 minute run.

2. Near the completion of the third 30 minute run cycle, collect two filtrate samples (50 mL each) for the BOD, TSS, turbidity, Particle Size and FEEM's testing. Label bottles as follows:

   Name of WWTP
   Date, Time
   Sample ID

   Note: Filtrate sample for BOD, TSS, turbidity, Particle Size analyses to go to laboratory selected by CWA/CSD; Filtrate sample for FEEM's testing to go to Hazen's Laboratory in Florida.

3. Following the third 30 minute run cycle and the last hand backwash, the UF membrane shall be cleaned with a 1,000 ppm chlorine solution. The procedure is to fill the module half way with the solution and then shake it for 1 minute 30 seconds. Fill the membrane casing with chlorine and set it aside for 15 minutes. Shake again and set aside in solution for another 30 mins. At the end of the second soak cycle drain it and fill half way with clean potable water and shake it. Repeat until all chlorine is removed.

4. Follow the same procedure with hydrochloric acid. At the completion of the flushing the module will be ready for final post filter Clean Water Flux Testing.

c) Post Filter Test - Clean Water Filtration Test –Following the cleaning as noted above, clean water test describe in item (a) above will be repeated. This test is performed to confirm cleaning and to make sure the permeability following cleaning is the same or returned to similar permeability as the new membrane. If permeability is not restored, the cleaning procedure should be repeated as noted above.

Note that these procedures shall be repeated at each of the three WWTP's.

Table 2-3: Membrane Filtration Data Sheet

Water Quality (CW, WW)/Test No.	**Time** (mins)	**Flow** (gpm)	**Feed Pressure P_1** Psi	**Filtrate Pressure P_2** psi	**Temp** °C
CW 1 - Baseline	0				
	1				
	2				
	3				
	4				
	5				
	10				
	15				
	20				
	25				
	30				
WW 1	0				
	1				
	2				
	3				
	4				
	5				
	10				
	15				
	20				
	25				
	30				
WW 2	0				
	1				
	2				
	3				
	4				
	5				
	10				
	15				
	20				
	25				
	30				
WW 3	0				
	1				
	2				
	3				
	4				

Table 2-3: Membrane Filtration Data Sheet

	5				
	10				
	15				
	20				
	25				
	30				
CW 2	0				
	1				
	2				
	3				
	4				
	5				
	10				
	15				
	20				
	25				
	30				

Note: test should be performed to maintain a constant flux rate (i.e. 30 gfd)

3. Final Reporting

Upon receipt of the wastewater quality lab results and the FEEM results, the data will be analyzed and a summary will be incorporated into TM-1, TM-2 and TM-3 and the Regional Report.

Appendix E: Pilot Study Raw Data

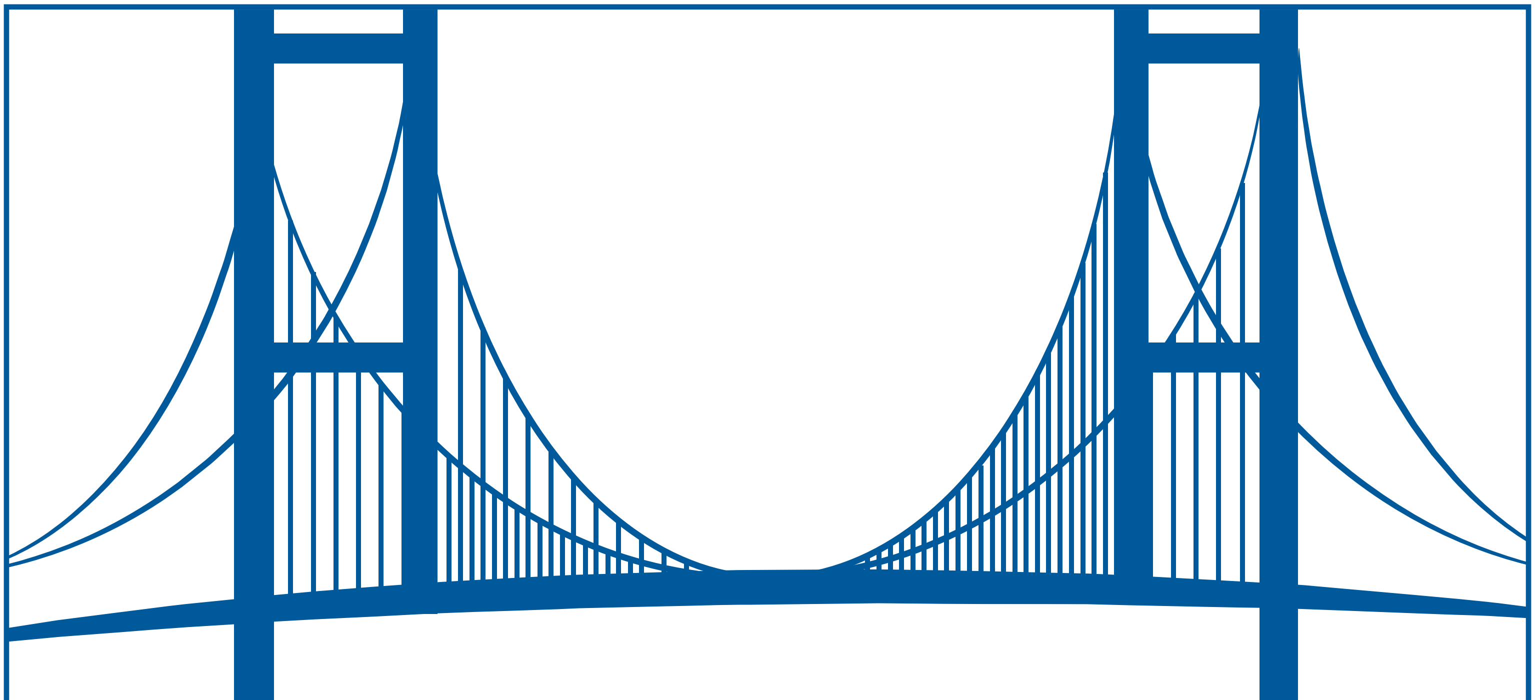
Valley Sanitation District		
Water Quality	**Amount**	**Unit**
Raw Secondary Effluent		
Conductivity	842	uS/cm
Temperature	29.5	degC
pH	7.65	unit
Turbidity	2.2	NTU
Filtrate		
Conductivity	859	uS/cm
Temperature	30.5	degC
pH	7.7	unit
Turbidity	0.15	NTU

Lab WQ Results		
Valley Sanitation District		
Water Quality	**Amount**	**Unit**
Raw Secondary Effluent		
Total Suspended Solids	2	mg/L
BOD	ND	mg/L
Filtrate		
Total Suspended Solids	ND	mg/L
BOD	ND	mg/L

VALLEY SANITATION DISTRICT

Membrane Area =	*0.18*	*m^2*	=	*1.937504*	*ft^2*							
	Time (min)	**Time (min)**	**Flow (GPH)**	**Feed Pressure (psi)**	**Filtrate Pressure (psi)**	**Temp (degC)**	**Differential Pressure (psi)**	**Flux (gpd/sq ft) or gfd**	**Dynamic Viscosity of Water (Pa*s)**	**Temperature Correction Factor to 20°C**	**Flux (gpd/sq ft) or gfd at 20°C**	**Specific Flux at 20°C (gfd/psi)**
	0	0	-	-	-	-	-	-	-	-	-	-
	1	1	4.4	2.5	0.5	27.9	2.0	45.5	8.37E-04	8.36E-01	38.0	19.0
	2	2	-	-	-	-	-	-	-	-	-	-
	3	3	4.0	2.0	0.5	28.2	1.5	49.5	8.32E-04	8.30E-01	41.1	27.4
	4	4	4.0	2.0	0.5	28.2	1.5	49.5	8.32E-04	8.30E-01	41.1	27.4
CW 1 - BASELINE	5	5	4.0	2.0	0.5	28.3	1.5	49.5	8.30E-04	8.28E-01	41.0	27.4
	10	10	4.0	2.0	0.5	27.9	1.5	49.5	8.37E-04	8.36E-01	41.4	27.6
	15	15	4.2	2.0	0.5	27.9	1.5	52.0	8.37E-04	8.36E-01	43.5	29.0
	20	20	4.0	2.0	0.5	27.8	1.5	49.5	8.39E-04	8.37E-01	41.5	27.7
	25	25	4.0	2.0	0.5	27.7	1.5	49.5	8.41E-04	8.39E-01	41.6	27.7
	30	30	4.0	2.0	0.5	27.7	1.5	49.5	8.41E-04	8.39E-01	41.6	27.7
	0	0	4.0	7.0	1.0	29.8	6.0	49.5	8.03E-04	8.02E-01	39.7	6.6
	1	1	4.0	7.0	1.0	29.8	6.0	49.5	8.03E-04	8.02E-01	39.7	6.6
	2	2	4.0	8.0	1.0	29.8	7.0	49.5	8.03E-04	8.02E-01	39.7	5.7
	3	3	4.0	8.5	1.0	29.8	7.5	49.5	8.03E-04	8.02E-01	39.7	5.3
	4	4	4.0	9.0	1.0	29.8	8.0	49.5	8.03E-04	8.02E-01	39.7	5.0
WW 1	5	5	4.0	10.0	1.0	29.8	9.0	49.5	8.03E-04	8.02E-01	39.7	4.4
	10	10	4.0	12.0	1.0	29.7	11.0	49.5	8.05E-04	8.03E-01	39.8	3.6
	15	15	4.0	14.5	1.0	29.7	13.5	49.5	8.05E-04	8.03E-01	39.8	2.9
	20	20	4.0	16.0	1.0	29.5	15.0	49.5	8.08E-04	8.07E-01	40.0	2.7
	25	25	3.8	17.5	1.0	29.5	16.5	47.1	8.08E-04	8.07E-01	38.0	2.3
	30	30	3.8	19.5	1.0	30.0	18.5	47.1	8.00E-04	7.98E-01	37.6	2.0
	0		4.0	12.0	1.0	30.1	11.0	49.5	7.98E-04	7.96E-01	39.5	3.6
	1	31	4.0	12.0	1.0	30.1	11.0	49.5	7.98E-04	7.96E-01	39.5	3.6
	2	32	4.0	12	1	30.1	11.0	49.5	7.98E-04	7.96E-01	39.5	3.6
	3	33	4.0	14.0	1.0	30.0	13.0	49.5	8.00E-04	7.98E-01	39.5	3.0
	4	34	4.0	14.0	1.0	30.0	13.0	49.5	8.00E-04	7.98E-01	39.5	3.0
WW2	5	35	4.0	15.0	1.0	30.0	14.0	49.5	8.00E-04	7.98E-01	39.5	2.8
	10	40	4.0	17.5	1.0	30.0	16.5	49.5	8.00E-04	7.98E-01	39.5	2.4
	15	45	4.0	20.0	1.0	30.0	19.0	49.5	8.00E-04	7.98E-01	39.5	2.1
	20	50	4.0	21.0	1.0	30.0	20.0	49.5	8.00E-04	7.98E-01	39.5	2.0
	25	55	4.0	23.5	1.0	30.3	22.5	49.5	7.95E-04	7.93E-01	39.3	1.7
	30	60	4.0	23.0	1.0	30.4	22.0	49.5	7.93E-04	7.91E-01	39.2	1.8
	0		4.0	15.0	1.0	30.3	14.0	49.5	7.95E-04	7.93E-01	39.3	2.8
	1	61	4.0	15.0	1.0	30.3	14.0	49.5	7.95E-04	7.93E-01	39.3	2.8
	2	62	4.0	15.0	1.0	30.3	14.0	49.5	7.95E-04	7.93E-01	39.3	2.8
	3	63	4.0	16.0	1.0	30.3	15.0	49.5	7.95E-04	7.93E-01	39.3	2.6
	4	64	4.0	17.5	1.0	30.3	16.5	49.5	7.95E-04	7.93E-01	39.3	2.4
WW3	5	65	4.0	19.0	1.0	30.2	18.0	49.5	7.96E-04	7.95E-01	39.4	2.2
	10	70	4.0	19.0	1.0	30.2	18.0	49.5	7.96E-04	7.95E-01	39.4	2.2
	15	75	4.0	23.0	1.0	30.0	22.0	49.5	8.00E-04	7.98E-01	39.5	1.8
	20	80	4.0	25.0	1.0	30.0	24.0	49.5	8.00E-04	7.98E-01	39.5	1.6
	25	85	4.0	25.5	1.0	29.9	24.5	49.5	8.02E-04	8.00E-01	39.6	1.6
	30	90	4.0	26.5	1.0	29.7	25.5	49.5	8.05E-04	8.03E-01	39.8	1.6
	0	0	4.0	14.0	1.0	31.2	13.0	49.5	7.80E-04	7.78E-01	38.6	3.0
	1	1	4.0	14.0	1.0	31.1	13.0	49.5	7.81E-04	7.80E-01	38.6	3.0
	2	2	4.0	15.0	1.0	31.1	14.0	49.5	7.81E-04	7.80E-01	38.6	2.8
	3	3	4.0	15.0	1.0	31.1	14.0	49.5	7.81E-04	7.80E-01	38.6	2.8
	4	4	4.0	15.0	1.0	31.1	14.0	49.5	7.81E-04	7.80E-01	38.6	2.8
CW 2 - BASELINE	5	5	4.0	15.0	1.0	31.0	14.0	49.5	7.83E-04	7.81E-01	38.7	2.8
	10	10	4.0	14.5	1.0	31.0	13.5	49.5	7.83E-04	7.81E-01	38.7	2.9
	15	15	4.0	14.5	1.0	30.9	13.5	49.5	7.85E-04	7.83E-01	38.8	2.9
	20	20	4.0	14.5	1.0	30.8	13.5	49.5	7.86E-04	7.85E-01	38.9	2.9
	25	25	4.0	14.5	1.0	30.7	13.5	49.5	7.88E-04	7.86E-01	39.0	2.9
	30	30	-	-	-	-						

Appendix F: Private Financing



EXPANDING THE MARKET FOR INFRASTRUCTURE PUBLIC-PRIVATE PARTNERSHIPS

ALTERNATIVE RISK AND PROFIT SHARING APPROACHES TO ALIGN SPONSOR AND INVESTOR INTERESTS

THE DEPARTMENT OF THE TREASURY
1789

U.S. DEPARTMENT OF THE TREASURY
Office of Economic Policy
April 2015

EXPANDING THE MARKET FOR INFRASTRUCTURE PUBLIC-PRIVATE PARTNERSHIPS: ALTERNATIVE RISK AND PROFIT SHARING APPROACHES TO ALIGN SPONSOR AND INVESTOR INTERESTS

U.S. DEPARTMENT OF THE TREASURY
Office of Economic Policy
April 2015

Abstract

Realizing the potential taxpayer benefits of public-private partnerships (PPPs) in infrastructure investment, including higher quality per dollar and faster project delivery, depends on allocating project risks to the party best able to manage them. Arguably, demand risk is the most important source of uncertainty affecting an infrastructure project's financial viability, particularly in the case of new build, or "greenfield" projects in which the private partner's compensation is determined by user volume, but for which no history of use exists. PPPs have typically used the basic user fee or availability payments models to allocate all demand risk and (therefore revenue risk) to either the private partner or the government, limiting the number of PPP deals that investors and project sponsors may find attractive. However, recent deals have migrated away from the basic user fee arrangement after several prominent PPPs using it encountered financial difficulty.

This paper presents three alternative incentive structures for PPP contracts that can potentially benefit both public sector sponsors, by delivering higher quality per dollar, and private investors, by generating attractive returns. The rate of return model, price cap model, and "sharing" model all apply principles from the regulation of privately-owned energy and telecom infrastructure to PPP projects that generate user fees. In addition, these alternative risk- and profit-sharing approaches may create choices that are attractive to investors and sponsors with risk preferences and return expectations not accommodated by more commonly used models. By expanding the options for sponsors and investors to consider in PPP negotiations, these incentive structures have the potential to increase the number of PPP deals and improve the odds of the projects' long-term success.

I. Introduction

Infrastructure investment is critical to America's continued economic success.[1] Our nation must modernize and maintain our roads, bridges, and water systems to help ensure that the United States remains a place for businesses to operate productively and grow, which will, in turn, create economic opportunity for Americans. Yet years of underinvestment in our public infrastructure have imposed massive costs on our economy. Drivers in the United States annually spend 5.5 billion hours in traffic resulting in costs of $120 billion in fuel and lost time.[2] U.S. businesses pay $27 billion in additional freight costs because of the poor conditions of roads and other transportation infrastructure.[3] Due to continuing deterioration of water systems throughout the United States, each year there are approximately 240,000 water main breaks resulting in property damage and repairs.[4] Despite the high costs imposed by insufficient or decrepit infrastructure, outlays for both capital investment and operations and maintenance (as a percent of GDP) made by all levels of government in transportation and water infrastructure have declined in recent decades.[5]

The need to reverse years of underinvestment in infrastructure, despite tighter budgets at every level of government, calls for us to rethink how we pay for and manage infrastructure investment. Some state and local governments have entered into public-private partnerships (PPPs) to provide and manage infrastructure that has traditionally been provided by the public sector. PPPs bring private sector capital and management expertise to the challenges of modernizing and more efficiently managing such infrastructure assets. Under a PPP, a government contracts with a private firm to design, finance, construct, operate, and maintain (or any subset of those roles) an infrastructure asset on behalf of the public sector. When the private sector takes on risks that it can manage more cost-effectively, a PPP may be able to save money for taxpayers and deliver higher quality or more reliable service over a shorter timeframe compared to traditional procurement. When sponsors contract with private partners that support strong labor standards, PPPs can also provide local economic opportunity and create good, middle-class jobs that benefit current and aspiring workers alike. Just as there is a range of roles that a private firm or firms can take on in a PPP, the nature of risk-sharing and compensation arrangements for bearing and managing risk can vary substantially from project to project and is

[1] This paper was authored by Elaine Buckberg, Owen Kearney, and Neal Stolleman.

[2] U.S. Executive Office of the President. National Economic Council and Council of Economic Advisers. 2014. *An Economic Analysis of Transportation Infrastructure Investment*. http://www.whitehouse.gov/sites/default/files/docs/economic_analysis_of_transportation_investments.pdf (accessed March 8, 2015).

[3] Ibid.

[4] "Aging Water Infrastructure." *Science Matters* 1, no. 1 (2010). http://www.epa.gov/ORD/sciencematters/april2010/scinews_aging-water-infastructure.htm (accessed April 13, 2015).

[5] Bosworth, Barry and Sveta Milusheva. "Innovations in U.S. Infrastructure Financing: An Evaluation." Presentation at the "Challenges for the Global Economy after the Tohuku Earthquake" Research Conference, Tokyo, Japan, November 7, 2011. http://www.nomurafoundation.or.jp/wordpress/wp-content/uploads/2014/09/20111107_Barry_Bosworth-Sveta_Milusheva_000.pdf (accessed March 8, 2015).

governed by contract. Expanding the options for risk- and profit-sharing is the focus of this paper.[6]

However, infrastructure — whether financed through traditional methods or PPPs — relies on funding sources to repay financing, whether debt, equity, or a combination. All infrastructure investments ultimately depend on either user fees, government tax revenues, or a combination of both. PPPs provide only financing and not funding. Therefore, community and political support for greater investment of government tax revenues or the imposition of user fees is critical to expanding investment in our nation's public infrastructure.

While PPPs cannot eliminate the need for government spending on infrastructure, we can help meet our nation's infrastructure needs by expanding the sources of investment and using those dollars, whether public or private, as effectively as possible to advance the public's interest. Other advanced economies, including Australia, Canada, and the United Kingdom, rely more heavily than the United States on PPPs to secure equity financing for infrastructure. This is due in part to the U.S. municipal debt market being the most developed of its kind in the world. Although the role of PPPs in the U.S. market is limited, the U.S. Department of the Treasury's research and engagement with stakeholders indicate that significant private capital could be mobilized for infrastructure investment. However, in order to attract this capital, U.S. public infrastructure assets will have to support higher rates of return than are currently generated through 100 percent low-cost debt financing in the municipal bond market. The challenge is for PPPs to demonstrate overall cost savings and efficiencies that outweigh the lower-cost financing advantage of traditional procurement.

PPPs allow governments to introduce private sector capital into a project and also harness private sector management and technical expertise. When a PPP transfers risks to the private sector that it can manage more cost-effectively, it can benefit taxpayers by lowering long-term project costs, improving the quality of services, or both. Yet a PPP is not necessarily the best choice for every project, and governments can evaluate whether a PPP achieves the same outcome for lower overall costs compared to traditional procurement by using a "Value for Money" (VfM) analysis. Canada, for example, requires VfM analyses for all major infrastructure projects (i.e., having capital costs greater than $100 million) to determine whether it is more cost-effective to use PPP or conventional procurement.[7]

This paper presents new and alternative PPP incentive structures that can potentially align public and private sector interests in infrastructure provision and management, in contrast to the "basic user fee" (i.e., toll) and "availability payments" models, which historically have been used in PPPs and allocate all demand risk (and therefore, revenue risk) to either the private sector partner or the government. Recently, PPP deals in the United States have begun migrating away from

[6] U.S. Department of the Treasury. Office of Economic Policy. 2014. *Expanding Our Nation's Infrastructure through Innovative Financing.* http://www.treasury.gov/press-center/press-releases/Documents/Expanding%20our%20Nation%27s%20Infrastructure%20through%20Innovative%20Financing.pdf (accessed March 8, 2015).

[7] VfM methodology involves: 1) creating a Public Sector Comparator (PSC), which estimates the lifecycle cost of carrying out the project through a traditional approach, 2) estimating the lifecycle cost of the PPP alternative, and 3) completing an "apples-to-apples" comparison of the costs of the two approaches.

the basic user fee model, after several prominent PPPs using it encountered financial difficulty, and some recent projects have incorporated revenue-sharing.[8] In order to increase awareness of incentive arrangements that can be mutually beneficial for government sponsors and private investors, we draw upon incentive structures used in private industries that are regulated to protect the public interest — electric power, gas and oil pipelines, and telecoms — and apply them to PPPs. These industries have attracted substantial private investment flows while providing for demand risk to be shared between the government and the private sector.[9]

This paper explains incentive structures that allow for profit-sharing. For example, the private partner may transfer a portion of its earnings directly to the government, thereby sharing with taxpayers, or the private partner's cost savings may lower the price of using the infrastructure, sharing those savings with consumers. As extensions of the basic user fee model, these structures can enhance the private sector's incentive to operate efficiently. By offering options that mitigate the demand risk borne by the private partner, these incentive structures may expand the scope for executing PPP deals. For example, some investors may be attracted by being able to share the project's upside with the government in return for some protection from downside demand risk. In some states, including Texas, Florida, and New Jersey, PPP-enabling legislation specifically provides for various types of sharing arrangements.[10] The appropriate choice of model for any given project will depend on project specifics and the risk preferences of the project sponsor and investors.

The remainder of the paper is organized as follows: section II provides an overview of PPPs, section III presents three incentive structures for PPP contracts meant to expand the set of options beyond the basic user fee and availability payment models, and section IV concludes.

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[8] For example, the Indiana Toll Road, Texas SH 130, and the South Bay Expressway in San Diego all experienced financial strain because actual demand turned out to be less than projected. *See* Mallet, William J. *Indiana Toll Road Bankruptcy Chills Climate for Public-Private Partnerships* (CRS Insights No. IN10156). Washington, DC: Congressional Research Service, 2014. http://www.ncppp.org/wp-content/uploads/2013/02/CRS-Insights-Indiana-Toll-Road-Bankruptcy-Chills-Climate-for-P3s.pdf (accessed March 9, 2015).

[9] Various types of revenue- and profit-sharing mechanisms have been used in the regulated telecommunications, electricity, natural gas, and (in New York state only) water industries. *See* Sappington, David E. M. and Dennis L. Weisman. "Price Cap Regulation: What Have We Learned from 25 Years of Experience in the Telecommunications Industry?" *Journal of Regulatory Economics* 38, no. 3 (2010): 227-257; and The Brattle Group. "Alternative Regulation and Ratemaking Approaches for Water Companies," September 30, 2013. http://www.nawc.org/uploads/documents-and-publications/documents/NAWC_Brattle_AltReg_Ratemaking_Approaches_102013.pdf (accessed March 8, 2015).

[10] Under Florida's PPP-enabling legislation, a negotiated portion of revenues from fee-generating uses must be returned to the public entity over the life of the agreement. *See* http://laws.flrules.org/2013/223 http://www.flsenate.gov/Session/Bill/2013/0085/BillText/er/PDF (accessed April 20, 2015). Under Texas PPP legislation, the responsible government entity may consider the opportunity for revenue-sharing as one of the project selection criteria, among other factors. *See* http://www.statutes.legis.state.tx.us/Docs/GV/htm/GV.2267.htm (accessed April 20, 2015). The PPP between the Bayonne New Jersey Municipal Authority (BMUA) and Kohlberg Kravis Roberts & Co (KKR) was approved pursuant to the provisions of the "New Jersey Water Supply Privatization Act." *See* http://www.nj.gov/dep/watersupply/pdf/statut_58.26-1.pdf (accessed March 12, 2015). The agreement incorporates revenue-sharing. *See* NW Financial Group, LLC. "Why the Bayonne Water/Wastewater Public-Private Partnership Succeeded," April 1, 2013. http://www.nwfinancial.com/pdf/NW-BMUA-Report.pdf (accessed April 14, 2015).

II. Background on Public-Private Partnerships

PPPs as an alternative to traditional infrastructure procurement and management

Publicly-owned infrastructure assets are typically designed, constructed, operated, and maintained through "conventional procurement," in which the sponsoring government owns the asset but separately contracts for each service, often from different private firms. Under conventional procurement, the government first contracts with a private entity to supply the infrastructure design, then seeks bids to build the asset according to that design, likely from a separate firm, and finally, operates and maintains the infrastructure asset, or takes bids from yet another firm. With competitive bidding, this approach allows the public sector to have highly qualified private firms fulfill the requirements of various project phases; however, contracted parties do not have an incentive to minimize lifetime project costs, only costs incurred during their respective phases.

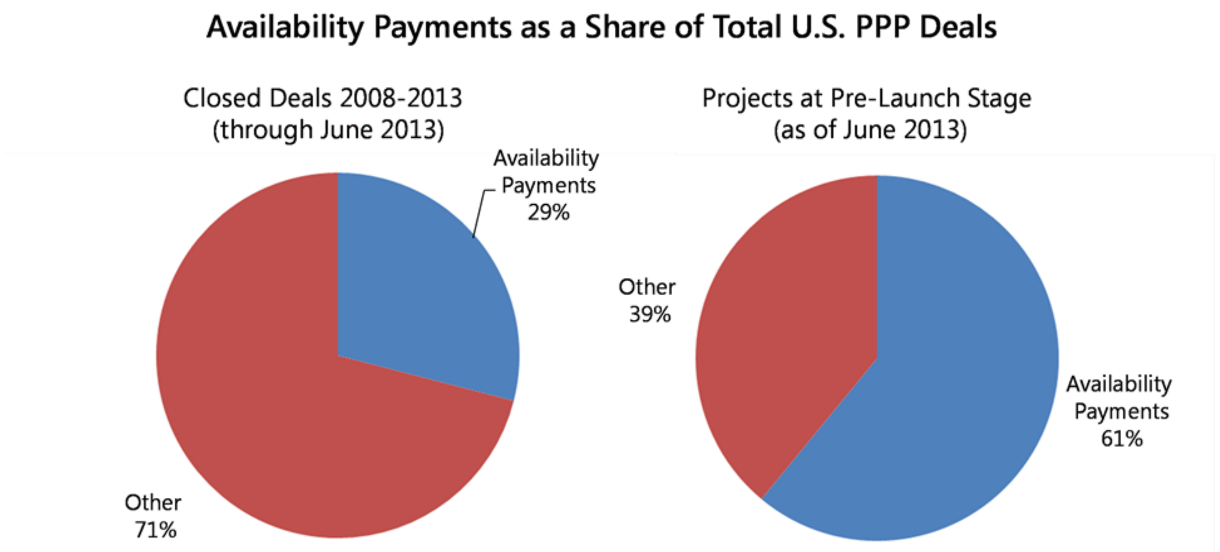
Under a PPP, the government retains ownership of the infrastructure asset, while the private sector is afforded a much greater role in delivering and managing the asset compared to conventional procurement. This paper focuses on PPPs that transfer responsibilities for multiple phases of a project to the private partner. Consider a PPP where the government contracts with a private company to build or improve an infrastructure asset and to subsequently maintain and operate that asset for a number of years in exchange for a stream of revenue during the life of the contract, where the revenue stream will take the form of either user fees or availability payments.[11] This contrasts with conventional procurement, as described above, in that the government is directly contracting with a *single* private entity or consortium to complete the various aspects of the project. As the single responsible party for multiple stages of the project, the private partner is then motivated to minimize costs across those project phases — an incentive that is lacking under conventional procurement. Although the government owns the asset, many PPP contracts extend for 30 years or more, so that the private partner has control over a significant portion of the useful life of the asset. Finally, PPPs can vary in the extent to which they transfer responsibilities from the public to the private sector.

A PPP requires dedicated revenue in order to be financially viable, whether from user fees or the government; a central consideration in structuring a PPP is which party will face uncertain project revenue due to the unknown future demand for the infrastructure asset's service. In the two basic models, the PPP places all demand risk (and therefore revenue risk, as well) with either the government or the private partner. In a basic *user fee* arrangement, the private partner collects and retains all fees from consumers of the service, e.g. bridge tolls and payments for water bills, and so bears all the risk of uncertain demand for the service. Alternatively, in an *availability payments* model, the government sponsor collects any revenue from users and makes fixed, recurring payments to the private partner provided the asset meets contracted quality

[11] *See* page 2 of Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. *The Economics of Public-Private Partnerships*. New York: Cambridge University Press, 2014.

standards; because availability payments do not vary with asset use, the government bears all the demand and revenue risk.[12]

Recently, private investors in PPP projects have sought to reduce exposure to demand risk following some troubled toll road PPP transactions.[13] As use of the basic user fee model has declined, the availability payment model has been adopted in an increasing percentage of U.S. PPPs, as illustrated by the chart below.



SOURCE: Allison, Peter. Welcoming remarks. Presentation at InfraAmericas US P3 Infrastructure Forum 2013, New York City, USA, June 18, 2013.

Driven in part by the loss of the bond insurance markets and a newfound conservatism among senior debt lenders, project sponsors have also found new ways to structure PPPs to mitigate or retain risks that private investors no longer find acceptable.[14] As shown in Table 1 below, a number of projects closed in the last three years incorporate revenue-sharing provisions.

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[12] For example, assume that the government expects 100 cars per week to use a toll road, and that it will use the collected tolls from 100 cars to fund the weekly availability payment to the private partner. If only 20 cars use the toll road during a given week, the government must still pay the private firm the equivalent of the toll collections from 100 cars because the availability payment is a fixed obligation.

[13] Mallet, William J. *Indiana Toll Road Bankruptcy Chills Climate for Public-Private Partnerships* (CRS Insights No. IN10156). Washington, DC: Congressional Research Service, 2014. http://www.ncppp.org/wp-content/uploads/2013/02/CRS-Insights-Indiana-Toll-Road-Bankruptcy-Chills-Climate-for-P3s.pdf (accessed March 9, 2015).

[14] *See* U.S. Department of the Treasury. Office of Economic Policy. 2014. *Expanding Our Nation's Infrastructure through Innovative Financing.* http://www.treasury.gov/press-center/press-releases/Documents/Expanding%20our%20Nation%27s%20Infrastructure%20through%20Innovative%20Financing.pdf (accessed March 8, 2015). Also *see* U.S. Department of Transportation. Federal Highway Administration. 2010. *Public-Private Partnership Concessions for Highway Projects: A Primer*. http://www.fhwa.dot.gov/ipd/pdfs/p3/p3_concession_primer.pdf (accessed March 11, 2015). If performance standards are not met, availability payments can be reduced or eliminated.

Table 1: U.S. PPP Deals, April 2012-April 2015

Project	Sector	Financial Close	Amount ($mil.)	Incentive Structure[15]
Midtown Tunnel	Transport	2012	2,100	Revenue-sharing
Presidio Parkway Doyle Drive Concession	Transport	2012	362	Availability payments
I-95 HOV/HOT Lanes	Transport	2012	923	Revenue-sharing
I-95 North, SR 406 to SR 44,	Transport	2012	118	Availability payments
SR 9B Extension - Duval County	Transport	2012	95	Availability payments
Maryland I-95 Travel Plazas Redevelopment	Transport	2012	56	Revenue-sharing
I-75 Expansion	Transport	2012	72	Availability payments
Rialto Water System	Water	2012	172	Revenue-sharing
Bayonne Water & Wastewater Concession	Water	2012	173	Revenue-sharing
Carlsbad Seawater Desalination Plant	Water	2012	903	Availability payments
Ohio River Bridges Project - East End Crossing	Transport	2013	763	Availability payments
North Tarrant Expressway Segments 3A, 3B	Transport	2013	1,350	Revenue-sharing
Goethals Bridge	Transport	2013	1500	Availability payments
Georgia Northwest Corridor (NWC)	Transport	2013	840	Basic user fees
US 36	Transport	2014	120	Revenue-sharing
I-69	Transport	2014	370	Availability payments
I-4 Ultimate	Transport	2014	2300	Availability payments
SH 183 - Dallas-Fort Worth (Gap Financing)	Transport	2014	848	Revenue-sharing
Pennsylvania Bridges Project	Transport	2015	900	Availability payments
Southern Ohio Veterans Highway	Transport	2015	553	Availability payments

Sources: InfraDeals and project descriptions from state departments of transportation and concession agreements.

Benefits of PPPs

By providing incentives to the private partner to minimize costs across project stages, while also requiring that stipulated quality standards be satisfied, a PPP can lower costs over the life of the asset, lower the cost of using the asset by improving quality of service, and reduce the time until the project is complete and operational. These incentives arise because the PPP contract both holds the private partner responsible for paying the unknown future costs of completing various project phases, and endows the private partner with full decision-making power and control of the asset in completing those phases. In other words, a PPP relies on transferring risks from the public to the private sector in order to ultimately realize efficiency gains.

[15] Projects categorized as “Basic user fees” collect user fees but their contracts do not include any sharing provisions. The projects categorized as “Revenue-sharing” also collect user fees, but their contracts generally stipulate that project revenues are shared between the public sponsor and the private partner in some fashion. In contrast to the basic use fee model, under the revenue-sharing model, the private partner does not bear all of the demand risk (and therefore not all of the revenue risk, either). These revenue-sharing structures may include some but not all of the elements of the incentive structures described in section III.

Mandating quality standards is important because a PPP incentivizes cost-cutting. Consumers care about both cost and quality; cost-cutting becomes undesirable if it results in *unacceptably* lower quality of the infrastructure asset and the service that it provides. Quality is "contractible" if the stipulated level of quality can be translated into contractual terms and readily verified by the government and the private party. Given the importance of contractible quality for potential efficiency gains through PPPs, whether or not quality is contractible carries implications for which types of infrastructure projects are appropriate for PPPs. In instances where quality is not contractible, a PPP contract is more likely to induce the private partner to cut costs in ways that result in suboptimal quality of the infrastructure service.[16]

Because a PPP incentivizes cost-cutting, some private partners may seek to reduce labor costs by lowering wages. Lowering wages for workers on a project may reduce costs but it does not create additional value for taxpayers. On the contrary, cutting wages is likely to reduce the quality of labor. Requiring strong labor standards is one strategy to ensure that the cost reductions from PPPs are not achieved simply through wage reductions.

By both transferring risk and imposing verifiable quality standards, a PPP contract can induce efficiency-increasing reductions in cost via two avenues:

1. **"Bundling" responsibility for multiple project phases** incentivizes the private partner to capture cost savings across phases, such as by making long-view investment choices in earlier phases of the project that reduce costs in later phases. For example, using higher quality but more expensive paving material on a road might prevent potholes and reduce maintenance costs. In conventional procurement, such incentives are absent because different parties are typically responsible for the construction and maintenance phases.[17] Bundling can also encourage accelerated project delivery; if the private partner is responsible for the construction, operation, *and* financing of the project, and receives a share of project revenues, then it will have increased incentives to complete construction and begin operation as early as possible in order to start providing a return to both debt and equity investors.

2. **Contractually obligating the private partner to meet minimum asset and service quality standards** can improve efficiency and produce further cost savings. Minimum standards can prevent the deferral of maintenance and resulting asset deterioration,

[16] In some situations where it is not possible to contract output quality directly, it might still be possible to do so indirectly by stipulating quality standards for the inputs. This is only effective, however, if the choice of inputs determines the quality of the output in a predictable way known by the project sponsor. Also, selection of inputs by the government precludes the private partner from using its technical and managerial expertise to choose the efficient mix of inputs. In these cases, a PPP may not be the best choice for organizing the project.

[17] For discussions of why the government might have difficulty achieving cost savings across project phases on its own, *see* Hall, John. "Private Opportunity, Public Benefit?" *Fiscal Studies* 19, no. 2 (1998): 121-140; and Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. "Public-Private Partnerships: When and How." Working paper, Yale University (2008). http://www.econ.uchile.cl/uploads/publicacion/c9b9ea69d84d4c93714c2d3b2d5982a5ca0a67d7.pdf (accessed March 12, 2015).

therefore lowering the costs to users imposed by a degraded asset (e.g. potholes on a road increase vehicle wear-and-tear).

Finally, the government may not realize the potential cost savings from a PPP discussed above if the procurement process is not competitive or if contract renegotiations resulting in additional reimbursement from the government to the private partner are prevalent. The possibility of successful renegotiation by the contract awardee induces "moral hazard": if the concessionaire believes that it can extract additional payments from the sponsor to cover its higher costs, then the incentive for cutting costs is blunted. While the benefit of setting minimum contractual quality standards is not unique to PPPs, it is particularly relevant for the long-term transfer of responsibility.

Risk and risk transfer in PPP contracts

The chief mechanism for realizing cost savings in a PPP, bundling, requires the transfer of multiple project risks from the public to the private sector. [18] Under conventional procurement, taxpayers bear most of the risks identified in Table 2 below, even those risks that the government is not well-positioned to influence.[19,20] The net benefit from PPP procurement is maximized when 1) a given controllable risk is allocated, and the related decision-making authority is delegated, to the party that can best influence it, and 2) any risk that no party can control is allocated to the party that is best able to manage or diversify it.[21]

[18] The term "bundling" can also have another meaning in the context of PPPs: "…contracting with one partner to provide several small-scale PPP projects in order to reduce the length of the procurement process as well as transaction costs." *See* page 17 of Deloitte Research. "Closing America's Infrastructure Gap: The Role of Public-Private Partnerships," 2007.
http://worldbank.mrooms.net/file.php/251/docs/optional_readings/Closing_America_s_Infrastructure_Gap.pdf (accessed April 13, 2015).

[19] An exception is performance risk, which is borne by users.

[20] This even includes the risk of construction cost overruns — which are borne by the construction company under the actual contract — if contract renegotiations are commonplace. *See* Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. *The Economics of Public-Private Partnerships*. New York: Cambridge University Press, 2014.

[21] A party more effectively manages a risk that cannot be directly controlled when it minimizes the expected dollar impact conditional on bad outcomes occurring, minimizes the probability of bad outcomes, or both.

Table 2: Major Risks in an Infrastructure Project[22]

Risk Category	Examples of (Downside) Risks
Design	▪ Design flaws
Construction	▪ Construction cost overruns ▪ Delays to completion
Operations and Maintenance	▪ Higher operations costs ▪ Higher maintenance costs
Performance	▪ Periods of service unavailability ▪ Lower service quality
Policy	▪ New competing capacity
Demand	▪ Lower utilization than initially forecasted
Financial	▪ Higher interest rates ▪ Less favorable exchange rates

In general, as the number of related risks that can be appropriately transferred to the private partner increases, the incentives for cost saving are strengthened. For example, the "design-build" (DB) contract transfers both design and construction risk, which incentivizes the private partner to design the project so as to minimize building costs and the likelihood of design flaws.[23] The "design-build-operate-maintain" (DBOM) model additionally encourages the private partner to select building methods and materials that minimize operations and maintenance costs, while the "design-build-finance-operate-maintain" (DBFOM) structure also incentivizes the private partner to reach the operations phase as early as possible to begin paying back investors. Performance risk is also transferred from users to the private partner when the PPP contract sets quality standards for the infrastructure assets and services.

Some risks to private investors in a PPP are in the public sector's control: for example, a local government could construct a non-tolled road competing for the same users as an existing PPP toll road.[24] Flexible contracts can minimize the need for renegotiation in these cases. Including adaptable competition clauses can help preserve the government's ability to build competing projects that are in the public interest while providing protections to investors. For example, Florida's PPP-enabling legislation for transportation facilities specifically requires that, among other things, proposed projects must have adequate safeguards in place to ensure that the Florida Department of Transportation has the opportunity to add capacity serving similar origins and

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[22] The categorization of risks in Table 2 follows, in part, the discussion in Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. *The Economics of Public-Private Partnerships*. New York: Cambridge University Press, 2014.

[23] In addition, project delivery time may be shortened compared to conventional procurement because of better coordination between the design and build functions.

[24] In some cases, state-specific PPP legislation may restrict the flexibility of PPP contracts, e.g. in Arizona and North Carolina, the public sector is *required* to maintain comparable non-tolled roads when it establishes new toll roads. Also, there are prohibitions against non-compete clauses in Alabama, Florida, Mississippi, North Carolina and Texas. *See* Appendix B of National Conference of State Legislatures. "Public-Private Partnerships for Transportation: A Toolkit for Legislators," October 2010. http://www.ncsl.org/documents/transportation/PPPTOOLKIT.pdf (accessed March 9, 2015).

destinations; having this type of flexibility is especially important if, for example, persistent congestion develops on the privately operated facility.[25]

When user fees comprise the entirety of the private party's revenue stream, demand risk is likely the central determinant of the PPP's financial viability. While all projects are subject to uncertainty regarding future utilization, demand forecasts for so-called greenfield projects are particularly unreliable because there is no past usage baseline.[26] According to the World Economic Forum, excessively positive forecasts have been common in PPP road projects.[27] Not coincidentally, a number of road PPP projects have entered bankruptcy.[28]

Demand risk differs from other risks that can be beneficially transferred to the private partner ─ such as design, construction, operations and maintenance, performance ─ in that the private partner's actions can do little to influence the risk. Yet, as with the models presented in the next section, exposing the private partner to some (if not necessarily all) demand risk might attract potential investors looking for upside potential not possible under an availability payments arrangement (in which they would be completely insulated from demand risk).

III. Innovative Revenue, Profit, and Risk-sharing Arrangements for Infrastructure Provision

Discussions of PPPs in the United States have often focused on user fee or availability payment agreements, where either the private partner or the government sponsor bears all of the demand risk (and therefore all of the revenue risk, as well).[29] Following the financial difficulties of some user fee toll road projects, private investors have looked increasingly to the availability payments model to reduce exposure to revenue volatility.[30] Project sponsors have also found new ways to

[25] The legislation states that, before approval, the Department of Transportation must determine that the proposed project "would have adequate safeguards in place to ensure that the department or the private entity has the opportunity to add capacity to the proposed project and other transportation facilities serving similar origins and destinations." *See* http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0300-0399/0334/Sections/0334.30.html (accessed March 30, 2015).

[26] A "greenfield" PPP infrastructure project is one in which the private partner designs and constructs a brand new infrastructure asset, and may operate it, depending on the specifics of the PPP arrangement. In a "brownfield" project, the private partner assumes temporary control of an existing asset for purposes of upgrading its capacity and/or quality, and may also operate it.

[27] World Economic Forum. "Strategic Infrastructure – Steps to Prepare and Accelerate Public-Private Partnerships," May 2013. http://www3.weforum.org/docs/AF13/WEF_AF13_Strategic_Infrastructure_Initiative.pdf (accessed March 8, 2015).

[28] Dezember, Ryan and Emily Glaser. "Drop in Traffic Takes Toll on Investors in Private Roads." *Wall Street Journal*, November 20, 2013.

[29] *See*, for example, Sobel, Patrick and Robert Puentes. "Private Capital, Public Good — Drivers of Successful Infrastructure Public-Private Partnerships." Brookings Institution, (2015). http://www.brookings.edu/research/reports2/2014/12/17-infrastructure-public-private-partnerships-sabol-puentes (accessed April 17, 2015).

[30] Mallet, William J. *Indiana Toll Road Bankruptcy Chills Climate for Public-Private Partnerships* (CRS Insights No. IN10156). Washington, DC: Congressional Research Service, 2014. http://www.ncppp.org/wp-

structure PPPs to mitigate or retain risks that many private investors no longer find acceptable, including introducing revenue-sharing. The allocation of demand risk, therefore, need not be limited to user fees or availability payments.

By further broadening the scope for PPP negotiations beyond the two basic models, this paper aims to increase the likelihood that potential partners will find a mutually agreeable structure that aligns public and private interests in infrastructure provision and operation. The remainder of this paper discusses three alternative incentive structures for PPP contracts that may help partners reach agreement and align interests. Which structure, including the basic models, is most suitable for a given project, will depend on the specifics of that project and the risk preferences of the project sponsor and investors. The frameworks discussed in this paper are formulated in terms of a single price for an infrastructure service, such as a toll per vehicle on a highway or rate per gallon of water consumed. However, the concepts are equally applicable to multiple prices within a given infrastructure service, such as variable rate tolling for managing demand and reducing congestion on highways.

In brief, the three alternative models are as follows:

- Rate of return model: The rate of return model balances consumer and investor interests by placing a limit directly on the *allowed* rate of return on investment, and setting a regulated price that generates the revenue the firm anticipates it will require to cover its expected costs and earn the designated return. The regulated price can be adjusted at set intervals so that the firm earns the designated rate of return. The regulated price will be increased if, for example, the actual rate of return falls short of the designated rate, where the time between price adjustments carries implications for risk-sharing and the incentive to operate efficiently. For instance, a long wait until the price can increase places more of the demand risk on the private firm while providing a strong incentive to hold down costs; conversely, a shorter wait until the price can increase places less of the demand risk on the private firm and provides less incentive to lower costs.

- Price cap model: A variation of the basic user fee model, the price cap model balances consumer and investor interests by limiting the price of the infrastructure service instead of the rate of return. Since profits are not directly constrained, there is a powerful incentive to minimize costs; also, the private firm assumes all demand risk because price cannot be increased in response to a demand shortfall. Under this model, the maximum price increases each year by the rate of inflation minus the *expected* rate of improvement in the firm's productivity, which achieves a balance between the public and private sector by compensating the firm for higher nominal input costs, while allowing consumers to benefit from anticipated productivity gains (the private firm retains *all* gains from productivity improvement in the basic user fee model). The built-in expected productivity assumption provides an added efficiency incentive because the firm is able to retain productivity gains in excess of projections; the expected productivity assumption can be varied periodically to keep it aligned with changes in actual performance.

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content/uploads/2013/02/CRS-Insights-Indiana-Toll-Road-Bankruptcy-Chills-Climate-for-P3s.pdf (accessed March 9, 2015).

- Sharing models: Contracts with profit-sharing can directly align sponsor and investor interests. For example, if the project exceeds or falls short of negotiated threshold rates of return, the partners can either share the excess return or absorb the shortfall in contractually defined proportions. This type of flexibility expands the universe of acceptable deals because investors may be more willing to enter into an agreement where they are required to share the project's upside potential with the government if the public sector, in turn, provides some protection from demand risk on the downside.

The rate of return and price cap models adopt principles used in public utility regulation, including the energy and telecom industries, where infrastructure assets are privately owned and regulation is used to protect taxpayer and customer interests while allowing reasonable profits.[31] Different forms of profit- or revenue-sharing have also been incorporated into the regulation of energy, water, and telecommunications sectors, as well as in some highway and water PPP projects.

The alternative incentive structures discussed below could be implemented by incorporating key characteristics of the contract into the competitive bidding process widely used to award PPP contracts.[32] For example, the public sponsor, with the assistance of outside financial experts, could define the structure of the desired contract, and private firms vying for the project would bid on the specific contractual elements, such as their preferred sharing percentages or demand and rate of return thresholds.[33] Similar processes are used in the energy and telecom industries, where regulators set the allowable rate of return after evaluating cost and demand information supplied by the public utility as part of the rate-setting process. In the context of a PPP transaction, the public sponsor would evaluate the bids, selecting the bidder most likely to deliver the project at the lowest lifecycle cost while meeting quality standards, thus maximizing value for taxpayers. Incorporating these additional elements should not impose onerous information requirements on bidders, since much of the required data would be needed for bid preparation in any event.[34]

In the remainder of this section, we provide a conceptual overview of the three incentive structures which can be applied in PPP projects where user fees can be collected, quality standards are contractible, and provision of the infrastructure service is characterized by

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[31] In public utility regulation, the "reasonableness" of profits generally is determined by regulators.

[32] Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. "Public-Private Partnerships: When and How." Working paper, Yale University (2008). http://www.econ.uchile.cl/uploads/publicacion/c9b9ea69d84d4c93714c2d3b2d5982a5ca0a67d7.pdf (accessed March 12, 2015).

[33] The agreed upon values for specific contract elements will depend on the specific project; demand uncertainty is greater for a new greenfield project compared to a brownfield project where existing assets with a documented history of demand are temporarily transferred to the private partner.

[34] To take a hypothetical example, if the public sponsor, after consulting with outside financial experts, specifies the contract will include a rate of return threshold of X% and that the sponsor will absorb Y% of any return shortfall, then private firms will simply submit bids on the minimum values of X and Y they are willing to accept, and the sponsor will select from among these. The logical structure of contract terms would be straightforward to implement.

economies of scale.[35] We review each model in terms of the incentives it provides for cost efficiency, technical innovation, and service quality during the project's operational phase, and how demand risk and operations and maintenance risk are allocated between the public and private partners.[36]

1. **<u>Rate of return model</u>:** ***A regulated price that covers costs and provides a return***

The rate-base rate of return model has been a cornerstone of public utility regulation in the United States since the early 1900s and has been widely used at both the federal and state levels to regulate privately-owned, public utilities such as electricity transmission, oil and gas pipelines, telecommunications, and water utilities, for which there is little or no competition by design. For example, the Federal Energy Regulatory Commission (FERC) is responsible for regulating the rates that interstate oil and natural gas pipelines charge for transportation, while individual state public utility commissions (PUCs) regulate the local distribution companies.

The rate of return model protects consumers from excessive rates by setting a regulated price that approximates what the price would be if the utility had to compete with similar firms instead of operating as a monopoly franchise.[37] At the same time, the price is calculated to explicitly allow the private firm to recover its costs and earn a return on its "rate base," which essentially is the value of fixed assets used to produce the infrastructure service.[38] Although the rate of return model has primarily been used to regulate private firms, we propose that the model offers similar protection to consumers of infrastructure services that exhibit natural monopoly characteristics or that are otherwise imperfectly competitive. Infrastructure project sponsors and private partners can agree to adopt a rate of return model by incorporating its salient features in a PPP contract.

How does the rate of return model work?

This simple formula illustrates how the allowable price is determined.

$$Allowable\ price = \frac{Operations\ \&\ maintenance\ expenses + depreciation + taxes + (rate\ base \times rate\ of\ return)}{Demand}$$

[35] Economies of scale means that a firm's output can be doubled for less than a doubling of cost. This often arises in large-scale infrastructure projects because a high proportion of total costs are fixed, meaning they do not vary with the level of output. The result is that the average cost of producing an additional unit of output falls as output increases.

[36] In situations where user fees cannot be collected or where quality standards are not contractible, conventional public provision of infrastructure may be more appropriate than public-private partnerships.

[37] Large-scale infrastructure is characterized by high fixed costs, e.g. transmission lines and towers for electricity supply or pipelines for gas and water supply, giving rise to economies of scale (because most costs are fixed and the firm's output can double, for example, for less than a doubling of cost). Firms characterized by this type of production are called *natural monopolies*, because one firm can produce the entire output of the market at a cost lower than what it would be if there were several firms.

[38] The rate of return is sometimes defined as a weighted average cost of capital, consisting of the cost of debt and the return on equity, where the weights are the shares of debt and equity in the capital structure.

The terms in the numerator add up to the "revenue requirement," i.e., the amount of money the firm expects it will need per time period (often a year) to cover operating expenses, capital costs, and taxes, while also earning a "fair" return on its rate base that is adequate to attract private capital. The concept of a "fair" return in the context of public utility regulation may include considerations such as whether the return 1) is sufficient to maintain the firm's financial viability, 2) enables the utility to attract additional capital, and 3) is comparable to the return earned by other companies with similar risks.[39] The denominator is the expected level of demand for the infrastructure service during the same time period, e.g. the annual number of gallons of drinking water consumed or projected number of vehicles traveling on a toll road. The ratio is the allowable price per unit, i.e. the price per gallon of water or toll charged per vehicle. Multiplying the allowable price by expected demand at that price yields the revenue requirement needed to cover costs and provide the designated return.

Regulators set the allowable rate of return after evaluating cost and demand information supplied by the public utility as part of an extensive rate-setting process that can involve testimony of expert witnesses for both the regulator and public utility.[40] In a PPP transaction, competitive bids would include supporting information about cost, demand, and the rate of return, and would be reviewed as part of the contract negotiations between the public sponsor and winning bidder.

In practice, the realized rate of return may differ from the rate assumed in the regulatory process. Rate of return regulation offers the public utility a *fair opportunity*, but not an ironclad guarantee, to earn its weighted average cost of capital; the regulated firm — or PPP — still has to contend with demand risk and operations and maintenance cost risk. For example, if actual water consumption and the costs of operating water treatment plants match the baseline assumptions used to set the allowable price, then the private firm will earn the designated rate of return. But if actual demand or costs differ from the baseline assumptions, then the realized rate will either fall short of or exceed the expected return until the allowable price is adjusted, either at the next scheduled rate hearing or by a short-term revenue stabilization measure implemented by the regulator.[41] The graph below illustrates these points using hypothetical data. The red line illustrates demand risk: with per unit operations and maintenance costs at the expected level, the rate of return varies with realized demand. For a given level of demand, operations and maintenance cost risk is illustrated by the two lines that are parallel to the red line: the rate of

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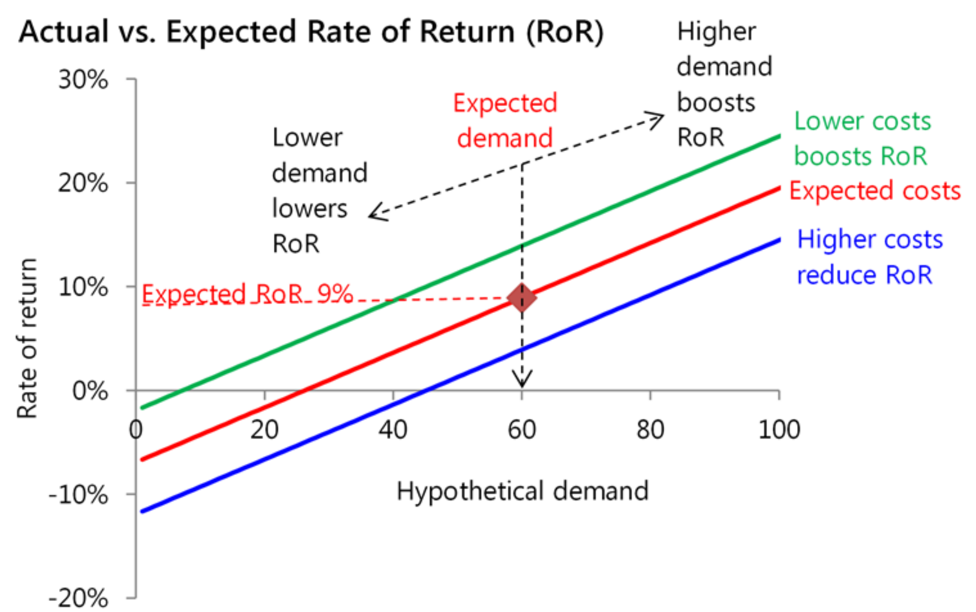
[39] *See* page 436 of Madden, Sean P. "Takings Clause Analysis of Utility Ratemaking Decisions: Measuring Hope's Investor Interest Factor." Fordham Law Review 58, no. 3 (1989): 427-446. Also see page 42 of Regulatory Assistance Project. "Electricity Regulation in the U.S.: A Guide," March 2011. *See also* www.raponline.org/docs/RAP_Lazar_ElectricityRegulationInTheUS_Guide_2011_03.pdf (accessed March 11, 2015). The Regulatory Assistance Project report cites Federal Power Commission vs. Hope Natural Gas Company and Bluefield Water Works and Improvement Company vs. Public Service Commission, 262 U.S. 679 (1923) as two key Supreme Court cases setting out general criteria that public utility commissions must follow when setting rates of return.

[40] In practice, public utility regulators use either historical data, projections for a future test year, or a combination to obtain cost and demand information for computing the regulated price. For greenfield PPPs, the allowable price would necessarily be based on projections, while for brownfield PPPs, it would incorporate historical data.

[41] *See* The Brattle Group. "Alternative Regulation and Ratemaking Approaches for Water Companies," September 30, 2013. http://www.nawc.org/uploads/documents-and-publications/documents/NAWC_Brattle_AltReg_Ratemaking_Approaches_102013.pdf (accessed March 8, 2015).

return is lower than expected if per unit costs are higher than expected (blue line) or the rate of return is higher than expected if per units costs are lower than expected (green line).



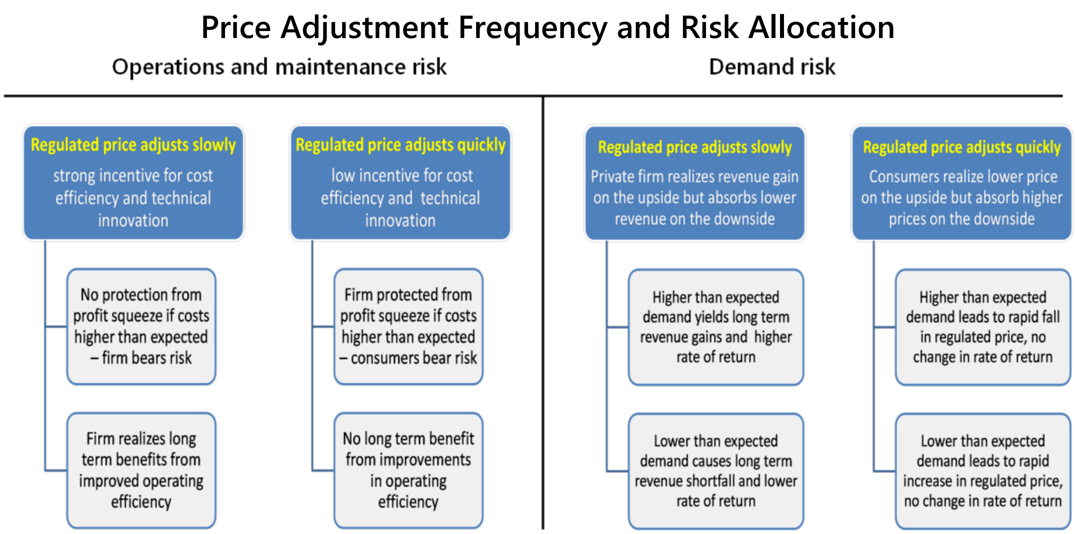
The private partner's incentive to operate in the most cost-efficient manner will be affected by how quickly the allowable price is adjusted when the actual rate of return differs from the target rate.[42] For example, if the contract allows higher costs to be quickly translated into higher prices, then the firm's incentive to hold down costs will be blunted. Similarly, the firm's incentive to use innovative cost-saving technology will be weakened if operational cost savings are swiftly reflected in lower prices.

By contrast, a PPP contract that constrains prices to adjust less frequently strengthens incentives for management to operate the project efficiently because the firm either has to absorb a portion of cost increases or can keep earnings from superior performance.[43] Negotiating this type of adjustment provision in a PPP contract requires the public and private entities to balance their interests in a way that has the potential to maximize expected long-term benefits for everyone.

[42] As mentioned earlier, there may be multiple prices for a single infrastructure service: for example, a public transit system might have reduced fares for seniors and/or students. A PPP contract may be designed to limit or exempt certain population segments, such as seniors, from price increases.
[43] *See* Ofwat. 2007. *New Approaches to Expenditures and Incentives.* http://www.ofwat.gov.uk/pricereview/pr09phase1/pap_con_apprchexpincent.pdf?download=Download# (accessed March 8, 2015). In the regulated UK water industry, if companies can deliver outputs with lower capital or operating expenditure than assumed, prices are lowered, but only after five years in order to provide incentives to reduce costs. The regulator also monitors delivery of outputs to make sure cost reductions are due to efficiency improvements and not due to failure to deliver services at acceptable quality levels. Quality monitoring needs to be an important part of PPP contracts, as discussed in Sections II and III.3.

The frequency of price adjustment for deviations in demand from baseline assumptions also determines to what extent the public or private partner bears the project's demand risk. If utilization of a PPP toll road falls short of projections because more drivers use a nearby non-tolled road, the arrangement requires that the allowable toll is increased so that the firm achieves its target rate of return. For regulated gas and electric utilities, annual adjustments are relatively common. Regulated utilities sometimes use "decoupling" to annually adjust rates and stabilize revenues in the time period between formal rate cases, which can be up to three years, depending on the state (annual rate adjustments that are made to stabilize revenue are referred to as "true-ups").[44] The negotiated frequency of price adjustment in a PPP contract must balance the public interest in avoiding sharp toll hikes with the private sector's need for a financially viable project.[45]

The magnitude of the price adjustment needed to restore the allowable rate of return depends in part on the price elasticity of demand, i.e. the responsiveness of demand to a price change.[46] Demand responsiveness tends to be low for infrastructure services because, in general, there are few substitutes readily available to consumers. However, availability of even an imperfect substitute will require a larger price increase in order to make up for the loss of users who shift to a nearby non-tolled but highly congested road.



[44] Eto, Joseph, Steven Stoft, and Timothy Belden. "The Theory and Practice of Decoupling Utility Revenues from Sales." *Utilities Policy* 6, no. 1 (1997): 43-55.
[45] For example, in the regulated UK water industry, if companies can deliver outputs with lower capital or operating expenditure than assumed, prices are lowered, but only after five years in order to provide incentives to reduce costs. In telecommunications, rate case moratoriums are sometimes implemented to guarantee the regulated firm that profits made at current prices will not be taken away. This process imposes a regulatory lag, typically 2-5 years, intended encourage the regulated firm to reduce operating costs (i.e., the firm will be able to retain the resulting increase in earnings). Similar provisions can be written into PPP contracts.
[46] The price elasticity of demand is defined as the percentage change in quantity demanded of a good resulting from a one-percent increase in its price.

Summary

The rate of return model sets a regulated price that allows the private firm to recover its costs and earn a designated return on its "rate base." In the case of a PPP, the project sponsors and their private partners can agree to adopt a rate of return model by incorporating it in a PPP contract. If actual demand and costs differ from the baseline assumptions, the price will be adjusted to enable the firm to earn its allowed rate of return. This feature provides the firm with greater protection against demand risk than does the basic user fee model; it also affords better protection against operations and maintenance cost risk than the user fee and availability payments models. However, the rate of return model provides somewhat less incentive for cost cutting than user fee and availability payment contracts because price is eventually reduced to reflect cost savings or eventually raised to reflect cost increases. As the frequency of price adjustments increases, the incentives for cost efficiency weaken.

2. **Price cap model**: ***The real price is adjusted for efficiency gains***

The price cap model protects consumers from the possibility of excessive price increases but, in contrast to the rate of return model, it does so by setting limits directly on the price of an infrastructure service, not on the rate of return. Since the focus of regulatory control is on prices and not on profitability, private firms have a powerful incentive to minimize costs and improve productivity performance in order to increase their profitability.

Price cap regulation has been used in the United Kingdom since the late 1980s and now applies to all of the privatized British network utilities.[47] In the United States, price cap regulation began replacing rate of return regulation in portions of the telecommunications sector in 1989 and is now used in most states as well as in interstate telecommunications regulation; price caps are also used in many other telecommunication markets throughout the world.[48,49] Other countries use price cap regulation beyond telecommunications, e.g., Australia (energy and transport) and France (postal service).[50,51]

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[47] Green, Robert. "Has Price Cap Regulation of UK Utilities Been A Success?" *Public Policy for the Private Sector* 132 (1997). http://siteresources.worldbank.org/EXTFINANCIALSECTOR/Resources/282884-1303327122200/132green.pdf (accessed March 11, 2015).

[48] Blackman, Colin and Lara Srivastava, editors. *Telecommunications Regulation Handbook.* Washington, DC:The International Bank for Reconstruction and Development / The World Bank, InfoDev, and the International Telecommunications Union, 2011. https://openknowledge.worldbank.org/bitstream/handle/10986/13277/74543.pdf?sequence=1 (accessed March 12, 2015).

[49] Sappington, David E. M. and Dennis L. Weisman. "Price Cap Regulation: What Have We Learned from 25 Years of Experience in the Telecommunications Industry?" *Journal of Regulatory Economics* 38, no. 3 (2010): 227-257.

[50] King, Stephen P. "Principles of Price Cap Regulation," In *Infrastructure Regulation and Market Reform: Principles and Practice*, edited by Margaret Arblaster and Mark Jamison, 46-54. Canberra: Australian Competition and Consumer Commission and Public Utility Research Centre, 1998.

[51] Reisner, Robert A.F. "Price Caps and the U.S. Postal Service: Prospects, Perils and the Public Interest." Paper prepared for the President's Commission on the U.S. Postal Service, Global Insight (2003). http://govinfo.library.unt.edu/usps/offices/domestic-finance/usps/docs/may_26_paper3.pdf (accessed March 12, 2015).

How does the price cap model work?

For public utilities subject to price cap regulation, an *initial* price is often calibrated such that the firm can cover its costs and earn a fair return, similar to the rate of return model. In a PPP contract, the initial rate of return and price would be negotiated between the private partner and project sponsor as part of the competitive bidding process used to award the PPP. From that point forward, as in public utility regulation, the maximum allowable price, or *cap*, would be allowed to increase at a rate tied to, but below, inflation (as measured, for example, by the Consumer Price Index (CPI), and expressed as a proportion):

$$Allowable\ price\ this\ year = Allowable\ price\ last\ year\ \times (1 + CPI - x)$$

where *x*, the so-called "x-factor", is the expected rate of improvement in the firm's productivity over the operational phase of the project.[52] For instance, the output of a bridge — the rate of traffic flow per year — might be increased by adjusting the inputs used to provide the service, e.g. upgrading to real-time, automated toll collection facilities or by installing traffic congestion management technology on approaches to the bridge. The x-factor measures by how much the growth of the firm's output is expected to outpace the growth of its inputs over the course of the project's operation.

The rationale for this approach is that while price should be allowed to increase with inflation to compensate the firm for higher input costs due to increases in the overall level of prices in the economy, slowing the annual rate of appreciation by subtracting *x* allows consumers to benefit from the firm's *expected* productivity improvement.[53] Put another way, the x-factor pares back the rate by which the price is adjusted to reflect inflation. Regulators also may allow a firm to adjust prices in response to factors beyond its control (via the "z-factor"), which can be a positive or negative adjustment.[54]

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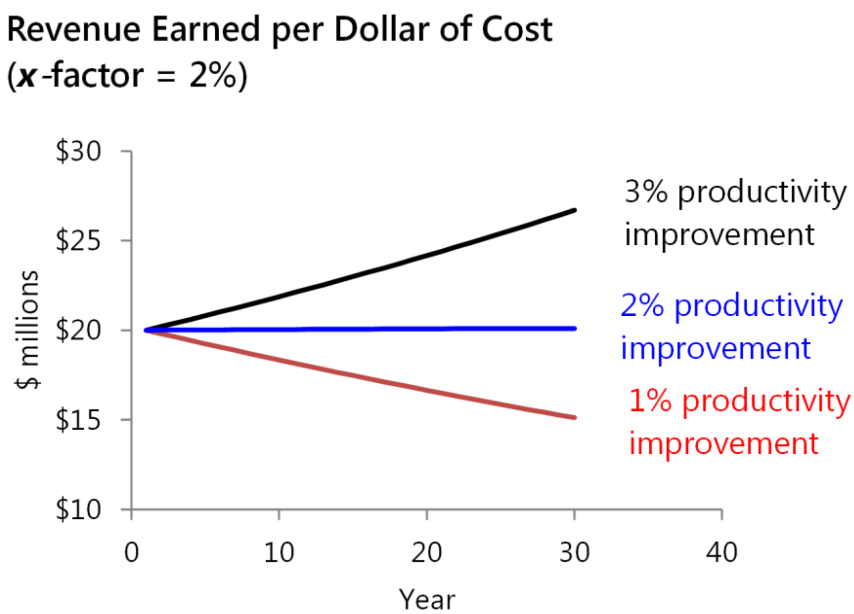
[52] The calculation of "x" can be based on the average productivity improvement that has been observed for similar firms, domestically or internationally. In a PPP contract, information developed as part of bid preparation and value for money analysis can be used to estimate the "x-factor" over the operational phase of the project, because these studies estimate project performance over the life of the contract.

[53] Some user fee and availability payments contracts include inflation adjustments and other economic factors but do not include an offset for the firm's expected productivity performance.

[54] The z-factor should reflect cost elements that are beyond the control of the regulated firm and that have a pronounced financial impact on the firm, such as an industry-specific tax change, new legislation, or a force majeure (e.g., floods, hurricanes and tornadoes). *See* Sappington, David E. M. and Dennis L. Weisman. "Price Cap Regulation: What Have We Learned from 25 Years of Experience in the Telecommunications Industry?" *Journal of Regulatory Economics* 38, no. 3 (2010): 227-257. In the UK, the charges distribution companies pay for connections to the transmission network and property taxes are treated as z-factors. *See* Joskow, Paul L. "Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks," In *Economic Regulation and Its Reform: What Have We Learned?* edited by Nancy L. Rose, 291-344. Chicago: University of Chicago Press, 2014. The price cap formula including the z-factor can be written as:
$Allowable\ price\ this\ year = Allowable\ price\ last\ year\ \times (1 + CPI - x\ (+/-)\ z)$.

In the price cap model, the firm has a built-in incentive to minimize costs because the focus of regulatory control is price, not profit; however, there is an added incentive to improve efficiency and reduce costs *beyond* the level required by the x-factor. By taking steps to make its actual rate of productivity improvement higher than *x*, management at the private partner can boost its profit potential. The chart below illustrates the relationship between a hypothetical firm's revenue per dollar of cost and productivity performance. If the firm's rate of productivity improvement just matches the hypothetical x-factor of 2 percent, revenue earned per dollar of cost will remain unchanged. However, if the annual rate of productivity improvement can be raised, revenue per dollar of cost will steadily increase, as illustrated by the 3-percent line. On the other hand, if actual productivity improvement is less than 2 percent because management fails to hold down operations and maintenance costs, revenue per dollar of cost will steadily decline.



In order to realize the price cap model's potential to balance investor and consumer interests while encouraging cost efficiency, contract negotiations must determine an appropriate value of *x*. If the public sponsor underestimates the firm's ability to improve its productivity, then the negotiated *x* value may be too low and a relatively large share of efficiency gains will accrue to the private partner. If *x* is set too high, then the price cap — and revenue — will be too low, possibly putting the project's financial soundness at risk and compromising the private partner's ability to be cost efficient.

The PPP contract should also be flexible enough to adjust to significant differences between the firm's actual and expected productivity performance that, for example, might be due to unanticipated technological innovation. A provision calling for a periodic reevaluation of the x-factor would prevent the contractual value of *x* from getting too far out of alignment with actual performance; it would also ensure that consumers continued to receive a share of efficiency gains and long term price protection, while preserving the firm's incentive to operate efficiently. For example, in the UK, the x-factor applied to British Telecom is reset by the regulator about every five years.[55]

Maintaining acceptable standards of service quality is an important consideration in any PPP contract, particularly in a price cap framework where cost-cutting incentives are especially strong and where the firm directly benefits from higher rates of asset utilization. Since we are dealing with projects in which quality metrics are observable, specific standards can be written into the contract to preclude cost cutting efforts that might otherwise lower quality.[56] In other situations, the private firm may have an incentive to make additional investments in quality if the benefit of a higher rate of asset utilization exceeds the investment cost.[57] A PPP contract could encourage quality-enhancing investments by incorporating these expenditures in the price cap formula as an additional factor.[58]

Similar to the basic user fee model, under a pure price cap model, demand risk is entirely borne by the private partner. The impact of demand variability on revenue is illustrated in the graph below.[59] If demand falls short or exceeds expectations, the firm's total revenue will rise or fall proportionately, as shown by the dashed black line.

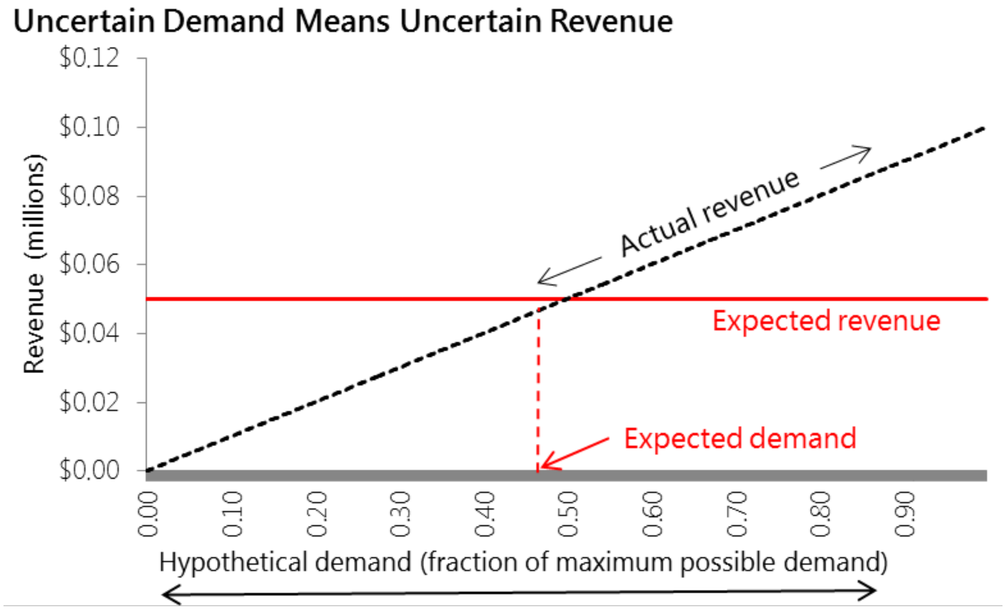
[55] Jamison, Mark A. "Regulation: Price Cap and Revenue Cap," In *Encyclopedia of Energy Engineering and Technology Vol. 3*, edited by Barney Capehart, 1245-1251. New York: CRC Press, Taylor and Francis. 2007.

[56] *See* Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. "Public-Private Partnerships: When and How." Working paper, Yale University (2008). http://www.econ.uchile.cl/uploads/publicacion/c9b9ea69d84d4c93714c2d3b2d5982a5ca0a67d7.pdf (accessed March 12, 2015). Examples of quality metrics include the number of potholes on a road that must be repaired per time period, or percent of on-time arrivals in a transit system. A system of penalties can be included in the contract for failing to meet minimum quality standards, such as adjusting the price cap formula to limit allowable price increases below the rate of inflation, or if quality shortfalls are egregious enough, having a provision that allows the public sponsor to terminate the contract and transfer control to another private consortium (i.e. making the market for the PPP project effectively contestable).

[57] For example, if using a superior brand of cement (to lower the probability of potholes and road buckling) increases the flow of toll-paying traffic enough to more than offset the higher construction costs, then it is in the firm's interests to do so.

[58] Stolleman, Neal. "Dynamic Effects of Regulation on Exchange Carrier Incentives," In *Quality and Reliability of Telecommunications Infrastructure*, edited by William H. Lehr, 63-82. New Jersey: Lawrence Erlbaum Associates, 1995.

[59] Since total revenue = price × quantity, the slope of the dashed black line is equal to the price cap prevailing within a given year (before the cap is adjusted for the next year).



Summary

The price cap model enables the project sponsor to transfer all demand risk to the private partner, as in the basic user fee model, while at the same time providing protection to consumers against large and unanticipated price increases. The embedded consumer protections in the price cap model may make PPP arrangements more attractive to project sponsors and local stakeholders. Moreover, the price cap framework encourages the private partner to be more cost efficient than does the user fee model by motivating the firm to do better than the x-factor, which constrains the rate of price appreciation.[60] Where the project sponsor sets the x-factor will determine both the extent of consumer price protection and the attractiveness of the project to potential partners: a higher *x* increases any private partner's efficiency incentives, but too high an *x* may deter or exclude many potential bidders.

3. **<u>Sharing models</u>: *A price cap model within rate of return bounds***

Contracts with explicit revenue- or profit-sharing provisions can align sponsor and investor interests in cases where the parties' risk preferences and return expectations are not well-served by the basic user fee or availability payment arrangements.[61] These sharing models have the potential to increase the number of PPP deals and increase the odds of the projects' long-term success by reducing the likelihood of bankruptcy or avoiding costly contract renegotiations.[62]

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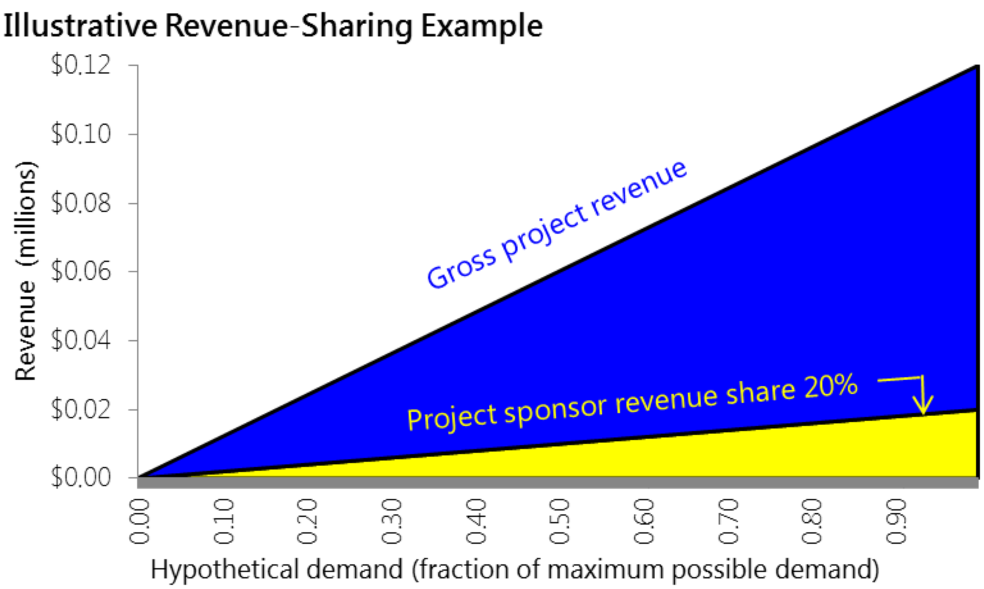
[60] Like the basic user fee model, firms operating under a price cap framework are exposed to operations and maintenance cost risk.

[61] With the exception of the first very simple example, the models in this section present profit-sharing, or more accurately, the sharing of return on investment. These models can also be applied to revenue-sharing; however, the risk allocation depends on whether profit or revenue is shared. The private partner is fully exposed and partially exposed to operations and maintenance risk under revenue-sharing and profit-sharing, respectively.

[62] Various types of earnings-sharing mechanisms have been used in the regulated telecommunications, electricity (27 states plus DC), natural gas (13 states) and water industries (New York state only). *See* Sappington, David E.

Sharing can be achieved when the private partner remits a contractually-defined proportion of revenue or profits to the government; risks are shared, rather than wholly allocated to one party or the other. In its simplest form, the government and private party share revenue in the same contractually-determined proportions at all revenue levels; the graph below illustrates an example where the project sponsor receives 20 percent of gross revenue.[63,64]



A risk-sharing contract should be flexible enough to provide investors and public sponsors with a set of acceptable risk-return tradeoffs over a range of uncertain future demand. In particular, a sharing contract can balance 1) the investor's willingness to share a portion of the project's upside potential in return for getting some downside risk protection, with 2) the sponsor's willingness to provide a degree of downside protection in exchange for a share of the project's

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M. and Dennis L. Weisman. "Price Cap Regulation: What Have We Learned from 25 Years of Experience in the Telecommunications Industry?" *Journal of Regulatory Economics* 38, no. 3 (2010): 227-257; and The Brattle Group. "Alternative Regulation and Ratemaking Approaches for Water Companies," September 30, 2013. http://www.nawc.org/uploads/documents-and-publications/documents/NAWC_Brattle_AltReg_Ratemaking_Approaches_102013.pdf (accessed March 8, 2015).

[63] While not depicted in the graph, a proportional revenue-sharing model in which the government bears downside risk will require the public sector to share in losses by making payments to the private party.

[64] Revenue-sharing arrangements can be more complex. The term sheet describing anticipated contract terms for the State Highway 183 Managed Lanes project to increase capacity and relieve expected congestion pressures, calls for revenue to be shared between the private partner and the Texas Department of Transportation according to applicable percentages for a given range of Toll Revenues. In the example, a 20 percent assumption is used for simplicity. *See* Texas Department of Transportation. 2012. *SH 183 Managed Lanes Project – Toll Concession Public-Private Partnership Agreement Term Sheet, SH138 Managed Lanes Project.* https://ftp.dot.state.tx.us/pub/txdot-info/dal/sh183_managed/rfq/terms.pdf (accessed March 12, 2015). Also *see* page 7 of *Overview of Public-Private Partnerships for Highway and Transit Projects: Testimony Before the Transportation and Infrastructure Committee Panel on Public-Private Partnerships*, United States House of Representatives. 113th Cong. 2014. http://transportation.house.gov/uploadedfiles/2014-03-05-bass.pdf.

upside gain. In a contract negotiation, both sides take positions based on their own forecasts of demand and project performance; an effective contract will allocate risks and returns in a way that is acceptable to both parties.

Sharing contracts can allow for both parties to share in project upside and downside. For example, if the project performs better than expected — by exceeding a negotiated threshold rate of return — the contract may call for the partners to split that portion of the return above the threshold in pre-determined proportions. Similarly, if the project performs worse than expected — the rate of return falls below a negotiated threshold — the contract may specify that each partner absorbs part of the shortfall. Contracts may therefore involve sharing of returns below a lower threshold, above an upper threshold, or as we emphasize in this section, both.

How do sharing models work?

For illustration, we discuss two types of profit-sharing models. Similar revenue-sharing arrangements have been used in road and transit PPPs in Europe, Latin America, and Asia.[65]

Proportional sharing of high and low returns

Sharing contracts can insulate both parties when demand deviates substantially from initial forecasts by allowing the private partner to retain all profits in a central range of the rate of

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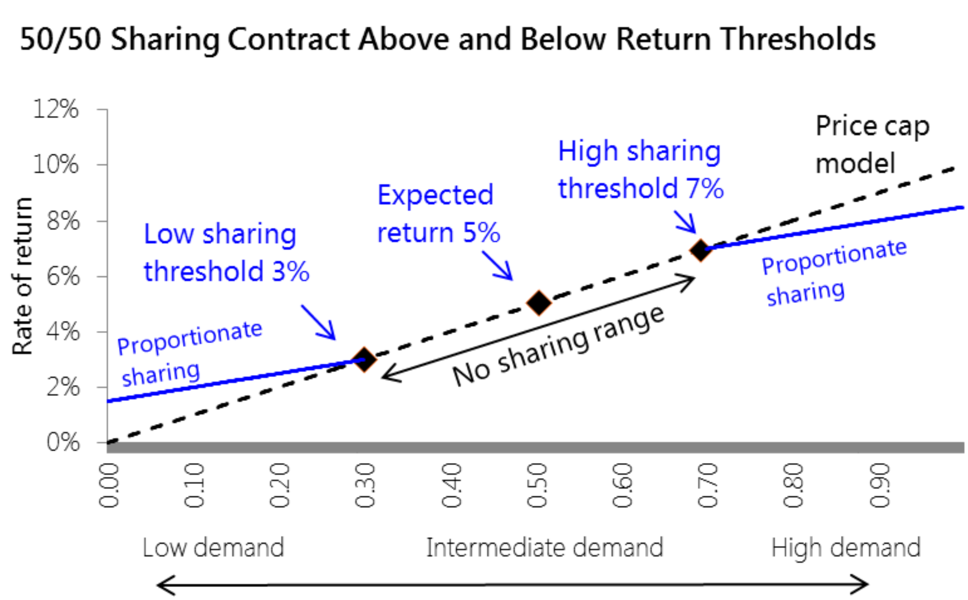
[65] Variations of sharing are used in a number of countries. On Federal Trunk Roads in Germany, approximately 20 percent of toll revenue is allocated to the toll operator for operating the electronic toll charging system, while the remaining 80 percent is allocated to enhancing federal transport networks. *See* Böger, Torsten R. "PPP Projects in Germany." Presentation at Konference om OPP med fokus på transportsektoren, May 27, 2014. http://www.toef.dk/file.php?name=/files/OPPHorten/Torsten%20B%20VIFG.pdf (accessed March 9, 2015). London Underground PPP contracts specify the allowable rate of return on equity and allow for a review of outputs and prices every seven and one-half years, including an extraordinary review if costs become significantly out of line with baseline assumptions. *See* Stern, Jon. "The Role of the Regulatory Asset Base as an Instrument of Regulatory Commitment." *European Networks Law & Regulation Quarterly* 2, no. 1 (2014): 15-27. and Bolt, Chris. "Regulating by Contract and License – The Relationship between Regulatory Form and its Effectiveness." Presentation at University of Bath School of Management, Bath, UK, March 20, 2007. http://www.bath.ac.uk/management/cri/pubpdf/Occasional_Lectures/19_Chris_Bolt.pdf (accessed March 11, 2015). The concession contract for the A28 Toll Motorway in France provides for revenue-sharing between the concession company and public sponsor, equal to 8 percent initially and growing to 18 percent when cumulative cash flows reach contractually determined thresholds. *See* Goavec, Jean-Yves. "The A28 Toll Motorway – An Innovative Approach to Financing." Presentation at European Transport Conference, Strasbourg, France, August 10, 2003. http://abstracts.aetransport.org/paper/index/id/1577/confid/9 (accessed March 12, 2015). Public authorities in Chile, Colombia and Korea have various forms of shared revenue risk according to ranges of revenue, e.g. if revenue rises above a threshold the concessionaire compensates the public authority (and conversely). *See* Vassallo, Jose M. "Traffic Risk Mitigation in Highway Concession Projects – The Experience of Chile." *Journal of Transport Economics and Policy* 40, no. 3 (2006): 359-381.; Irwin, Timothy. "Public Money for Private Infrastructure – Deciding When to Offer Guarantees, Output-Based Subsidies, and Other Fiscal Support." Working paper, The World Bank (2003). http://elibrary.worldbank.org/doi/pdf/10.1596/0-8213-5556-2 (accessed March 12, 2015).; and Kim, Yong-Seong. "Public and Private Partnerships in Korea." Presentation at the Third Session of the United Nations Economic Commission for Europe Team of Specialists on Public-Private Partnerships, Geneva, Switzerland, April 19, 2011. http://www.unece.org/fileadmin/DAM/ceci/ppt_presentations/2011/TOS_PPP3/5.3_Yong-Seong_Kim.pdf (accessed March 12, 2015).

return, corresponding to the most likely outcomes, while permitting profit-sharing outside that range. Consider a contract where the private partner retains all profits within the 3 to 7 percent range, but the government project sponsor shares 50-50 in any return shortfall below 3 percent or any returns in excess of 7 percent, as illustrated by, the graph below.[66] The upward-sloping dashed black line represents the rate of return under a pure price cap model, in which the private sector takes on all of the demand risk; the solid blue lines represent the private sector return above and below the negotiated return thresholds. The private partner keeps *all* of the return between the negotiated thresholds of 3 percent and 7 percent (the "Intermediate" demand range) and assumes all of the demand risk. In this range, in which there is no sharing, the contract operates like a pure price cap model. The incentives for cost efficiency and exposure to operations and maintenance risk are the same as in the price cap model.[67,68]



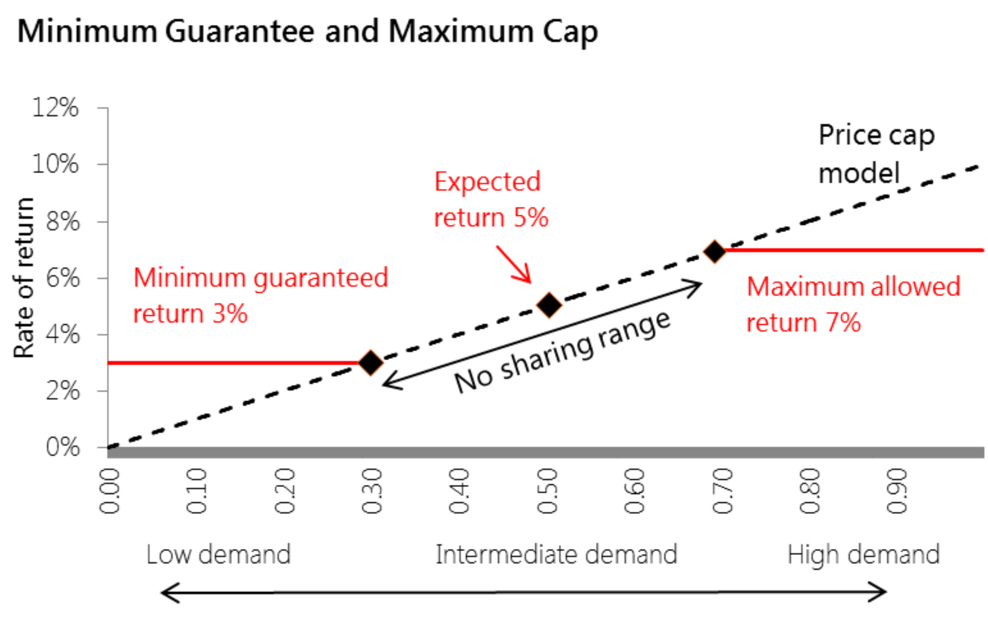
In both the "Low" and "High" ranges, demand risk, incentives for cost efficiency and exposure to operations and maintenance risk are qualitatively the same as in the rate of return model.[69] If

[66] By return, we mean: [revenue – (operations & maintenance expenses + depreciation + taxes)] /fixed assets. In a rate of return model, fixed assets would essentially correspond to the rate base.
[67] Since the price cap is constant within a given year, the extra revenue produced by an increase in demand along the x-axis, e.g. one additional vehicle on a toll road translates into a higher rate of return on the rate base, which is shown on the y-axis. In this simplified example, costs are also assumed constant during the year.
[68] Engel, Eduardo, Ronald D. Fischer, and Alexander Galetovic. "The Basic Public Finance of Public-Private Partnerships." *Journal of the European Economic Association* 11, no. 1 (2013): 83-111.
[69] In the Low and High ranges, the closer the blue line is to the dashed black line, the more efficiency incentives and risk exposures resemble the price cap model, while the closer the blue line is to the horizontal, the more incentives and risk exposures resemble the rate of return model with very frequent (i.e. instantaneous) price adjustments. If there is a demand shortfall, for instance, and a price increase is implemented to reestablish the rate of return *along the blue line*, the size of the required price increase will be smaller than otherwise, because the allowed return in the Low range is less than three percent. As a result, the public sector still has exposure to demand risk, but the magnitude of the exposure is reduced compared to the rate of return model.

demand falls into the Low range, the private firm will absorb just half of the shortfall between the 3 percent threshold and the actual rate of return, experiencing the return illustrated by the solid blue line. The government will either compensate the private partner for half of the shortfall below 3 percent either by raising taxes, issuing public debt, or reallocating funds from other public uses, or it may allow the private partner to adjust prices quickly to raise the rate of return in future periods. The PPP contract would stipulate whether returns outside the no-sharing range would be addressed with payments between the project sponsor and private partner, with price adjustments, or a combination.[70] Similarly, if demand reaches the High range, the private firm will share half of the return above 7 percent with the project sponsor, such that the retained return increases less steeply, as illustrated by the solid blue line. The private partner will pay the government an amount equal to half the return above 7 percent, which the government may use to make public investments in other parts of its regional economy, lower taxes, or retire debt. The contract may also call for the price to be adjusted going forward.

Minimum profit guarantees and maximum profit cap

PPP contracts can also be structured to provide complete downside protection to the private partner in exchange for a limit on the upside. Consider a contract that provides the private partner a minimum guaranteed return of 3 percent and a maximum return cap of 7 percent, as illustrated by the graph below. The upward-sloping dashed black line again represents a pure price cap model in which the private partner bears all of the demand risk; the solid red lines represent the private partner's minimum and maximum allowable returns at the negotiated return thresholds.



[70] A PPP contract could use payments to adjust for the past shortfall and price increases to prevent future shortfalls; alternatively, it could call for price adjustments large enough to compensate for the past return shortfall and prevent future shortfalls.

As in the previous example, the private partner keeps all of the return between the negotiated thresholds of 3 percent and 7 percent (the Intermediate demand range) and assumes all of the demand risk. In the no-sharing range, the contract operates like a pure price cap model without any sharing, and incentives for cost efficiency and exposure to operations and maintenance risk are the same as in the price cap model. However, in both the Low and High demand ranges, demand risk, incentives for cost efficiency, and exposure to operations and maintenance risk also match the rate of return model.

Compared to the 50-50 proportional sharing model discussed above, the *magnitude* of the subsidy to the private partner or payments to the project sponsor are larger. If demand falls into the Low range, the private firm will avoid the *entire* shortfall between the 3 percent threshold and the actual rate of return, earning the return illustrated by the lower solid red line. To cover this shortfall, the government will compensate the private firm for the entire shortfall below 3 percent by raising taxes, issuing public debt, or reallocating funds from other public uses; depending on the terms of the PPP contract, it may also allow the price to be increased quickly to prevent future shortfalls. If demand reaches the High range, the private firm will receive a constant return of 7 percent. The private partner will pay the government an amount equal to the entire return above 7 percent, which the government may use to make public investments in other parts of its regional economy, lower taxes, or retire debt. The PPP contract may also call for price reductions to bring future returns into the 3 to 7 percent range.
Which contractual form is most attractive to investors and project sponsors will depend on risk appetites and return expectations. Relatively risk-averse investors or investors with low confidence in the demand forecasts may be willing to accept a maximum return cap in exchange for being fully protected if returns are much lower than expected. Investors who are willing to assume greater risk and are more optimistic about demand may prefer the first contract because it offers higher return potential in exchange for less protection on the downside.

Summary

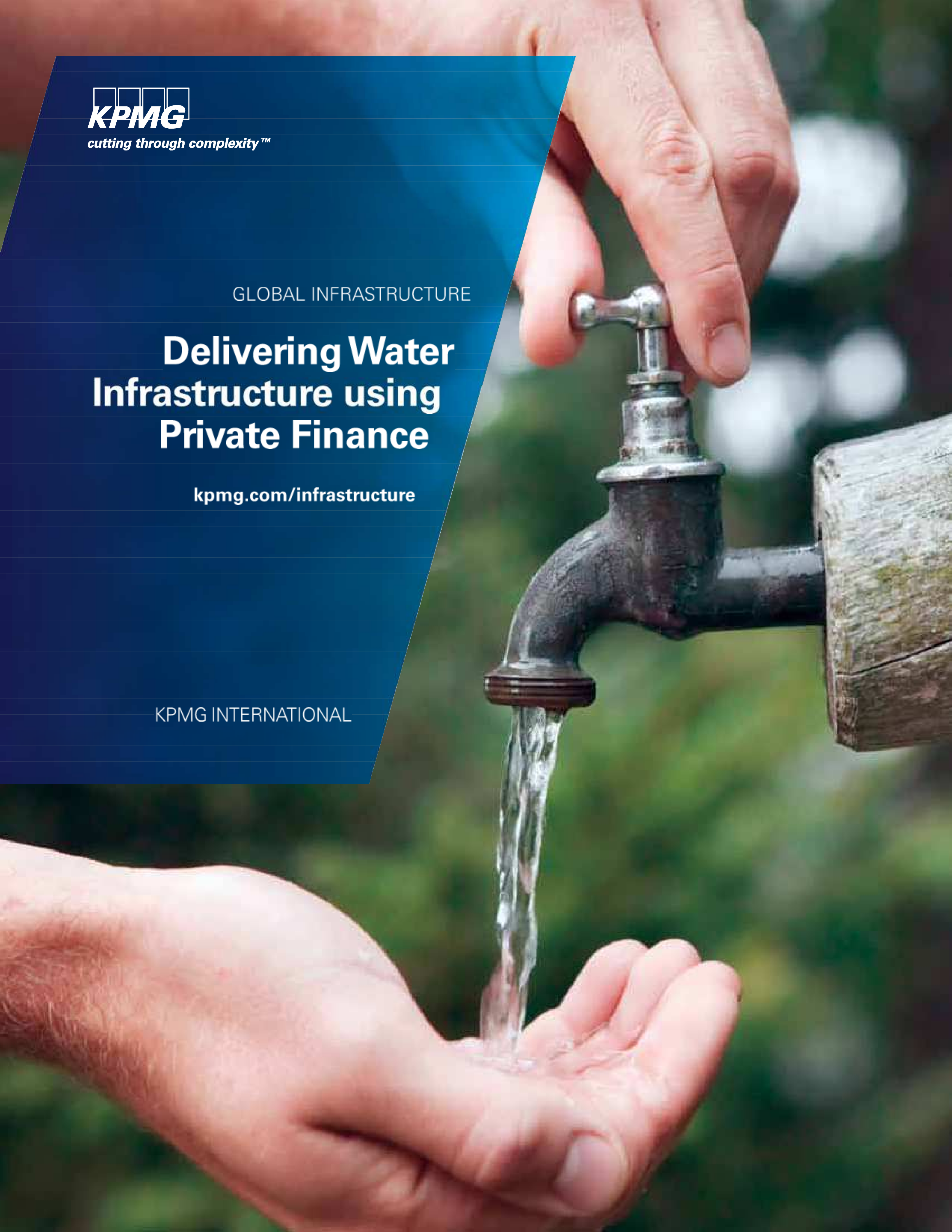
Sharing models retain the private partner's financial incentive to increase profits while aligning the interests of government and investors. Moreover, for greenfield projects ― where demand projections are most uncertain ― sharing the impact of large forecast errors reduces the risk of contract renegotiation. Arrangements that include sharing when returns fall below contracted rate of return thresholds would partially insulate the private firm from the demand shortfall, reducing the risk that the project company enters bankruptcy or seeks to renegotiate to avert bankruptcy.

Sharing models can also protect the project sponsor and local stakeholders against underestimation of demand or large rate increases by the private partner. If demand is much higher than expected, the government will receive revenue that it can deploy to make other investments, lower taxes, or retire debt. The benefit of the shared revenue to the government and its constituents should reduce the government's incentive to renegotiate. Similarly, the sharing of returns above an upper threshold will dampen the private partner's incentive to raise prices to a level that would drive returns above the threshold.

IV. Conclusion

Realizing the potential benefits of PPPs for taxpayers — including lower costs, better service quality and faster project delivery — depends on allocating project risks to the party best able to manage them. Arguably, demand risk is the most important source of uncertainty affecting the financial viability of an infrastructure project in which user volume determines the private partner's compensation, particularly in the case of new build, or "greenfield" projects, for which no history of use exists.

We introduce three incentive structures for PPP contracts that may benefit both public sector sponsors, by creating value for taxpayers, and private investors, by generating attractive returns. Applying principles from the regulation of privately-owned energy and telecom infrastructure to PPP projects in which the private partner assumes temporary control of the infrastructure, the proposed approaches are designed to broaden the scope for PPP negotiations that voluntarily incorporate some of these features into PPP contracts. This process can help to create options attractive to investors and sponsors with risk preferences and return expectations not accommodated by more commonly used models. By aligning investor and sponsor interests, these incentive structures have the potential to increase the number of PPP deals and increase the odds of the projects' long-term success.



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Contents

Introduction

Water is vital to human survival, but it is also a precious commodity ruled by the same forces of supply and demand that govern other markets. The cost of producing water where it is plentiful is significantly cheaper than in arid countries.

Treating raw water, making it available to the public, and managing wastewater are expensive processes. The average cost to desalinate seawater is USD 1,000 per cubic meter per day (m^3/d) and USD 400 per m^3/d to treat wastewater, bearing in mind the average per capita daily consumption in the Gulf Cooperation Council or in the United States is in the range of 400 to 500 liters. Typically, the average capital investment in water projects runs between USD 200 million to USD 300 million. To manage the cost of infrastructure assets, governments have long used available funding methods, such as user fees, taxes, and municipal bonds. However, some governments are embracing concessions and other forms of Public Private Partnerships (PPPs or P3s) to help turn a significant short-term financial cost into a long-term financial proposition for sponsors. Under such deals, a private sector provider commonly designs, builds, finances, and operates a plant, receiving payment on the basis of the availability of the facilities and for the amounts of water actually provided. These contractual relationships between public and private entities involve aligning a significant investment of private capital, transferring some risk to the private sector, and increasing the public benefit from public infrastructure.

This white paper examines the risks and rewards of water PPPs and discusses how municipal governments and potential investors can benefit.

Using private finance to build, operate, and maintain water infrastructure

Water: Vital commodity

Although more than 70 percent of the earth is covered by water, it remains an extraordinarily valuable commodity in arid regions such as the Middle East, Asia Pacific, and Africa. Governments have been driven to improve water infrastructure by the twin requirements of improving water supply in regions subject to scarcity and enhancing the effectiveness of wastewater treatment and recycling.

There are three principal water services that governments provide for their citizens:

- Water Treatment Plants (WTPs) and distribution to customers
- Wastewater Treatment Plants (WWTPs) and collection
- Wastewater recycling (treatment technology has advanced to the point that sewer water can be cleaned and repurposed for irrigation, industrial use, or aquifer recharge)

Regional trends

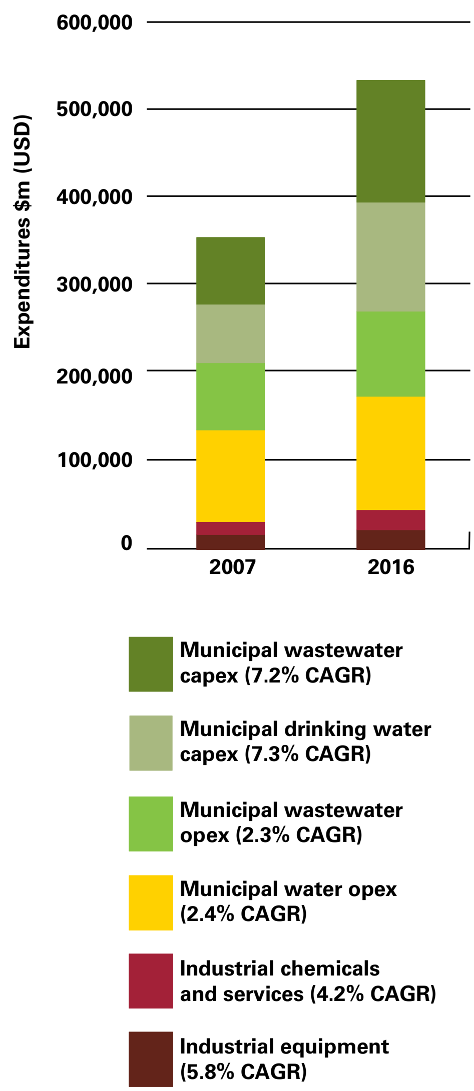
Investments in the water sector are expected to total more than USD 6 trillion over the next 20 years, according to Siemens Financial Services.

As illustrated by the chart to the right, demand for investment in water infrastructure is projected to increase substantially. But not every region has the same water needs and challenges. For instance, the Asia Pacific region is driven by growing population densities such as China, where there is an emphasis on efficient management of water resources and a pressing need to upgrade wastewater facilities.

Growth in the Middle East and Africa is driven by scarcity, population growth, and broad economic development, which means there is a large need for desalination facilities and an urgent need to increase treated wastewater reuse.

The needs in Eastern Europe are not driven by population density or scarcity of supply, but rather by European Union (EU) regulations that require new entrants to comply with EU water and wastewater standards. These countries must therefore upgrade their wastewater facilities to be accepted into the EU and benefit from its economic opportunities.

Global water market growth 2007–2016



Source: *Global Water Intelligence (2007)*

The long-term nature of a PPP increases financial flexibility while providing dependable cash flow.

Traditional vs. privately financed procurement

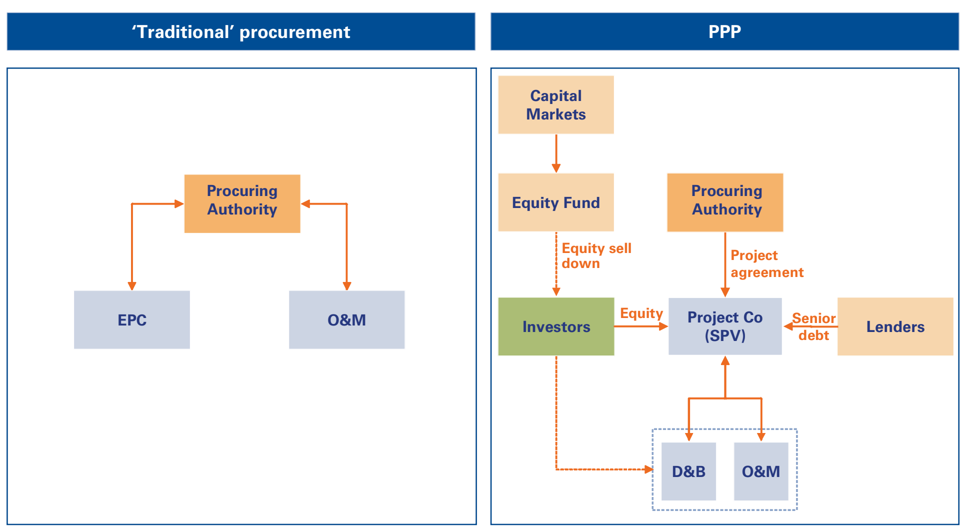
Traditionally, governments have addressed the cost of building and maintaining water plants and networks by collecting user fees, raising taxes, and issuing bonds against those revenue streams. The government entities assume most of the financial risks for the project such as construction delays and repair costs.

However, shortages of capital funding and rising maintenance costs of old and failing facilities, as well as more stringent environmental standards, have placed many governments in the position of needing to undertake substantial capital replacement, refurbishment, or expansion of their facilities without sufficient available capital.

The fundamental basis of privately financed transactions, whether concessions or PPPs, is that they provide a proven mechanism for governments to alleviate the need for direct capital expenditure on new facilities while also potentially improving service provision.

Under many of these structures, a private sector operator is contracted to design, build, finance, and operate a plant and/or a network, borrowing capital from a lender, either through debt or bonds, and investing equity. The provider then receives payment from the government and/or the end users for the duration of the contract that covers the cost of operations, repays the loan, and provides a return on investment.

Privately financed transactions: A very different game

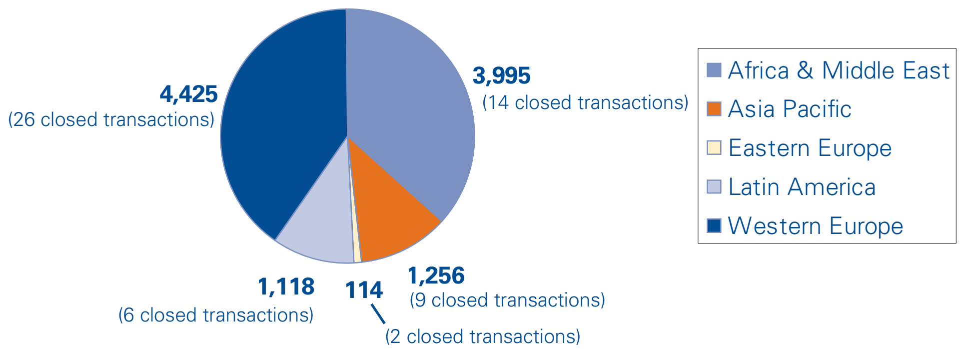


Source: *KPMG International, 2010*

EPC – Engineering Procurement and Construction
O&M – Operate and Maintain
D&B – Design and Build
SPV – Special Purpose Vehicle

The long-term nature of a PPP provides a source of dependable cash flow for project sponsors (contractors, operators, and other long-term private sector investors that invest in public infrastructure). Both the PPP investment capital and the PPP infrastructure projects are often public in nature. Although these transactions bring together groups with traditionally different objectives – public needs vs. private interests – they are bound by a common commitment to deliver long-term benefits to society as a whole.

Cumulative value of closed transactions since 2005 (in USD millions)



Source: *KPMG International, 2010*

Private financing in the water sector – a proven strategy

Private sector participation is a proven strategy in the water sector, as demonstrated by the steady growth in the number of projects and by the diversity of new entrants into this market.

Internationally, there are many types of active projects, including:

- Concessions (e.g. in Italy, Morocco or China)
- Leases and affermage contracts (e.g. in Cameroon, the US, Armenia or Russia)
- Management contracts (e.g. Oman, Saudi Arabia or Algeria)

Why involve the private sector?

Private participation can help where public sector reform is not enough. By engaging a private sector firm, governments widen their reform options by:

Creating a focus on service and commercial performance

A well-designed private participation arrangement will hold a private firm accountable for its contribution to service improvements and reward it for controlling costs and introducing a businesslike approach to billing and collection. This can translate into a changed culture and attitudes, creating an organizational focus on providing service at least cost.

Making it easier to access capital

Providers of finance, such as banks and the bond markets, may be more willing to put their money in a utility if they see it has a credible, commercial management approach. Having a private firm run the utility is one way to provide that credibility.

Just as important is what private firms cannot do:

No free money

Involving a private firm can make it easier to get finance for the water sector. But finance will only be provided when the operating cash flows of the utility are expected to provide a return on the investment and repay the investment over time. In other words, the cost of service ultimately has to be met by customers or, if the government agrees to provide subsidies, taxpayers.

No unlimited risk-bearing

Private firms are able to manage many risks, such as (depending on the circumstances) billing customers properly, controlling operating costs, and expanding networks. But they will be cautious about accepting major risks beyond their control, such as droughts or rapid exchange rate changes, and they will price accordingly if asked to bear these risks. Private firms will also want to know that governments will respect the rules of the game and not create risk by changing policies mid-stream.

Government responsibility continues

Citizens will continue to hold governments accountable for the quality of their water services. Governments do not usually escape this accountability by involving the private sector. Rather, governments need to consider whether delegating some service provision responsibilities to a private firm will make it easier to ensure that the services that people want are provided.

Governments do not escape accountability by involving the private sector.

Opportunities

Privately funded water facilities can offer investors and public entities long-term benefits. Following is a sample list:

- *Multiple vs. single service providers:* Competition for integrated (i.e. design, build, finance, and operate) long-term contracts focusing on public service outcomes can harness private sector creativity, resulting in innovations that better serve the public interest. To achieve these innovations, the procurement process requires transparency and accountability throughout the contract. A limitation of the design-bid-build (which is most common to the US market) process is that the public agency only sees the architectural and engineering solution

A case for water P3s in the US

The United States appears to be a prime candidate for PPPs, especially since state and local budgets have been significantly impacted by the collapse of the US housing market. The collapse and the subsequent credit crunch have contributed directly to depressed property values, resulting in reduced proceeds from property taxes, tighter credit, and wider municipal budget gaps.

Many municipal infrastructure projects, including the upgrading of long-neglected United States water and sewer systems, were conceived when funding from taxes was steady and commercial bank capital was readily available at attractive rates. Tougher economic conditions in the US have left state and local treasuries looking for a massive cash infusion from the federal government in order to help pay for vital municipal services and infrastructure rebuilding. Although the Drinking Water Revolving Fund makes funds available for building and maintaining community water systems, communities that are particularly stretched may be inclined to reach out to private investors and the innovative financing of PPPs to help bridge municipal budget gaps.

Over the past several years, a few successful PPP projects in the US have demonstrated to municipal officials the potential of using PPP methods to meet their water and wastewater systems needs. These successes appear to be helping PPP become a more familiar and acceptable tool in industry and have contributed to increased interest in exploring PPP solutions across the country.

of one service provider, with one combination of cost, quality, and time attributes. A single service provider, however, is never in a position – either technically or financially – to fully consider and compare all alternatives for design, technology, initial, or life cycle costs. As a result, the single service provider's limitations become those of the owner.

- *Advantages of multiple service providers:* Innovative procurement processes permit the owner to review multiple design concepts from multiple service providers. The design-build, design-build-operate-maintain, and design-build-finance-operate project delivery systems, as well as their derivatives, increase the amount of conceptual and functional design done by proposing parties. Thus, the government can evaluate several design concepts, which also integrate the life cycle tasks of production and maintenance to varying degrees.

Projects spectrum

The contractual arrangements typically used for these transactions span an entire spectrum, from simple management contracts to partial or full-scale divestiture.

All refer to financial and commercial arrangements with the following defining characteristics:

- Long-term contractual arrangement
- Public sector retains strategic control over service delivery – by setting the specifications and regulating prices
- Private sector contractor takes full responsibility for design, delivery, and operations and accepts the responsibilities and risks of delivering the project
- Payments are made by one or both of the following:
  - Users of the service (e.g. water rates or connection fees)
  - The public sector partner for performance and availability and, in some cases, usage
- Whole life costs are minimized
- Designed to encourage the most efficient use of public sector resources (i.e. value for money)

In traditional procurement, the public is in charge of financing and the contracting authority has all the business responsibilities: it is responsible for managing the business, operating and maintaining the assets, investing in new assets, and financing the business. In concessions, the operator has practically all the business responsibilities (business responsibilities exclude such policy responsibilities as setting tariffs and quality standards). In management contracts, affermages-leases, and hybrid arrangements, business responsibilities are shared between the operator and the contracting authority. A big part of designing the arrangement is deciding how to allocate business responsibilities between the operator and the contracting authority.

Risks come about because the world is unpredictable. For instance, demand for water services may be higher or lower than forecasted. Costs may be higher or lower than forecasted. Exchange rates will change. The question is who should bear these risks? Who should bear the losses or experience the gains? If the operator bears cost risks, for example, then the operator makes bigger profits if costs fall and smaller profits – or losses – if costs rise. On the other hand, if customers bear cost risks, then customers lose if costs rise and win if they fall; the operator's profits are unaffected.

It is useful to think about responsibilities and risks together. Operators may be given responsibility for the things they are able to do better than government, and may take the risks naturally associated with those responsibilities. For example, if the operator is responsible for collections, it will often be a good idea for the operator to bear collection risk (that is, for the operator's profits to depend in part on the utility's ability to collect what customers owe).

Allocating risks

Appropriate and acceptable allocation of risks can be complex and requires careful consideration.

The key is to ensure that project agreements reflect an acceptable risk allocation mechanism for all parties. This is not simply a question of identifying output specifications and performance standards. It also means recognizing the practical constraints, i.e. policy, managerial, and operational, that could restrict the private sector from developing an optimal solution.

Risk can be divided into two broad categories:

1. *Operation-related risks* – the set of risks associated with operating and maintaining service
2. *Investment-related risk* – the set of risks associated with investment in new infrastructure, for example, extending a distribution network, developing a new bulk water source, or constructing a new wastewater treatment facility.

Within these broad categories, there are many more specific risks associated with particular responsibilities or aspects of the operating environment. The figure on the next page illustrates the relationship between key risks and how they ultimately affect cash flows. Each box is associated with a specific risk: a variation in any of these parameters will flow through to cause an increase, or a decrease, in the total value of the business.

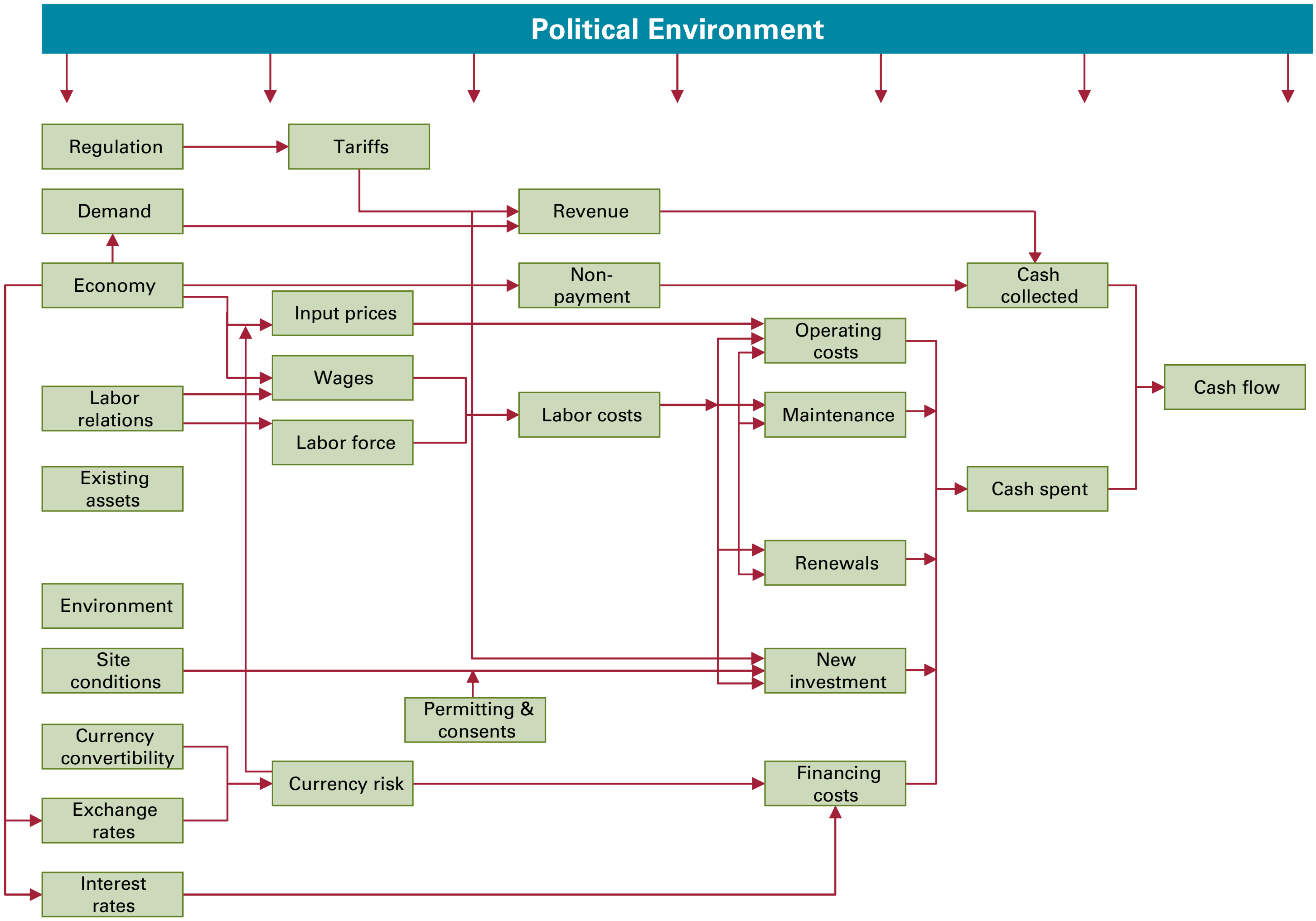
Identifying and allocating risks is complicated for several reasons:

There are multiple risks. Many risks affect the water sector, including demand, cost, construction, nonpayment, etc.

One risk is often a bundle of other, more specific risks. For example, construction risk can include unpredictable variation in input prices, the condition of the construction site, or in the cost or availability of labor.

Risks are interrelated. An unexpected change in demand, for example, will influence revenue, operating and maintenance costs, the need for new investment, and the need for financing. Depending on the tariff-adjustment rules, a change may also lead to new tariffs, which, in turn, influence demand.

To illustrate the considerations involved in deciding how specific risks should be allocated, it is useful to focus on an important risk: demand risk.



Source: *The World Bank – PSP Toolkit*

Demand risk

Demand risk affects many elements of the water and sanitation sector and can have a significant impact on business value. Fluctuations in demand can make new investments too big or too small, which can increase costs. Demand risk can affect all parts of a water and sanitation company, including commercial performance, operation and maintenance, and new investment.

Given the potential business impact of demand variations, it is important to consider carefully who is best placed to bear demand risk.

Who can best predict changes in demand? Private water and sanitation companies generally have the technical expertise needed to derive reasonable projections of demand as long as data on historical usage, customer numbers, and economic and demographic trends are available and accurate.

Different approaches

A Middle East–based property developer
Albeit having slowed down since the financial crisis, there is still a trend in the Middle East for large-scale developments where all utilities can be delivered through concessions (water, wastewater, power, etc.). Examples include Palm Islands in Dubai and the King Abdullah Economic City in Saudi Arabia, which will eventually be home to more than a million people and include a variety of economical industrial activities.

The many reasons why these property developers decided to rely on private funding to procure the utilities include:

- Accessing private sector financing and leveraging their own funds for other priority projects
- Fulfilling the utilities' needs within the developments faster than traditional procurements
- Creating a market that maximizes interest and competition among potential concessionaires, including both international and local players, and increases value for money for the end users

Structuring these concessions represents particular challenges, e.g. in terms of demand-risk allocation and minimum off-take guarantees to be provided to the concessionaires (as the population is not yet there). But these concessions also enable the developers to better attract and retain businesses and industries and use their own funds for more suitable purposes.

Moreover, these concessions represent a higher value to developers than traditional EPC contracts. The developers may benefit by setting up their own utility company, which would retain a stake in the projects and receive part of the profits generated by the concessionaire.

Who can influence the risk? Influencing the demand for water services is difficult. Once customers are connected, they can use as much or as little water as they wish. But customer behavior can be influenced through metering policies, changes in tariffs, legislated rationing, and public relations campaigns to discourage waste.

Who can control the impact? Operators can mitigate the impact of unexpected demand variations by adjusting maintenance and investment programs. If demand falls, the operator might defer a planned water source expansion or cut back on leakage reduction. Conversely, if demand increases unexpectedly, the operator might seek to optimize system capacity by increasing investment in leakage reduction.

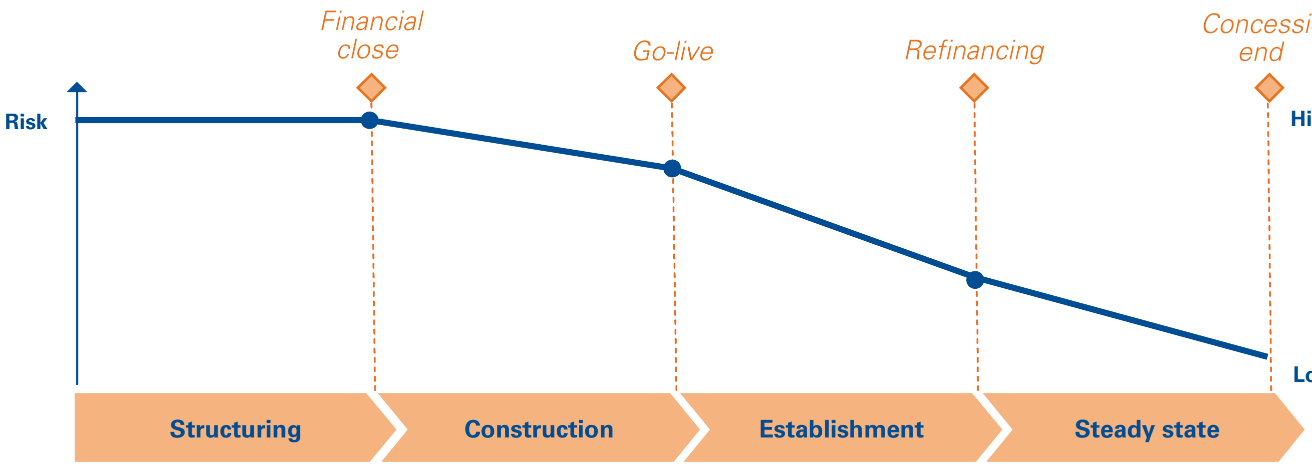
Who can diversify or absorb the risk? The ability of water and sanitation companies to absorb demand risk is limited by their cost structure. A large proportion of costs is fixed. So when demand falls, the average cost to the operator of delivering each unit of water rises. Therefore, it is at least plausible to allow tariffs to increase if demand is substantially below forecast levels. If tariff-setting rules leave demand risk largely with the operator rather than customers, the operator's overall risk exposure increases significantly, and the sustainability of the arrangement may be threatened.

The extent to which demand risk is shared between the contracting authority and the operator depends on the particular circumstances of the project, including the availability of good information on demand, economic stability, and the operator's willingness to accept risk. In practice, operators will be reluctant to fully assume demand risk and will seek to pass it on to customers in tariffs or reduced service levels, or to enter into a take or pay, where their payments are not directly linked to the volume of service consumed.

Risk allocation under different private sector participation models

Each of the standard models of private participation – management contracts, leases, and concession – is associated with, and to some extent defined by, a particular allocation of responsibilities and risks. One way of designing the arrangement is to determine whether one of the three standard models (management contracts, lease and concession) can deliver the desired

Evolution of project risk



Source: *KPMG International, 2010*

outcome. In practice, allocation of risk and responsibility under these three standard models may not match the preferred outcome. If this is the case, a tailored or hybrid approach can be developed to achieve the desired allocation. Hybrids of different models are common.

Management contract

Under a management contract, the operator fills key management positions in the water company with appropriately skilled staff. The publicly owned water company continues to be accountable for other responsibilities – operating and maintaining existing assets and undertaking new investment. The risk transferred to the operator depends on the performance bonus. If there is no performance bonus, the operator bears the risk of not being paid by the contracting authority, but bears little of the risks of the water business. If there is a performance bonus, the formula for the bonus determines in large part how much risk is shifted to the operator. For typical management contracts, very little risk is transferred to the operator. (How risk is shared between the contracting authority and customers depends on rules governing tariff adjustment).

Affermage – Leases

Under an affermage or lease, the responsibility for operating and maintaining existing assets, plus commercial and management responsibilities, is passed on to the operator. The contracting authority retains responsibility for new investment. The risk transferred from the

contracting authority to the operator is usually significant, but it depends on the details of the contract and, in particular, the way the operator's remuneration is determined. Under an affermage, the tariff-adjustment rules that matter most are those applying to the operator's tariff (or affermage fee). Under a lease, the operator gets the customer tariff minus a lease payment, so the tariff adjustment rules that matter most are those that apply to the customer tariff.

Concessions

Under a concession, the operator assumes full responsibility for service delivery, management, operation and maintenance of existing assets, and new investment. The risk transferred from the contracting authority to the operator is usually substantial, but depends on the form of the contract (e.g. Will it be by way of transfer of ownership, exclusive lease, or license of site or assets?) and, in particular, the rules for adjusting the customer tariff. This concession-based approach does expose the private sector to substantial degree of risk (i.e. there is high exposure to regulatory and policy risks, with risks attached to contractual arrangements such as tariff revision formula). Risks that one would expect the private sector to bear under the concession model include operation, upgrade, and improvement of systems risk.

Hybrid models

Various types of customized risk-sharing arrangements are possible. These could include an "affermage-lease plus" arrangement. Under a standard affermage-lease the contracting authority retains full responsibility for undertaking and financing new investment. However, it may be desirable to transfer some responsibility for investment to the operator. For example, the operator is usually better placed to manage construction of new assets. Mechanisms for sharing responsibility for new investment include:

- *Limited investment targets for the operator.* For example, the operator could be given responsibility for extending service coverage to poor areas, or peri-urban neighborhoods, while the contracting authority retains responsibility for other investments.

- *Co-financing.* Co-financing agreements between the operator and the contracting authority, or a development agency, under which investment and finance costs and risks would be shared.
- *Sharing investment responsibility between the parties.* An affermage-lease contract can include responsibility for some investments (such as network extensions).

Other key considerations

In addition, public sector parties and private investors should be aware of the following:

- *Concession and PPP agreements are complex and require long-term commitments from both parties.* Because of the potential risks and returns involved, these agreements tend to be complex. Public sector agencies must be vigilant and secure experienced advisors to support them in negotiations and to bring proven practices to the table to protect the public interest. This means seeking legal, financial, demand and revenue forecasting, and engineering support.
- *There must be effective communication with stakeholders.* A common challenge facing innovative financing programs and projects is maintaining open, credible, and effective communications among interested stakeholders. This means clearly articulating the business case, or justifying the need for engaging in such a transaction. Such a business case must be articulated in clear, nontechnical language so all stakeholders can understand it. All too often, concession or PPP contracts contain technical, financial, and engineering jargon that is difficult for most stakeholders to understand. This technical language is not clarified in an overall business case, leading some to believe this is intentionally done to confuse public stakeholders into believing relying on private funding is the only way to proceed with needed projects.
- *Participants must navigate the learning curve:* The days of robust governmental funding have ended as the proceeds from taxes have failed to keep pace with infrastructure needs. Other nations have experienced successes as well as some failures through this process. There are lessons to be learned and a "learning curve" to climb. Still, the prospects for success are strong; otherwise, the private sector would not be willing to participate in such transaction.

Private sector participation can extract additional value from infrastructure in two principal ways – by monetizing future user charges and by improving long-term operational efficiency and effectiveness. Private sector creativity has a major role to play in creating value from infrastructure using both methods.

Extracting value from infrastructure

Monetization

Generally, user charges do not cover the cost of provision, but most domestic agencies have not aggressively adjusted charge rates to a market rate or a revenue-optimizing rate as there has been strong user resistance to raise them. This hesitancy to charge at market rates begs the question: Would people be willing to pay a higher charge in exchange for the certainty of getting water on demand?

Private sector concessionaires believe in the value of a fair charge and have been willing to make considerable upfront payments in exchange for a long-term concession. Nevertheless, the public sector retains fundamental control of the concession through administering the terms of the contract. Long after the concession agreement is signed, the following risks will remain:

- The private sector will likely bear the investment risk
- The public will bear the risk of future charge increases
- The governing agency will bear the risk of adverse public opinion if the concession is not well managed

The attempt to balance these risks to the public, the private operator, and the public agency will help assure that the agreement will result in enhanced water availability to the public, a fair return to the private company, and proper oversight by the governing agency. The two key considerations in the monetization of an asset are the term of the agreement and the flexibility in setting charge rates.

Water demand and pricing risk

The private sector must also manage the demand risk in calculating its upfront payment, while the governing agency must protect itself against excessive charge rate increases. The greater the ability of the concessionaire to raise charges, the larger the upfront payment they will likely make. Even though free market forces might permit a certain level of charge increases, governments must regulate the tolls to a reasonable level in the concession agreement. Governments must demonstrate to the public that they received value for the charge paid each and every time they use water.

The risks associated with poor projections

The high degree of financial leverage necessary to produce a winning bid on the part of the private entity may produce unintended results if the private entity cannot service the debt. Excessive or poorly structured debt could cause the private entity financial stress, increasing the need for a government takeover should the operator default. Any default could diminish the appetite in future concession deals.

Alternatively, if the private sector is initially excessively pessimistic about the project's cash flow and it actually results in significant profits, the result can be a policy backlash. No politician can justify excessive profits to the voting public. To protect against this risk, a properly designed concession agreement would provide for payments back to the governing agency in the event the private sector exceeds the maximum internal rate of return.

A final issue in monetization is the distinction between existing assets (brownfield assets) and new assets (greenfield assets). Brownfield assets have less demand risk because there is a history of demand patterns and there is no risk of construction cost overruns. Greenfield assets generally have a higher risk transfer to the private entity and, accordingly, may have higher implicit rates of return.

Operational efficiency

The traditional infrastructure procurement method used to budget construction, enhancement, maintenance, and/or operation of water facilities may result in suboptimal outcomes. That's because most government budgets are based on a one or two year budget cycle for operating costs, with capital projects subject to a five-year work plan. Often, governments may find themselves pressured to balance the budget by incrementally deferring maintenance or deferring capital projects – a process that may appear innocent on a project-by-project basis. But the exponential nature of deferring maintenance or capital projects over time can result in breakdowns in infrastructure or capacity shortages that compromise public needs.

Once a government gets behind in maintenance, it becomes very difficult to recover. The government is then put into a position of choosing between maintaining or rehabilitating existing infrastructure or building capacity necessary to fuel the growth in its economy. This dilemma can lead to unintended maintenance backlogs, substandard service quality, and life-cycle costs that are considerably higher than would have been achievable with optimal maintenance.

How private funding impacts operational efficiency

The long-term nature of concession and PPP contracts allows governments to build maintenance costs into the net present value of the monetization and assign responsibility for maintenance to the private sector. The private sector can plan and implement accordingly, since it focuses on the long-term internal rate of return, not the current-year budget cycle that can compromise service quality.

This long-term approach, often referred to as life cycle asset management, can be reflected in the innovative design and construction solutions for privately funded water facilities, such as using more expensive construction materials that may increase the investment cost but decrease the longer-term maintenance costs, thereby decreasing the total net present value of the project. Governments also have the ability to impose strict operations and maintenance requirements in concession agreements and lock in future maintenance costs. While this approach may decrease upfront payments from private concessionaires, governments can effectively remove the responsibility for maintenance from their budgets and thus not make those costs subject to year-to-year budget pressures.

Conclusion

Water is vital to human survival, and it is also expensive to treat, distribute, and recycle. Capital and maintenance funding needs – coupled with ongoing budget pressures – have necessitated governments to seek creative funding and project delivery options for building new water treatment facilities and recycling plants.

Relying on private funding can serve as a proven alternative to traditional infrastructure provision for leveraging scarce public resources and relieving the pressures on government entities. When considering whether private sector participation can serve their needs, both state governments and investors should consider the following:

- *Accessing private funding is a tool for public sector procurement that focuses on public service outcomes.* Infrastructure procurements have been traditionally based on money allocated to individual contracts compared to privately funded transactions that holistically seek value based on the outcome of the facility. In traditional procurements, state governments focus on meeting contract letting schedules and seeking the lowest cost bidder, instead of adherence to completion schedules and budgets. In concessions and PPP contracts, the focus is on the outcomes of quality projects delivered on time and within budget on a highly accelerated development timetable.
- *Private sector participation can harness private sector creativity and encourage efficiency for public benefit.* Competitions for integrated (i.e. design–build–finance–operate) long-term contracts focusing on public service outcomes harness private sector creativity, resulting in innovations that can serve the public interest.
- *Value can be extracted from infrastructure through monetizing future user charges and through improving long-term operational efficiency and effectiveness.* Concessions and PPPs create value from infrastructure in two ways: monetizing future user charges and improving long-term operational efficiency and effectiveness. Private sector creativity plays a major role in creating value from infrastructure using both methods.
- *The public sector retains full control even when relying on private funding.* These transactions encourage accountability as they retain the public sector client's fundamental control based on the contractual relationship between the two entities. If the public sector is dissatisfied with substandard service relative to the terms of the contract agreement, it can require the contractor to perform according to the agreed-to standards or terminate the contract based on a breach of the performance requirements contained in the contract terms.

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Bastien Simeon joined KPMG in France in 2007 after almost 10 years with Veolia Water, part of the Veolia Environment group – the world leader in environmental services.

An engineer by background, he has worked on numerous water projects in the Middle East (e.g. King Abdullah Economic City in Saudi Arabia), as well as Asia (e.g. the first water BOT in China, a 270,000 m^3/d water treatment plant in Chengdu), and Europe.

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