Salinity Management Plan

South Metro WISE Authority

TM 1 - Salinity Removal

February 2020

Salinity Management Plan

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Acronyms and Abbreviations

Ac	Acre
af	Acre Feet
afy	Acre Feet per Year
CWCB	Colorado Water Conservation Board
BWPF	Binney Water Purification Facility
Ca	Calcium
Cl	Chlorine
ECCV	East Cherry Creek Water and Sanitation District
EDR	Electrodialysis Reversal
ELACM	Engineering, Legal, Administrative and Construction Management
Hp	Horsepower
Hypo	Sodium Hypochlorite
kgal	Kilogallon (thousands of gallons)
LAS	Liquid Ammonium Sulfate
LF	Linear Feet
MF	Microfiltration
Mg	Magnesium
mgd	Million Gallons per Day
Na	Sodium
NF	Nanofiltration
O&M	Operations and Maintenance
Parker Water	Parker Water and Sanitation District
PS	Pump Station
PWP	Prairie Waters Project
RBF	Riverbank Filtration
RO	Reverse Osmosis
SAR	Sodium Adsorption Ratio
SMWA	South Metro WISE Authority
SO_4	Sulfate
TDS	Total Dissolved Solids
TM	Technical Memorandum
TSS	Total Suspended Solids
WDA	Water Delivery Agreement
WISE	Water Infrastructure and Supply Efficiency

1. Introduction

The purpose of this study is to explore options to mitigate elevated total dissolved solids (TDS) concentrations present in return flows from the South Platte River that will be delivered to the South Metro WISE Authority (SMWA) by Aurora Water and Denver Water as part of the Water Infrastructure and Supply Efficiency (WISE) project. When practical, options are configured to allow others in the region to also participate in and benefit from the salinity management solutions.

Key overall goals of this study include the following:

1. Investigate how desalination options can be configured to reduce salinity in South Platte River return flows.

2. Study options for brine disposal beyond deep-well injection.

3. Develop water blending concepts incorporating the extension of existing blending concepts and the identification of new blending concepts.

4. Gain increased insight into long-standing questions on inland salinity management and brine disposal principals.

The Salinity Management Plan required numerous interrelated evaluations to be performed. To effectively manage the work effort, the Plan has been broken into the following documents:

- Project Summary

- **TM 1 – Salinity Removal (this memorandum)**

- TM 2 – Brine Disposal

- TM 3 – Water Blending

1.1 Objectives of the Salinity Removal Evaluation

One option for managing salinity in unblended WISE water from the South Platte River is to physically remove it through a desalination process. Objectives of this portion of the project were to:

- Identify a range of potential salinity removal technologies that may be utilized by SMWA to meet their water quality goal for TDS

- Identify potential sites to locate a new desalination facility

- Develop example layout facilities on selected sites to provide an idea of land requirements

- Identify specific and plausible risks that could increase the salinity removal cost

- Determine the incremental increase in cost associated with each salinity removal risk

- Provide a summary of cost ranges

- Identify actions and next steps that will narrow desalination implementation uncertainty

1.2 Relevant WISE Background

The WISE Project is an agreement between SMWA members, Denver Water and Aurora Water. Denver Water and Aurora Water deliver their reusable return flows diverted from the South Platte River to SMWA as "WISE water," allowing SMWA members to reduce their dependence on non-renewable groundwater. WISE water is diverted from the South Platte via the Aurora Water Prairie Waters Project (PWP) Riverbank Filtration Wells (RBF Wells) at the Aurora Water North Campus in Brighton, CO and then treated at the Aurora Water Binney Water Purification Facility (BWPF)

Through May 31, 2030, Denver Water and Aurora Water are required, per the WISE Water Delivery Agreement (WDA), to deliver water with a TDS concentration at or below 500 mg/L. Currently, Denver Water and Aurora Water meet this water quality goal by blending some their low TDS mountain water supplies to reduce TDS concentrations in WISE water diverted from South Platte River return flows. Following May 31, 2030, the WDA allows Denver Water and Aurora Water to deliver unblended WISE water to SMWA.

Salinity in water diverted by Aurora Water's RBF Wells can vary from below 500 mg/L of TDS during spring runoff periods to above 700 mg/L of TDS during periods with lower flow, generally in the early fall and winter. Although the water quality agreement of the WDA expires in 2030, Denver Water and Aurora Water are still required per the WDA to deliver SMWA 100,000 acre-feet (af) of WISE water over defined 10-year periods. The WDA asserts that deliveries of WISE water from Denver Water and Aurora Water to SMWA can range from a daily flowrate of 0 million gallons per day (mgd) to 30 mgd. If Denver Water and Aurora Water delivered WISE water at a constant rate (100,000 af over 10 years), SMWA would receive approximately 9 mgd of daily flow. The flowrate range outlined in the WDA (0 mgd to 30 mgd) and the average flowrate (9 mgd) are the design flowrate ranges utilized in this study.

1.3 Information Referenced from Accompanying TMs

This TM focuses exclusively on salinity removal technologies and the accompanying **TM 2 – Brine Disposal** focuses on brine disposal. Key information to keep in mind when reviewing this TM include the following:

1.3.1 Information Referenced from TM 2 – Brine Disposal

- If injection wells are used for brine disposal, 2 wells would be needed for a facility designed for the average flow of 9 mgd and 4 to 6 wells would be needed for a 30 mgd facility depending on the performance of the injection wells.

- Based on limited available data, it is assumed that injection wells should be located between 0.75 – 1 mile (horizontally) from any neighboring injection well, and therefore brine disposal using deep-well injection requires footprint considerations for the treatment plant and injection well sites.

- If deep-well injection rates become unsustainable or non-permittable, brine could be concentrated to a dewatered salt waste through a mechanical evaporation processes (similar to distillation) and the dewatered salt waste could be disposed of at a non-hazardous or hazardous landfill (depending on the characteristics of the dewatered brine). Infrastructure for this technology can be over 100-feet tall and have an industrial appearance and would likely need to be located in an area zoned for industrial land use.

1.3.2 Information Referenced from TM 3 – Water Blending

- Unit costs for water conveyance facilities (pipelines, pump stations, etc.).

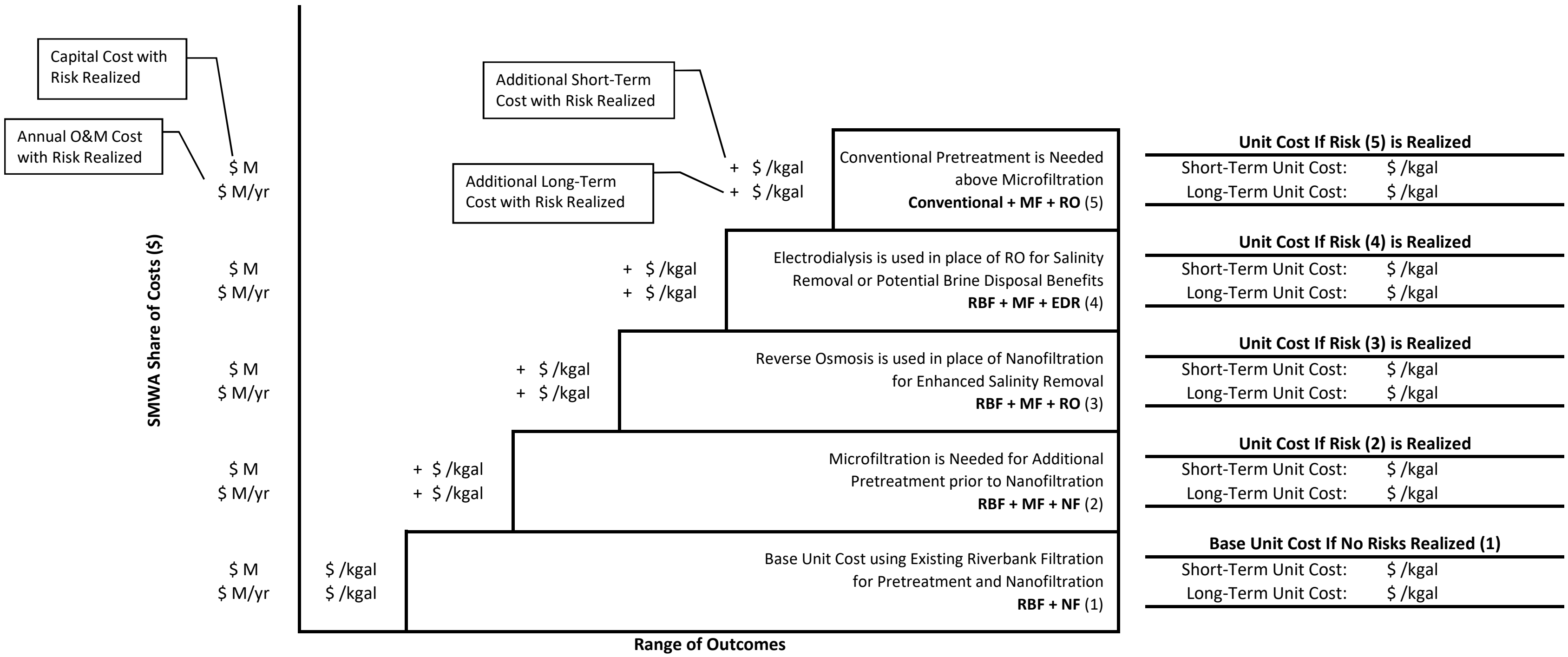
2. Potential Salinity Removal Processes

SMWA could physically remove salinity from their source water by constructing a desalination facility. A new salinity removal facility would need to be accompanied with a process for disposal of brine waste from the salinity removal process (see **TM 2 – Brine Disposal**).

Theoretically, several different salinity removal, or desalination, processes could be used to allow SMWA to meet their water quality goals. At this preliminary stage, the five desalination processes listed below are considered

- Riverbank Filtration + Nanofiltration (RBF + NF)
- Riverbank Filtration + Microfiltration + Nanofiltration (RBF + MF + NF)
- Riverbank Filtration + Microfiltration + Reverse Osmosis (RBF + MF + RO)
- Riverbank Filtration + Microfiltration + Electrodialysis Reversal (RBF + MF + EDR)
- Flocculation, Sedimentation, Mixed Media Filtration + Microfiltration + Reverse Osmosis (Conventional + MF + RO)

Note that RO or EDR could be used in the last listed desalination processes. **Figure 1** presents a template used in this TM to provide a relative comparison of costs among the above list of potentially required processes. The implementation of one process versus another would be based on the potential realization of water quality risks that would require a more robust desalination process.



Notes:

- Costs presented within the graph area and right of the graph area would be in addition to the base WISE water rate charged by Aurora Water and Denver Water
- Future WISE water rate is unknown and therefore not shown numerically on this schematic

Risk Details:

(1) Base cost assumes no additional cost for using AW Riverbank Filtration System for South Platte water and using Nanofiltration for Salinity Removal
(2) Microfiltration is needed in addition to Riverbank Filtration ahead of Nanofiltration
(3) Reverse Osmosis replaces Nanofiltration for salinity removal to remove monovalent ions unable to be removed by NF
(4) Electrodialysis Reversal replaces Reverse Osmosis for salinity removal, which may allow for optimization of salinity removal and brine disposal
(5) Aurora Water changes to surface diversion or other factors require additional pretreatment above Microfiltration.
Additional Pretreatment would include Rapid Mix, Flocculation, Sedimentation and Mixed Media Filtration (Conventional Treatment)

2.1 RBF Pretreatment

There are two primary methods that Aurora Water can use to divert water from the South Platte River at their North Campus: 1) Riverbank Filtration (RBF) or 2) surface water diversion.

RBF is a water diversion and treatment approach where wells adjacent to the river withdraw river water through the shallow subsurface alluvium of the river. RBF provides removal of suspended solids and potentially microorganisms and effectively “pretreats” the surface water prior to downstream treatment.

A direct surface water diversion does not provide this pretreatment benefit and therefore would likely require additional pretreatment prior to conveying to a subsequent desalination process.

Through discussions with Aurora Water, it was discovered that Aurora Water plans to continue to use a subsurface diversion system for both their existing and future expanded diversion system. Aurora Water would only convert to a surface water diversion if alluvium conditions resulted in an unexpected low water extraction rate from riverbank wells.

For this reason, RBF is assumed for all but one of the evaluated scenarios.

2.2 RBF + NF

Nanofiltration (NF) is a membrane filtration process that removes suspended solids, viruses, bacteria, protozoa, and divalent ions (charged ions with a charge of +/- 2, respectively). NF does not remove all ions responsible for total dissolved solids, but the divalent ions removed by nanofiltration reduces total dissolved solids in the treated effluent (permeate). The waste product from nanofiltration is a brine that contains the ions removed by the nanofiltration process along with suspended solids. The RBF + NF processes represents the least robust salinity removal option because it does not have any treatment processes between the RBF and NF processes and because NF only removes select ions.

Figure 2 shows a process flow diagram for the RBF + NF desalination process. Note that the “Concentrate Treatment / Disposal” step of this and each of the following process flow diagrams will be discussed in the accompanying **TM 2 – Brine Disposal** but is shown here for completeness.

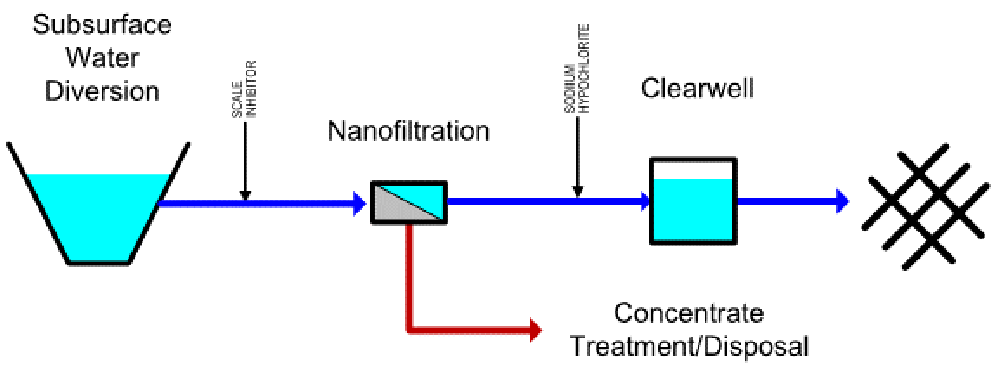


Figure 2. RBF + NF Process Flow Diagram

2.3 RBF + MF + NF

If it is either predicted or observed (via pilot or full-scale testing) that RBF does not sufficiently remove total suspended solids (TSS) and other particulates from the water prior to NF treatment, Microfiltration (MF) may be required. This process removes inorganic (e.g. metals), organics (e.g. TOC), and TSS that are commonly responsible for fouling membranes. It does not remove ions from the water supply, so MF cannot replace NF. MF only enhances water quality entering the NF process to potentially decrease the frequency of membrane fouling.

Figure 3 shows a process flow diagram for the RBF + MF + NF desalination process

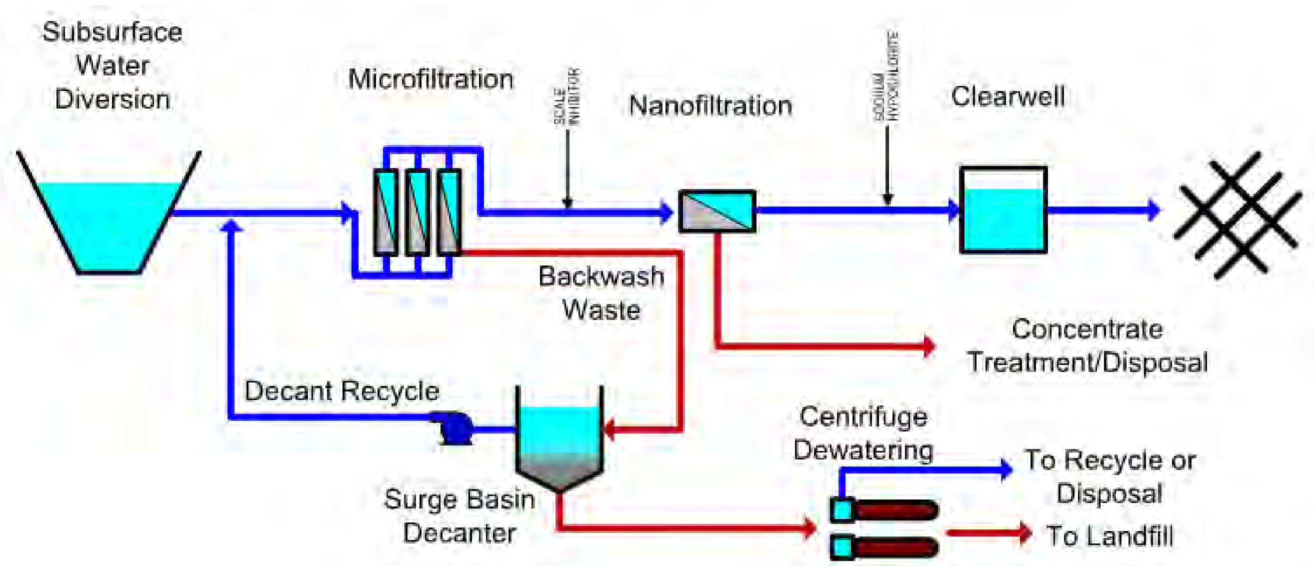


Figure 3. RBF + MF + NF Desalination Process Flow Diagram

2.4 RBF + MF + RO

If it is determined that removal of only divalent salts through NF does not sufficiently reduce total dissolved solids to meet SMWA's water quality goal for TDS, other salinity removal technologies may be employed. Reverse Osmosis (RO) membrane technologies may be implemented in place of an NF process. RO is like NF; however, it removes nearly all ions from the influent water supply, including monovalent ions (ions with charges of +/- 1) that the NF process does not remove. This results in a much lower TDS in the product water and higher concentrations of dissolved solids in the brine waste.

Figure 4 shows a process flow diagram for the RBF + MF + RO desalination process.

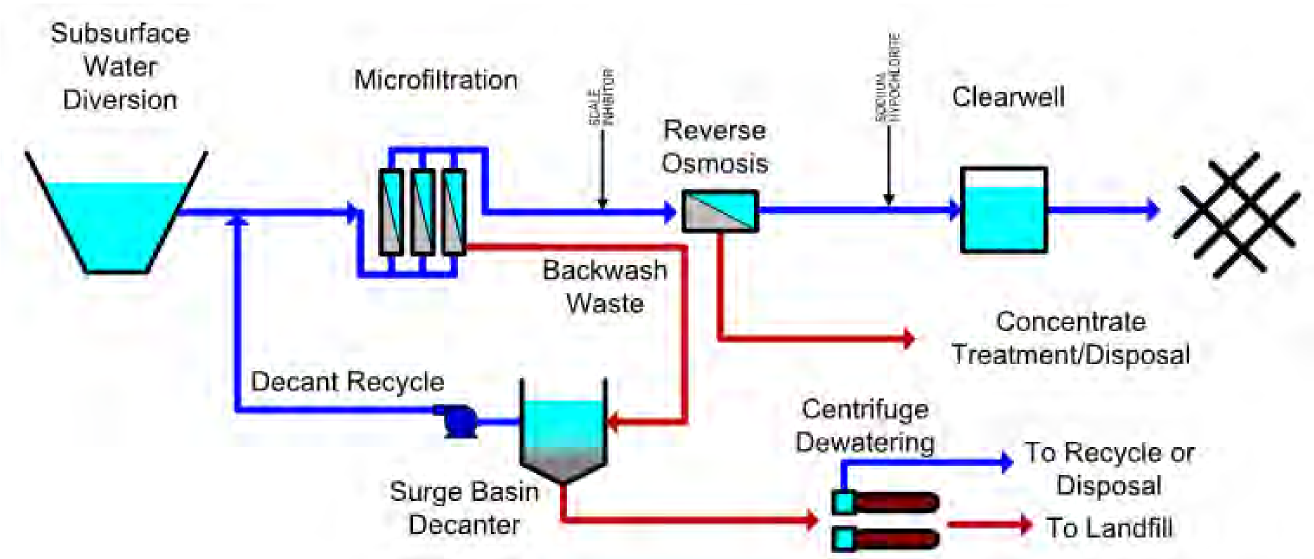


Figure 4. RBF + MF + RO Desalination Process Flow Diagram

2.5 RBF + MF + EDR

An alternative to RO that may offer the potential benefit of alternate brine characteristics is Electrodialysis Reversal (EDR), an ion removal process that could be utilized in place of RO. EDR uses a combination of membranes and a direct current electric field to separate charged ions from the water. This technology has been used to produce a brine stream that has lower sodium levels than brine from RO treatment processes and therefore the brine stream could potentially (under the proper conditions) be used for irrigation water on salt tolerant crops. This approach can have increased water loss (higher concentrate flow rate) to maintain suitable brine water quality for crop irrigation. However, using the brine for crop irrigation could be a more cost-effective brine disposal method than some other disposal options.

Figure 5 shows a process flow diagram for the RBF + MF + EDR desalination process.

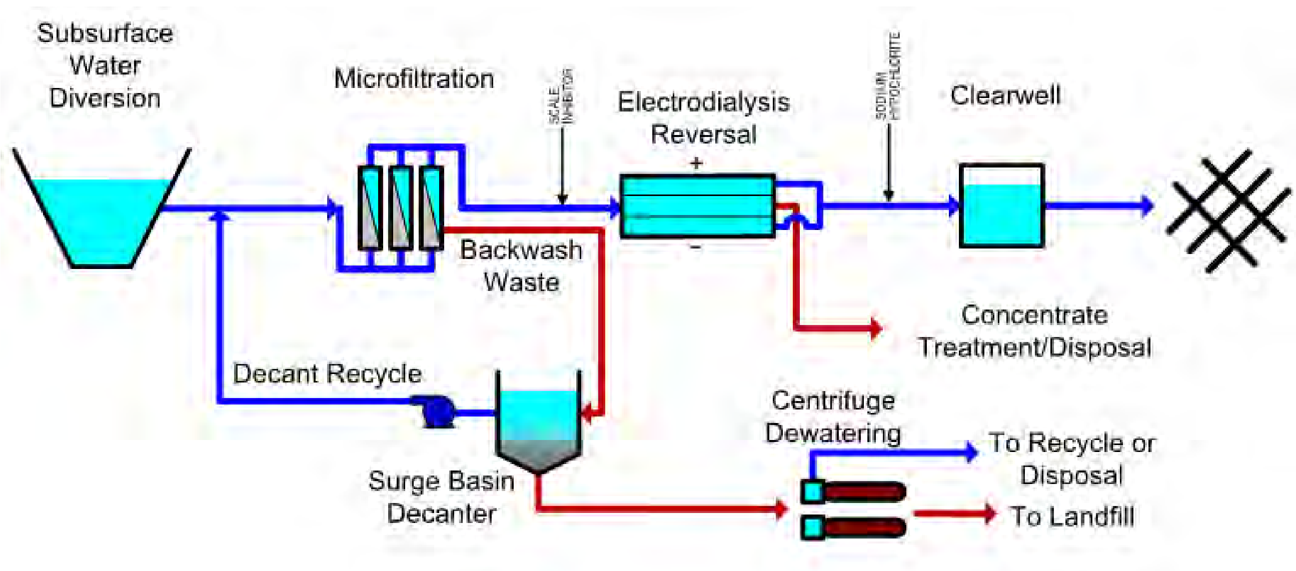


Figure 5. RBF + MF + EDR Desalination Process Flow Diagram

2.6 Conventional Treatment + MF + RO

If is it determined that the raw water quality is such that pretreatment is required prior to MF to avoid fouling of the MF membranes, then a complete conventional treatment process may be required prior to MF. This would include a flocculation and sedimentation for TSS removal, potentially followed by ozone plus biologically active carbon filtration for organics and further TSS removal. This should sufficiently pretreat essentially any type of South Platte River water quality to avoid fouling of MF membranes. After the MF membranes, RO or EDR can be used for final salinity removal. Note that it may be possible to omit the MF process under this configuration; however, this would require extensive pilot study to ensure the ability to implement at full scale and is assumed MF at this planning stage.

Figure 6 shows a process flow diagram for a Conventional + MF + RO desalination process

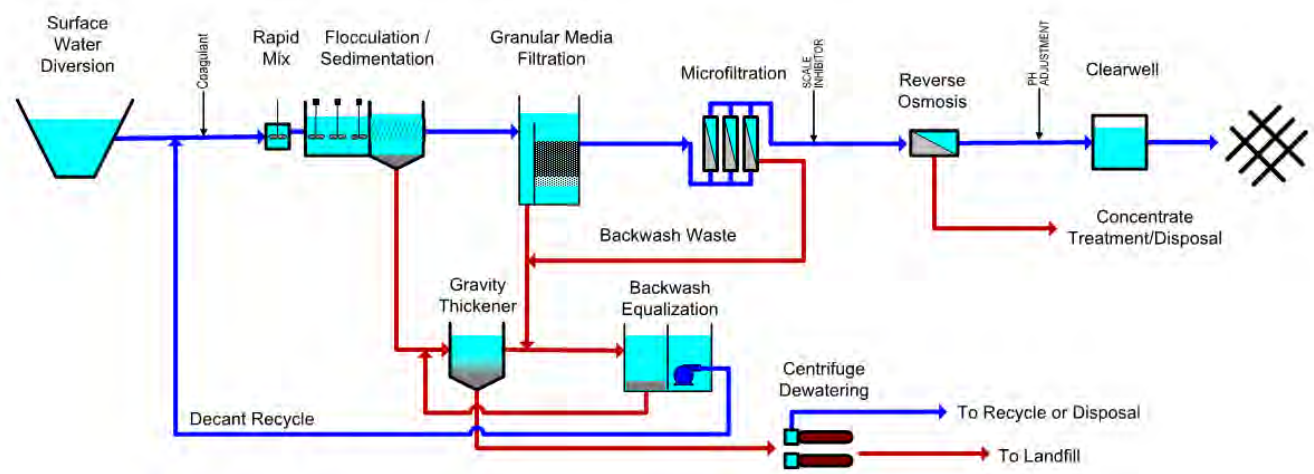


Figure 6. Conventional + MF + RO Desalination Process Flow Diagram

2.7 Considerations for EDR Salinity Removal

Depending on actual pilot test findings, EDR could be slightly more or less expensive than RO. However, it is important to note that if the goal of the EDR process is to produce brine potentially usable for irrigation water then “loose NF” should also be considered. The loose NF process removes a lower percentage of certain ions and a greater percentage of other ions. With loose NF, calcium (Ca), magnesium (Mg), and sulfate (SO_4) are enriched in the brine stream. The brine stream still contains sodium (Na) and chloride (Cl) but at reduced levels. This brine stream has an improved (lower) sodium adsorption ratio (SAR) due to the increased ratio of divalent (Ca and Mg) relative to monovalent ions (Na and Cl). Generally, a lower SAR indicates that water is more suitable for irrigation. Note that considerations of SAR values are only relevant to the water quality characteristics of the brine stream and is a measure of the potential usefulness of the brine stream to be used for irrigation of salt-tolerant crops. This type of brine disposal requires minimum brine concentration and results in maximum water loss. All parties have indicated that they want to minimize water loss from brine disposal, so this type of brine disposal is no longer being considered and SAR benefits are not relevant.

3. Potential Sites for Salinity Removal Facilities

A new SMWA desalination facility incorporating one of the previously presented processes could be located anywhere along the PWP Pipeline between the Aurora Water North Campus and the Aurora Water BWPF or planned WISE Binney Connect Pipeline between the BWPF and the WISE Smoky Hill Tank. A workshop was held to identify three potential sites for a new SMWA desalination facility, including one site that was located strategically to allow for partnerships with other regional water providers with desalination needs. During the workshop, all sites listed below and shown on **Figure 7** were considered:

- Site near PWP Pump Station (PS) #1 (selected and referred to as North Desalination Site)
- Site near PWP PS #3 (selected and referred to as Central Desalination Site)
- Site near BWPF (selected and referred to as South Desalination Site)
- Site near the existing East Cherry Creek Valley Water and Sanitation District (ECCV) Northern Water Treatment Plant (not selected)
- Site on or near Front Range Airport (not selected)
- Site near PWP PS #2 (not selected)

Generally, sites evaluated were located near the PWP System (including the North Campus, Pipeline and Pump Stations and the BWPF) to avoid excessive conveyance costs and to return desalinated water to the PWP System at existing pump station equalization tanks.

3.1 Desalination Sites Considered, but not Evaluated

Sites near the ECCV Northern Treatment Plant, Front Range Airport and PWP PS #2 were all considered for their ability to promote regional sharing of a new desalination facility by SMWA, ECCV and the Parker Water and Sanitation District (Parker Water). The ECCV Northern Treatment Plant and Front Range Airport are both approximately 6 miles from the PWP System and would require significant conveyance infrastructure to divert and return WISE water (and water from other potential partners) back to the PWP System. Due to the large conveyance costs required, sites near the ECCV Northern Treatment Plant or Front Range Airport have been removed from consideration. The PWP PS #2 site would have allowed for regional partnerships between SMWA and ECCV. However, the PWP PS #2 is further from the planned Parker Water Lower South Platte Pipeline than the Central Site. Therefore, the site near PWP PS #2 was removed in favor of the Site near PWP PS #3.

3.2 Desalination Sites Evaluated

Sites near PWP PS #1, #3 and BWPF were chosen to investigate for a new SMWA desalination facility. The Northern Site (near PWP PS #1) allows for SMWA to remove dissolved solids from their WISE water nearest to the diversion point. Depending on the disposal method, SMWA may realize pump cost savings due to brine disposal water losses occurring upstream of other sites. The Southern Site (near the BWPF) reduced pretreatment cost risk because the water will have already been treated at the BWPF. The Central Site (near PWP PW #3) was selected as the most viable site to allow for regional partnerships between SMWA, ECCV and Parker Water, where Parker Water would reduce the size of (or entirely forgo) a planned desalination facility along the Lower South Platte and use available capacity in the SMWA desalination facility.

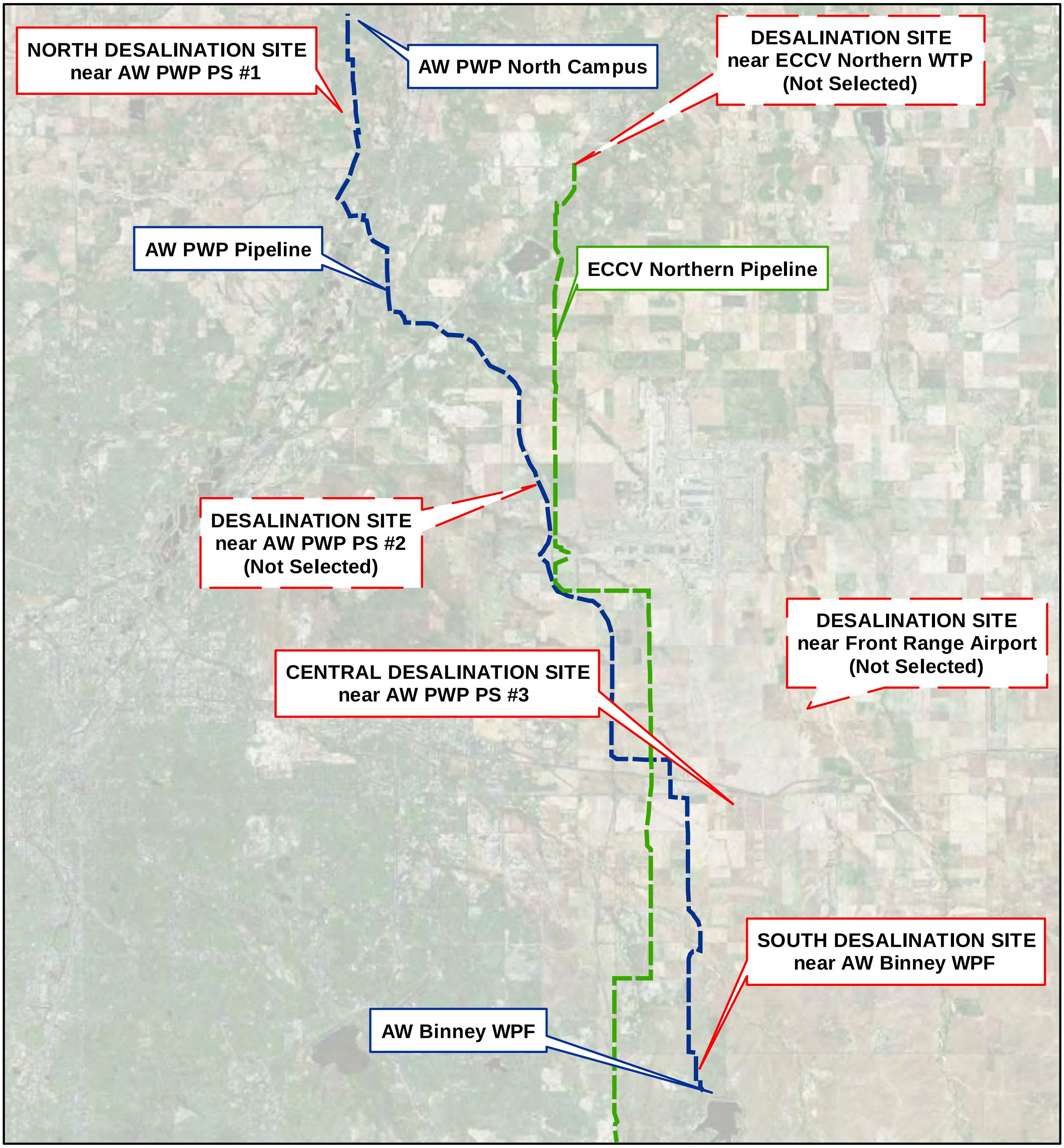
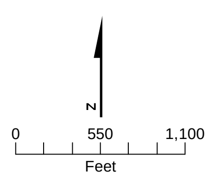


FIGURE 7
New SMWA Desalination Facility
Site Options Overview
TM 1 - Salinity Removal
WISE Salinity Management Plan



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4. Desalination Facility Site Layouts

Preliminary site layouts were developed to understand the amount of land needed for a new SMWA desalination facility and to understand how each facility would fit into the existing landscapes surrounding the three selected sites.

4.1 Site Layout Assumptions

Site layouts were developed for each potential desalination site. The site layouts were developed assuming the worst-case design flow rate (30 mgd) and assuming the worst-case treatment process footprint. Specifically, 30 mgd facilities with the following processes were assumed:

- North Site – Conventional + MF + RO
- Central Site – Conventional + MF + RO
- South Site – MF + RO

Conventional pretreatment would likely not be needed at the South Site because WISE water would have already been treated at the BWPF South Platte Treatment Train, which includes precipitative softening, biologically active filtration and granular activated carbon adsorption. To avoid redundancy, it is therefore assumed that there would be no situation where conventional pretreatment would be needed ahead of salinity removal processes at the Southern Site.

For each site, adequate space between buildings is provided to allow access roads to chemical storage buildings and provide ease of site mobility for plant operators. Specific processes were grouped where appropriate to use site space efficiently. Chemical and solids handling buildings were located near access roads for ease of chemical deliveries and sludge pickup by dump trucks.

In addition, extra land (beyond land required for the desalination facility infrastructure) is shown for four injection wells and injection pump buildings. Per **TM 2 – Brine Disposal**, it is estimated that between two and six wells would be needed to sustainably inject brine produced from desalinating 10,000 afy of WISE water. It is also recommended in **TM 2 – Brine Disposal**, that injection wells should be placed between 0.75 – 1 mile from any neighboring injection well. Each conceptual site plan layout includes four injection well sites and space for mechanical evaporation equipment, if needed. SMWA may consider acquiring the land between injection well sites and the desalination facility in case injection rates became unsustainable or non-permittable, the extra land could be used for locating mechanical evaporator type brine treatment facilities combined with storage ponds or evaporation ponds.

4.2 North Site

Facilities required for a Conventional + MF + RO salinity removal process to treat up to 30 mgd with injection wells for brine disposal on the North Site are shown on **Figure 8.**

WISE water would be diverted from the PWP Pipeline and conveyed to the headworks of the desalination facility. WISE water would leave the south end of the site and return by gravity to the equalization tank at PWP PS #1 for subsequent conveyance to the BWPF for treatment and delivery to the WISE distribution system.

The North Site would be accessed from East 168th Avenue where treatment plant operators, chemical deliveries and disposal trucks could enter and exit the site. All buildings would be able to be accessed from one entrance. At a minimum, SMWA would acquire 21 acres for the desalination facilities and islands for injection well sites and would acquire a total of 14 acres of pipeline easements to transport concentrate from the desalination facility to each injection well. Alternatively, SMWA could acquire four parcels totaling 413 acres. This would allow SMWA to have continuous land ownership for the desalination facility, injection wells and space for future uses or alternate brine disposal mechanisms.

Table 1 summarizes site-specific items that are required for the North Site in addition to the desalination process facilities. Site specific items were sized for 9 and 30 mgd. Pipelines were sized for approximately 49 percent of the desalination facility size (see Section 5.2 for more details) and the pump station was sized to provide 25 feet of static lift plus conveyance losses from the desalination site to the PWP PS #1 equalization tank.

Table 1. Site-Specific Items and Sizes Needed at the North Site for Each Facility Size

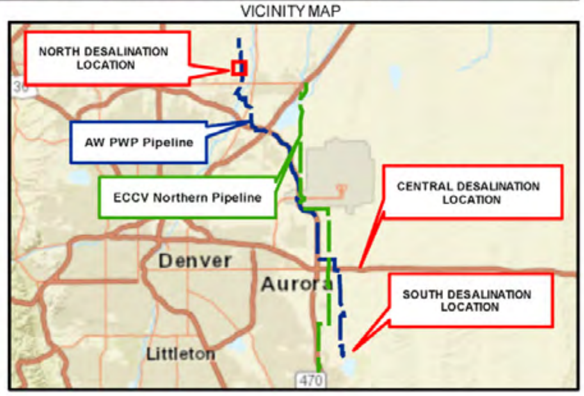
Site-Specific Item	9 MGD Size	30 MGD Size
Pipeline from PWP Pipeline to Plant Headworks (200 LF)	16-inch	30-inch
Pump Station from Plant Clearwell to PS #1 Equalization Tank	100 Hp	200 Hp
Pipeline from Plant Clearwell to PS #1 Equalization Tank (4,000 LF)	16-inch	30-inch
Maximum Land Required (Acquisition)	413 Ac	413 Ac
Minimum Land Required (Acquisition / Pipeline Easements)	21 / 14 Ac	21 / 14 Ac

Key

- 1 = Rapid Mix, Flocculation, Sedimentation
- 2 = Granular Media Filtration
- 3 = Microfiltration
- 4 = Reverse Osmosis
- 5 = Gravity Thickener
- 6 = Centrifuge
- 7 = Surge Basin Decanter
- 8 = Pump Station
- 9 = Chemical Storage
- 10 = Concentrate Equalization Tank
- 11 = Injection Well and Pumps
- 12 = Vertical Evaporator, Crystallizer, Plate Filter Press

- Site/Access Roads
- Salinity Removal Building Footprint
- Brine Disposal Building Footprint
- Maximum Estimated Property Boundary
- Estimated Property Boundary for Injection Well Islands or Mechanical Evaporation
- Estimated Pipeline Easement for Injection Well Islands

VICINITY MAP



N

0 400 800
Feet

FIGURE 8
NORTH SITE LAYOUT
WISE Salinity Management Plan
Desalination Site Layouts

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4.3 Central Site

Facilities required for the Conventional + MF + RO salinity removal process to treat up to 30 mgd with injection wells for brine disposal on the Central Site are shown on **Figure 9**.

WISE water would be diverted from the PWP Pipeline and conveyed to the northwest corner of the assumed desalination facility site. WISE water would also be conveyed from the desalination facility site back to the PWP PS #3 equalization tank for conveyance through the PWP Pipeline to the BWPF for treatment and delivery to the WISE distribution system.

The Central Site would be accessed from the Interstate 70 Frontage Road where treatment plant operators, chemical deliveries and disposal trucks could enter and exit the site. All buildings would be accessible from one entrance. At a minimum, SMWA would acquire 22 acres for the desalination facilities and islands for injection well sites and would acquire a total of 14 acres of pipeline easements to transport concentrate from the desalination facility to each injection well. Alternatively, SMWA could acquire four parcels totaling 577 acres. This would allow SMWA to have continuous land ownership for the desalination facility, injection wells and space for future uses or alternate brine disposal mechanisms.

Table 2 summarizes site-specific items needed in addition to the desalination facility that would be required for implementation of salinity removal on the Central Site. Pipelines were sized for approximately 49 percent of the desalination facility size (see Section 5.2 for more details) and the pump station was designed to provide 80 feet of static lift plus conveyance losses from the desalination site to the PWP PS #3 equalization tank. Note that sizes and infrastructure presented in **Table 2** is adequate for SMWA to treat WISE water only. Options for using the desalination plant as a regional facility to also treat water for others is discussed in a later section.

Table 2. Site-Specific Items and Sizes Needed at the Central Site for Each Facility Size

Site-Specific Item	9 MGD Size	30 MGD Size
Pipeline from PWP Pipeline to Plant Headworks (5,000 LF)	16-inch	30-inch
Pump Station from Plant Clearwell to PS #3 Equalization Tank	100 Hp	200 Hp
Pipeline from Plant Clearwell to PS #3 Equalization Tank (5,000 LF)	16-inch	30-inch
Maximum Land Required (Acquisition)	577 Ac	577 Ac
Minimum Land Required (Acquisition / Pipeline Easements)	22 / 14 Ac	22 / 14 Ac

Key

1 = Rapid Mix, Flocculation, Sedimentation

2 = Granular Media Filtration

3 = Microfiltration

4 = Reverse Osmosis

5 = Gravity Thickener

6 = Centrifuge

7 = Surge Basin Decanter

8 = Pump Station

9 = Chemical Storage

10 = Concentrate Equalization Tank

11 = Injection Well and Pumps

12 = Vertical Evaporator, Crystallizer, Plate Filter Press

Site/Access Roads

Salinity Removal Building Footprint

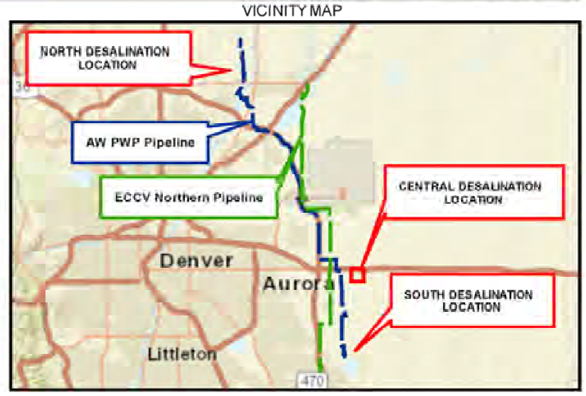
Brine Disposal Building Footprint

Maximum Estimated Property Boundary

Estimated Property Boundary for Injection Well Islands or Mechanical Evaporation

Estimated Pipeline Easement for Injection Well Islands

VICINITY MAP



N

0 400 800

Feet

FIGURE 9
CENTRAL SITE LAYOUT
WISE Salinity Management Plan
Desalination Site Layouts

4.4 South Site

The South Site is assumed to incorporate desalination processes following treatment of WISE water at the BWPF. Therefore, there is no need to reserve space on this site for pretreatment processes except for MF. **Figure 10** shows a facility layout for MF + RO for up to 30 mgd with four injection wells

WISE water would be diverted from the WISE Binney Connect Pipeline conveying water from the BWPF to the WISE Smoky Hill Tank. Following desalination, a chloramine residual would need to be added prior to returning the desalinated water to the Binney Connect Pipeline. A finished water pump station would be required to match the pressure in the WISE Binney Connect Pipeline.

The South Site would be accessed from South Robertsdale Way where treatment plant operators, chemical deliveries and disposal trucks could enter and exit the site. All buildings would be accessible from one entrance. At a minimum, SMWA would acquire 17 acres for the desalination facilities and islands for injection well sites and would acquire a total of 15 acres of pipeline easements to convey concentrate from the desalination facility to each injection well. Alternatively, SMWA could acquire four parcels totaling 457 acres. This would allow SMWA to have continuous land ownership for the desalination facility, injection wells and space for future uses or alternate brine disposal mechanisms.

Table 3 summarizes site-specific items needed in addition to the desalination facility that would be required for implementation of salinity removal on the South Site. Unique to this site is the requirement of chemical addition of sodium hypochlorite (Hypo) and liquid ammonium sulfate (LAS) to create a chloramine residual for desalinated water prior to entering the WISE distribution system. Pipelines were sized for approximately 49 percent of the desalination facility size (see Section 5.2 for more details) and the pump station was designed to provide 240 feet of static lift required to match pressure in the WISE Binney Connect Pipeline.

Table 3. Site-Specific Items and Sizes Needed at the South Site for Each Facility Size

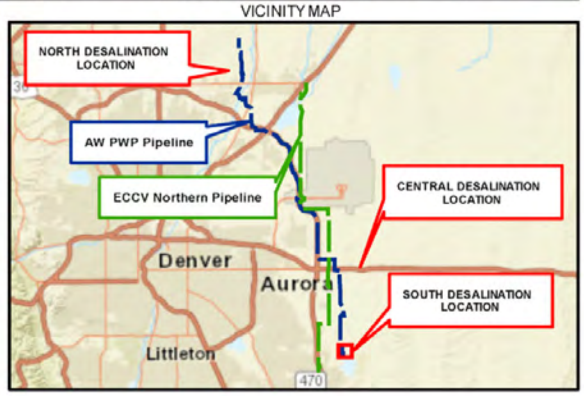
Site-Specific Item	9 MGD Size	30 MGD Size
Pipeline from Binney Connect Pipeline to Plant Headworks (200 LF)	16-inch	30-inch
Average Dose of Sodium Hypochlorite for Chloramine Residual	2.5 mg/L	2.5 mg/L
Average Dose of Liquid Ammonium Sulfate for Chloramine Residual	2.3 mg/L	2.3 mg/L
Pump Station from Plant Clearwell to Binney Connect Pipeline	300 Hp	900 Hp
Pipeline from Plant Clearwell to Binney Connect Pipeline (200 LF)	16-inch	30-inch
Maximum Land Required (Acquisition)	457 Ac	457 Ac
Minimum Land Required (Acquisition / Pipeline Easements)	17 / 15 Ac	17 / 15 Ac

Key

- 1 = Microfiltration
- 2 = Reverse Osmosis
- 3 = Surge Basin Decanter
- 4 = Centrifuge
- 5 = Chemical Building
- 6 = Concentrate Equalization Tank
- 7 = Injection Well and Pumps
- 8 = Vertical Evaporator, Crystallizer, Plate Filter Press

- Site/Access Roads
- Salinity Removal Building Footprint
- Brine Disposal Building Footprint
- Maximum Estimated Property Boundary
- Estimated Property Boundary for Injection Well Islands or Mechanical Evaporation
- Estimated Pipeline Easement for Injection Well Islands

VICINITY MAP



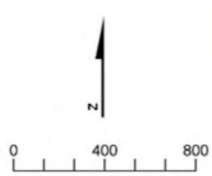


FIGURE 10
SOUTH SITE LAYOUT
WISE Salinity Management Plan
Desalination Site Layouts

JACOBS

5. Salinity Removal Costs

Cost estimates were developed based on two desalination plant sizes of 9 and 30 mgd. It is assumed that a 9 mgd facility would operate almost continuously regardless of whether WISE water is being delivered to SWMA. The theory being that if SMWA reduces salinity concentrations of the water in the PWP pipeline, it will continuously reduce the amount of low TDS mountain water that Aurora Water needs to meet Aurora Water salinity targets. The stored low TDS water could later be used as blend water for SMWA during peak WISE water deliveries to SMWA. It is important to note that this concept relies on use of Aurora Water owned mountain reservoirs to store low TDS mountain water on behalf of SMWA while the 9 mgd desalination facility is in operation and SMWA is not taking WISE water. Detailed hydrologic evaluations of the Aurora Water system are required to determine if Aurora Water owns sufficient reservoir capacity for their mountain water supplies to accomplish this objective without negatively impacting Aurora Water operations.

Based on a general understanding of the Aurora Water system, it is assumed that detailed investigations would show a desalination facility somewhat larger than 9 mgd but smaller than 30 mgd could be constructed to meet both parties operating objectives, if coordinated operations were determined to be feasible.

The 30 mgd desalination facility is sufficiently sized to desalinate peak flow of WISE water deliveries per the WDA.

The complete cost of a new desalination facility is broken into three groups of costs:

- **Site-Specific Costs** including conveyance infrastructure required to convey WISE water to and from existing systems to the desalination plant. At select sites, chemical equipment required to created disinfection residuals to match that of existing systems is also required. These costs also include contingency and engineering, legal and administrative, and construction management costs of infrastructure and land acquisition costs.

- **Desalination Facility Costs** including buildings, desalination, chemical, mechanical and electrical equipment, computer systems, instrumentation and controls, yard piping, contractor markups, contingency and engineering, legal, administrative and construction management costs.

- **Brine Disposal Costs** that are presented in the accompanying **TM 2 – Brine Disposal**.

Full costs for a new desalination facility are presented in **Project Summary** Section 2.3.

5.1 Site-Specific Costs

5.1.1 Site-Specific Cost Assumptions

Site-Specific Costs were developed using the following assumptions:

- Pump stations and pipelines capital and O&M costs were developed using unit costs from **TM 3 – Water Blending**.

- Land acquisition costs were developed from the greater of two unit costs: (1) an area weighted average of appraised value of identified parcels from county property databases for each desalination site or (2) $15,000/Ac. Often, appraised values of land are significantly below market price, therefore $15,000/Ac is used to better understand market cost of land acquisition. Note that $15,000/Ac is based on review of recently listed or sold lands that were over 20-acre parcels and within 10 miles of the north, central, and south sites. In each of the north, central, and south locations, there are example land values be between $6,000/Ac and $12,000/Ac. Providing for 25 percent for land acquisition administrative costs,

$15,000/Ac is used a rough estimated of land costs, unless county property databases show higher values. Further research should be done to confirm/refine the assumed land acquisition costs after the general location of desired facilities is identified.

- Costs for pipelines, pump stations and chemical addition infrastructure includes a contingency of 30 percent and allowances of 10 percent for engineering, 5 percent for legal, 5 percent for administrative and 5 percent for construction management (totaling 25 percent).

5.1.2 North Site

Site-specific capital costs for the North Site (located in Weld County) are shown in **Table 4**. According to the Weld County Property Search, the area weighted average assessed value of parcels within the North Site was $2,100/Ac, which is below the alternate $15,000/Ac unit cost. Therefore, $15,000/Ac was used for land acquisition costs. SMWA may reduce the amount of land purchased by acquiring small, isolated land parcels for injection pumps and wells and acquiring a pipeline easement to convey waste brine flow to injection sites.

Table 4. Summary of Site-Specific Capital Costs for the North Site

Site-Specific Item	9 mgd Cost	30 mgd Cost
Pipeline from PWP Pipeline to Plant Headworks (200 LF)	$38,000	$56,700
Pump Station from Plant Clearwell to PS #1 Equalization Tank	$2,560,600	$4,063,100
Pipeline from Plant Clearwell to PS #1 Equalization Tank (4,000 LF)	$759,100	$1,134,500
Maximum Land Acquisition (413 Ac)	$6,190,100	$6,190,100
Total of Site-Specific Capital Costs	**$9,547,800**	**$11,444,400**

The total annual operations and maintenance (O&M) costs for site-specific infrastructure shown in **Table 4** are $74,700/year and $92,700/year for the 9 mgd and 30 mgd facility sizes, respectively.

5.1.3 Central Site

Site-specific capital costs for the Central Site (located in Arapahoe County) are shown in **Table 5**. According to Arapahoe County's ArapaMap Database, the area weighted average assessed value of parcels within the Central Site was $136/Ac, which is below the alternate $15,000/Ac unit cost. Therefore, $15,000/Ac was used to for land acquisition costs. SMWA may reduce the amount of land purchased by acquiring small, isolated land parcels for injection pumps and wells and acquiring a pipeline easement to convey waste brine flow to injection sites.

Table 5. Summary of Site-Specific Capital Costs for the Central Site

Site-Specific Item	9 mgd Cost	30 mgd Cost
Pipeline from PWP Pipeline to Plant Headworks (5,000 LF)	$948,900	$1,418,100
Pump Station from Plant Clearwell to PS #3 Equalization Tank	$2,560,600	$4,063,100
Pipeline from Plant Clearwell to PS #3 Equalization Tank (5,000 LF)	$948,900	$1,418,100
Maximum Land Acquisition (577 Ac)	$8,655,000	$8,655,000
Total of Site-Specific Capital Costs	**$13,113,400**	**$15,554,300**

The total annual O&M costs for site-specific infrastructure shown in **Table 5** are $99,600/year and $113,900/year for the 9 mgd and 30 mgd facility sizes, respectively.

5.1.4 South Site

Site-specific capital costs for the South Site (located in Arapahoe County) are shown in **Table 6**. According to Arapahoe County's ArapaMap Database, the area weighted average accessed value of parcels within the Central Site was $27,900/Ac, which is above the alternate $15,000/Ac unit cost typically used to estimate land acquisitions costs. Therefore, the assessed value of $27,900/Ac plus an allowance of an additional 25 percent for administrative land acquisition costs was used to develop the land acquisition cost for the South Site. SMWA may reduce the amount of land purchased by acquiring small, isolated land parcels for injection pumps and wells and acquiring a pipeline easement to convey waste brine flow to injection sites.

Table 6. Summary of Site-Specific Capital Costs for the South Site

Site-Specific Item	9 mgd Cost	30 mgd Cost
Pipeline from Binney Connect Pipeline to Plant Headworks (200 LF)	$38,000	$56,700
Chemical Storage and Feed for Chloramine Residual	$2,220,000	$2,220,000
Pump Station from Plant Clearwell to Binney Connect Pipeline	$5,323,000	$11,065,700
Pipeline from Plant Clearwell to Binney Connect Pipeline (200 LF)	$38,000	$56,700
Maximum Land Acquisition (457 Ac)	$15,932,000	$15,932,000
Total of Site-Specific Capital Costs	**$23,551,000**	**$29,331,100**

The total annual O&M costs for site-specific infrastructure shown in **Table 6** are $228,700/year and $425,100/year for the 9 mgd and 30 mgd facility sizes, respectively.

5.2 Desalination Facility Costs

Desalination facility costs are presented graphically using the template shown on **Figure 1.** Salinity removal processes were designed assuming South Platte Water from the RBF wells contained 700 mg/L of TDS during fall/winter periods and that SMWA would target 400 mg/L of TDS. Desalination treatment throughout the year would depend on the timing of WISE water deliveries and the actual water quality during the delivery period. Although SMWA's water quality goal for delivery to their members is 500 mg/L, treating water to 400 mg/L of TDS would allow SMWA members the opportunity to implement reuse of WISE water. To treat water to 400 mg/L of TDS, approximately 49 percent of the total flow of WISE water would need to be treated at the desalination facility, while the other 51 percent would bypass the desalination facility and blend with finished water from the desalination facility to achieve a blended concentration of 400 mg/L of TDS in WISE water following desalination.

5.2.1 Desalination Facility Cost Assumptions

Costs for each desalination process and facility size were developed with the following assumptions:

- Costs were developed and reported in January 2019 dollars (Engineering News Record Construction Cost Index from Denver, CO = 7,505.86).
- Unit costs were obtained from 2018 R.S. Means (adjusted to Denver, CO) and Jacobs' historical unit cost database.

- Equipment costs were based on R.S. Means rates and local equipment vendor quotes. This estimate does not include escalation. Costs were based on market research of web-based cost indices.

- Allowances of 6 percent for overall site work, 6 percent for the plant computer system, 9 percent for yard electrical and 8 percent for yard piping was applied to develop a complete desalination facility Construction Cost.

- Contractor overhead at 12 percent was applied to the Construction Cost.

- Contractor profit of 10 percent was applied to the subtotal of the Construction Cost and Overhead.

- Mobilization/Bonds/Insurance at 3 percent was applied to the subtotal of the Construction Cost, Overhead and Profit.

- A contingency of 30 percent was applied to the subtotal of Construction Costs, Profit, Overhead, and Mobilization/Bonds/Insurance.

- Allowances of 10 percent for engineering, 5 percent for legal, 5 percent for administrative and 5 percent for construction management (totaling 25 percent) were applied to the subtotal of Construction Costs, Profit, Overhead, Mobilization/Bonds/Insurance and Contingency.

The 30 percent contingency has been included in this estimate as a provision for unforeseeable, additional costs within the general bounds of the scope, particularly where previous experience has shown that unforeseen events that would increase costs are likely to occur. Additional allowances for finishes, instrumentation and controls, mechanical and electrical items specific to each proposed facility can be found in detailed cost estimates presented in **Appendix A – Cost Appendix**.

Annual O&M costs for the 9 mgd desalination facility assume a 100 percent annual utilization (i.e. the plant runs continuously with no downtime). Annual O&M costs for the 30 mgd facility assume a 30 percent annual utilization. On a long-term average basis, WISE water flow through the facility would be 9 mgd of the 30 mgd capacity.

5.2.2 **Desalination Facility Costs**

Capital costs for 9 and 30 mgd facilities are presented on **Figure 11** and **Figure 12**, respectively for the Central Site as an indication of combined desalination facility and site-specific costs. If the desalination facility were constructed at the North Site, implementation costs would decrease approximately 2 percent, while constructing the desalination facility at the South Site would increase implementation costs by approximately 12 percent. Costs are shown from low to high where the lowest cost would be realized if pilot testing showed limited pretreatment was required prior to the desalination equipment and the highest costs would be realized if extensive pretreatment is required.

Desalination facility costs are presented in three different formats on **Figure 11** and **Figure 12**:

- Capital and Annual O&M Costs

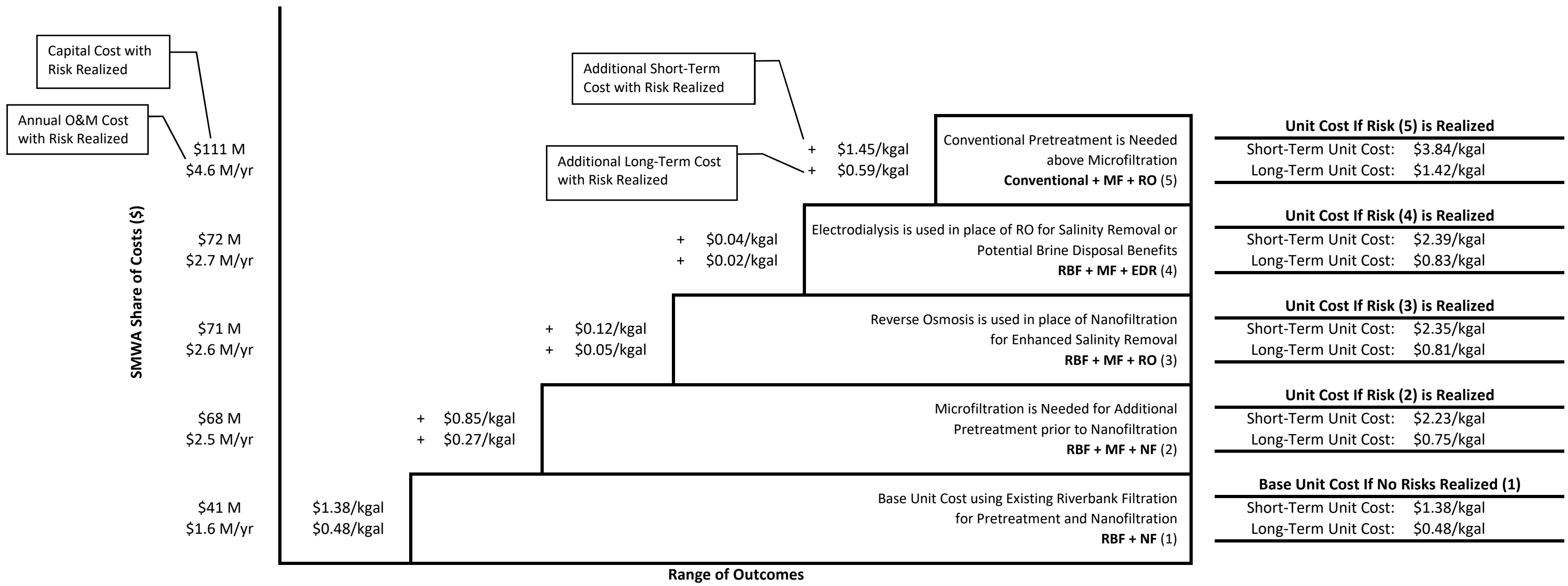
- Unit Cost Impacts to the WISE Water Rate

- Incremental Unit Cost Impacts to the WISE Water Rate for each cost risk

Capital and Annual O&M costs are presented on the left y-axis of each figure (capital cost is listed above the annual O&M cost for each salinity removal process).

Unit Costs are presented to the right y-axis of each figure. It is important to note that these unit ($/kgal) costs would be ***in addition*** to the future WISE Water Rate. Unit costs are presented for two different time frames: short-term and long-term. The short-term costs include the repayment of a 25-year bond at 5 percent interest financing desalination facility capital costs plus the annual O&M costs to treat 10,000 afy of WISE water. The long-term unit cost is only the annual O&M costs to treat 10,000 afy of WISE water.

Incremental Unit Costs are also presented to show the incremental cost impact of realizing a given cost risk.



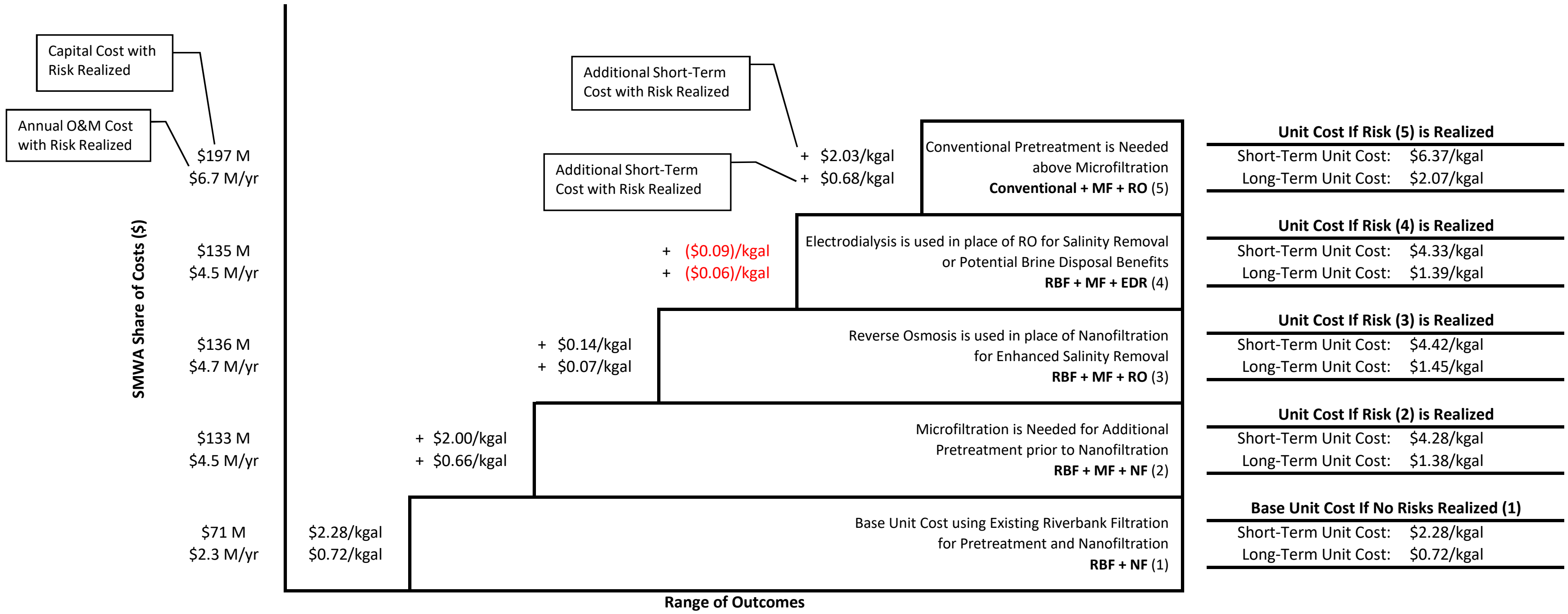
Notes:

- Costs presented within the graph area and right of the graph area would be in addition to the base WISE water rate charged by Aurora Water and Denver Water
- Future WISE water rate is unknown and therefore not shown numerically on this schematic
- Costs presented are for salinity removal processes and site specific costs at the Central Site. Costs for other sites can be found in **Appendix A**

Risk Details:

(1) Base cost assumes no additional cost for using AW Riverbank Filtration System for South Platte water and using Nanofiltration for Salinity Removal
(2) Microfiltration is needed in addition to Riverbank Filtration ahead of Nanofiltration
(3) Reverse Osmosis replaces Nanofiltration for salinity removal to remove monovalent ions unable to be removed by NF
(4) Electrodialysis Reversal replaces Reverse Osmosis for salinity removal, which may allow for optimization of salinity removal and brine disposal
(5) Aurora Water changes to surface diversion or other factors require additional pretreatment above Microfiltration.
Additional Pretreatment would include Rapid Mix, Flocculation, Sedimentation and Mixed Media Filtration (Conventional Treatment)

WISE Salinity Management Plan	JACOBS	TM 1 - Salinity Removal	Figure 11
		Unit Cost Impacts to the WISE Water Rate for Salinity Removal Processes (9 mgd)	



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- Future WISE water rate is unknown and therefore not shown numerically on this schematic
- Costs presented are for salinity removal processes and site specific costs at the Central Site. Costs for other sites can be found in **Appendix A**

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(5) Aurora Water changes to surface diversion or other factors require additional pretreatment above Microfiltration.
Additional Pretreatment would include Rapid Mix, Flocculation, Sedimentation and Mixed Media Filtration (Conventional Treatment)

5.3 Economies of Scale and Shared Use of a 30 MGD Facility

If SMWA is required to construct a desalination facility with a peak flow capacity of 30 mgd, SMWA will only need 30 percent of the desalination capacity to treat an average of 10,000 afy (9 mgd continuously) of WISE water. Therefore, it may be possible to share 70 percent of the long-term average treatment capacity with others.

Parker Water is planning to construct infrastructure to divert Lower South Platte water that would yield at least 11,000 afy. To meet their water quality goal of 400 mg/L of TDS, a desalination facility would be needed to treat an estimated 13,000 afy (before water losses to brine waste) to meet their intended yield. As part of the project, a pipeline would be constructed to convey water from the Lower South Platte to Reuter-Hess Reservoir that would pass nearby the Central Site. Therefore, it might be feasible for Parker Water to forgo (or reduce) their planned desalination facility on the Lower South Platter and use the intermittently available excess capacity in a new SMWA desalination facility at the Central Site.

5.3.1 Regionalization Assumptions

In this hypothetical example, it is assumed that a MF + RO process is installed at the Central Site with a peak flow capacity of 30 mgd to meet SMWA's desalination needs. As mentioned previously, a desalination facility designed to reduce the salinity levels in WISE water from 700 mg/L to 400 mg/L would require approximately 49 percent of the WISE water to pass through MF + RO and the remainder of the WISE water would bypass the desalination process. Therefore, 14.9 mgd of MF + RO would be needed for the peak 30 mgd WISE water delivery flow rates, but 4.4 mgd would be utilized for the average WISE water delivery flow rate of 9 mgd.

If Parker Water were to send 11.6 mgd (13,000 afy) of water to this site with a need to reduce salinity levels from about 1,200 mg/L to 400 mg/L, this type of water would require about 71 percent of the water to pass through the MF + RO facilities. This results in about 8.2 mgd of required MF + RO facilities to meet average Parker Water treatment needs.

Therefore, on average, there is enough MF + RO capacity to meet the needs of both parties (8.2 mgd + 4.4 mgd) versus 14.9 mgd of installed salinity removal capacity. However, for Parker Water to handle variable use of the desalination capacity by SMWA, Parker Water would need to accept relatively low TDS water during some periods and high TDS water during other periods and operate to achieve a long-term blend of between 400 and 500 mg/L of TDS.

5.3.2 Shared Use of a 30 mgd Desalination Facility

Table 7 summarizes capital and annual O&M costs for a 9 mgd and 30 mgd SMWA desalination facility at various percentages of annual utilization. The 9 mgd plant at 100 percent annual utilization is representative of a SMWA only plant designed for average WISE water flowrates. The 30 mgd plant at 30 percent utilization is representative of a SMWA only plant where the idle capacity is not used. The 30 mgd plant at 85 percent utilization represents the average utilization if Parker Water and SMWA share the 30 mgd plant.

Table 7. Economies of Scale for Shared Use of 30 mgd MF + RO Treatment

Item	9 mgd Size	30 mgd Size			
Source Water Flow (afy)	10,000	10,000	22,512	28,560	33,600
Annual Percent Utilization	100%	30%	67%	85%	100%
Capital Cost	$47 M	$103 M	$103 M	$103 M	$103 M
Annual O&M	$2.6 M	$4.5 M	$6.5 M	$6.8 M	$7.8 M
Unit Cost* ($/kgal)	$1.82/kgal	$3.62/kgal	$1.89/kgal	$1.52/kgal	$1.38/kgal
Unit Cost* ($/af)	$594/af	$1,181/af	$615/af	$496/af	$451/af

* Unit cost during repayment of bonds financing capital costs.

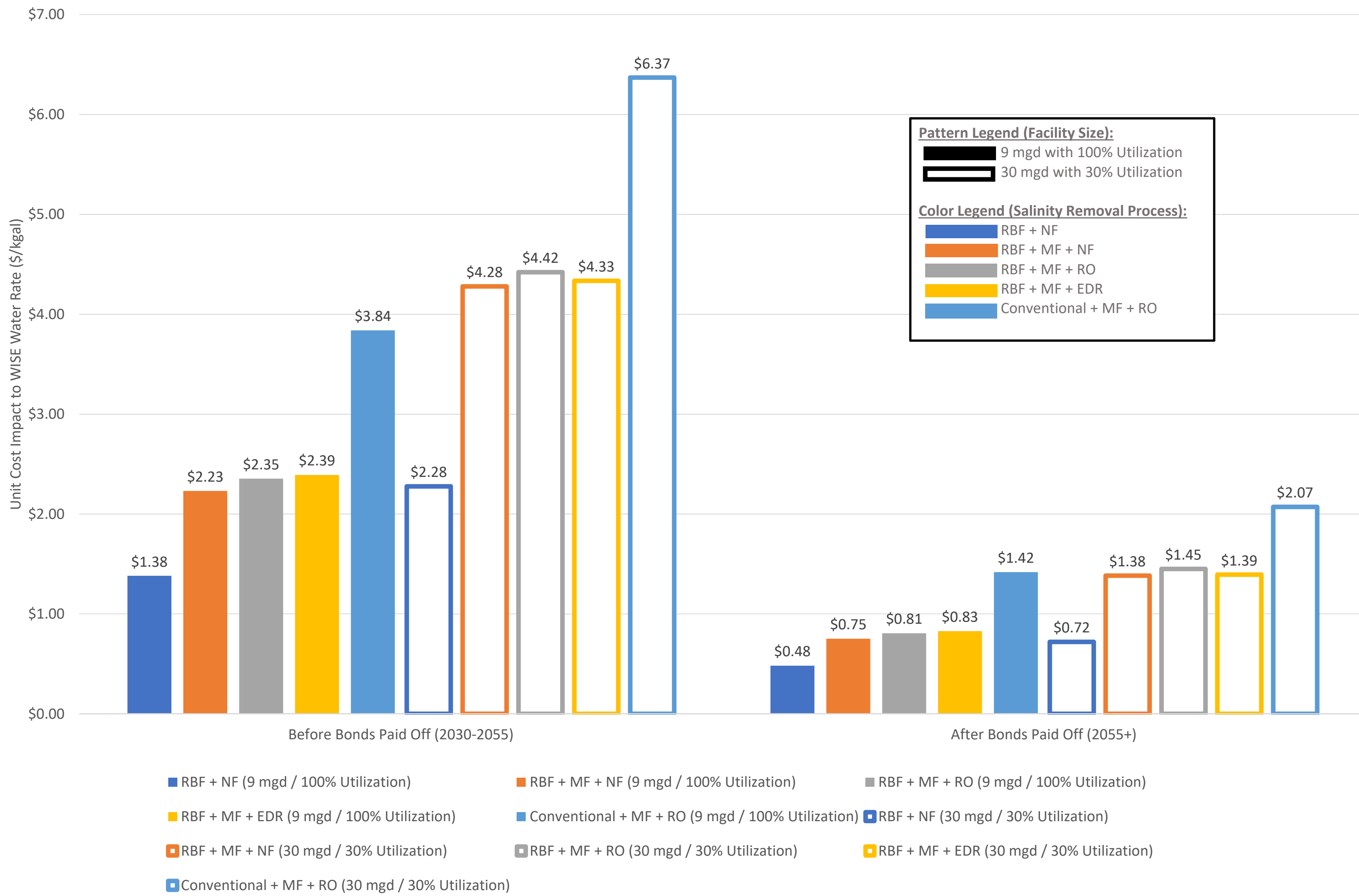
In the 85 percent utilization scenario in **Table 7**, Parker Water would pay $496/af of flow treated through the MF + RO processes. Under this scenario, Parker Water may save $1.7 M annually in capital repayment costs by not constructing their own desalination facility. In the same scenario, SMWA would save about $6.85 M annually (no partner cost of $1,181/af – partner cost of $496/af for 10,000 afy) due to cost sharing and economies of scale realized. A lower unit cost allocated to Parker Water could mean a larger cost savings to Parker Water and lower annual savings by SMWA, but still potentially advantageous to both parties. If the regionalization savings were evenly split, both parties would save $4.3 M annually ($6.85 M + $1.7 M / 2). This would reduce the cost to desalinate WISE water for WISE members by about $1.15/kgal. Note, there may also be further cost savings by sharing in the brine disposal facilities. See the **Project Summary** for the full potential cost savings associated with sharing a 30 mgd desalination and brine disposal facility.

6. Summary of Findings

All presented desalination processes at either the North, Central or South Sites could potentially be implemented to meet SMWA's water quality goal. However, there are significant cost uncertainties based on the wide range of potential desalination processes required and site-specific implementation considerations. The following section outlines potential next steps to reduce the cost uncertainty of a desalination facility.

Figure 13 presents unit cost impacts to the WISE Water Rate before (short-term) and after (long-term) the bond repayment period. The lowest cost option would be the implementation of RBF + NF. However, the NF process may not provide enough salinity reduction in WISE water or RBF may not provide sufficient pretreatment to adequately protect the NF membranes. The unit cost to install a MF pretreatment process to reduce membrane fouling is between 1.6 and 1.9 times more expensive than NF alone, depending on the facility size. The unit costs to install RO or EDR in place of NF to enhance salinity reduction in WISE water are no more than 10 percent more expensive. **Figure 13** shows that implementation costs among membrane processes are similar. However, additional unit costs for additional pretreatment (MF or Conventional) to avoid membrane fouling does vary significantly.

Unit costs presented in **Figure 13** would be the additional unit cost above the future WISE water rate and would also need to include costs for brine disposal presented in the accompanying **TM 2 – Brine Disposal**. The **Project Summary** presents a holistic summary of costs associated with desalination options (salinity removal and brine disposal).



Note:
Costs presented are for salinity removal processes and site specific costs at the Central Site. Costs for other sites can be found in **Appendix A - Cost Appendix**

WISE Salinity Management Plan	JACOBS	TM 1 - Salinity Removal Unit Cost Impacts to the WISE Water Rate for Evaluated Salinity Removal Processes	Figure 13

7. Pilot Testing Recommendations

The cost uncertainty presented herein can be reduced and the range of project cost estimates can be narrowed by better understanding the amount of pretreatment required ahead of the desalination process, the removal efficiency of different desalination technologies, geologic conditions in locations where deep well injection would be desired, land acquisition costs, and brine characteristics if deep well injection is not feasible and landfill disposal is required. To better understand the required pretreatment and desalination processes as well as brine characteristics, water quality sampling and pilot testing is recommended.

Aurora Water already collects and samples raw water from the PWP system. However, laboratory testing on those samples may not be focused on key water quality characteristic that are informative for selecting desalination technologies. SMWA should coordinate with Aurora Water to develop a specific sampling and laboratory testing plan to provide insight into desalination facilities design. Key constituents include a suite of anions and cations as well as specific constituents known to present operational challenges for NF, RO and EDR processes, such as barium, silica and the silt density index. This level of sampling is not required to be completed prior to beginning a pilot study but is recommended to be completed prior to commencing final design.

Following a better understanding of the raw water quality, publicly available equipment design software can be used to estimate design requirements for RO and NF processes. This software will also provide the resulting effluent and brine water qualities. Design and resulting water qualities for EDR systems will require vendor input.

Pilot testing of salinity removal technologies provides multiple benefits to project planning. While a theoretical analysis conducted by publicly available software improves overall project understanding beyond the level presented in this investigation, pilot testing can significantly remove uncertainty related to the type of required pretreatment and desired desalination process. Pilot test results can also be used to support permitting and the final design of a new SMWA desalination facility.

A robust pilot study investigating salinity removal options could include the following:

- A representative water supply indicative of worst-case salinity conditions in the South Platte River
- Continuous (24 hours per day, 7 days per week) operation once online
- At least 12 weeks of operation; 26 weeks of operation is recommended
- Gaining understanding of fouling potential for the membranes and whether pretreatment or extensive cleaning of the membranes would be required
- If brine minimization technology (e.g. Rotec, Desalitech or EDR) is investigated, it is recommended to test a minimum of two options
- Parallel operation of technologies is preferred as performance for identical influent water qualities can be investigated

During the pilot operation, extensive sample of influent, permeate and brine waste water quality should be conducted. Large datasets from piloting will allow verification of chemical doses, construction materials, and can offer a prediction of a system mass balance that can inform full-scale design.

Recommended tests that should be considered for a pilot test are:

- Varying flux through the investigated membrane processes. During these tests, flux is constant for a minimum of two weeks to allow the system to stabilize and track the system performance over varying influent water quality. A varying flux test would allow the selection of the optimal design flux.

- If EDR is tested, conduct flux and voltage variation tests. Similar to flux tests, change flux or voltage and allow the system to stabilize for a minimum of two weeks while tracking system performance. A varying flux and voltage test would allow the selection of the optimal design flux and voltage.

- If EDR is tested, varying the membrane type to target specific permeate and brine water qualities may be possible. Change the type of membrane used and allow the system to stabilize for 72 hours while monitoring the system performance.

- If brine minimization technologies from either Rotec and/or Desalitech are tested, vary operational parameters including cycle times, cross flows, blowdown frequencies, and others and allow the system to stabilize for two weeks while monitoring performance.

- Water quality spike tests. During this test, the raw water quality could be spiked with a salt solution or other constituents of interest to monitor performance. A spike test should typically run for a minimum of 24 hours.

The goal of the pilot test is to gain a robust understanding of the potential performance of salinity removal technologies and their limitations. Data from each of the presented tests can be used for revised cost estimating, full scale design, permitting and equipment bidding.

Appendix A. Cost Appendix

Salinity Removal Cost Summary (Central Site)																	
			9 mgd Facility Size					30 mgd Facility Size (30% Utilization)					30 mgd Facility Size (100% Utilization)				
Unit Process	Capital Cost	O&M Cost	RBF + NF	RBF + MF + NF	RBF + MF + RO	RBF + MF + EDR	Conventional + MF + RO	RBF + NF	RBF + MF + NF	RBF + MF + RO	RBF + MF + EDR	Conventional + MF + RO	RBF + NF	RBF + MF + NF	RBF + MF + RO	RBF + MF + EDR	Conventional + MF + RO
Rapid Mix: 9 mgd	$654,000	$8,000					1										
Rapid Mix: 30 mgd (30%)	$935,000	$15,000										1					
Rapid Mix: 30 mgd (100%)	$935,000	$20,000															1
Flocculation: 9 mgd	$2,553,000	$117,000					1										
Flocculation: 30 mgd (30%)	$2,766,000	$84,000										1					
Flocculation: 30 mgd (100%)	$2,766,000	$93,000															1
Lamella Clarifier: 9 mgd	$2,827,000	$86,000					1										
Lamella Clarifier: 30 mgd (30%)	$4,443,000	$164,000										1					
Lamella Clarifier: 30 mgd (100%)	$4,443,000	$166,000															1
Filter: 30 mgd (30%)	$7,253,000	$106,000										1					
Filter: 30 mgd (100%)	$7,253,000	$106,000															1
Microfiltration: 9 mgd	$5,684,000	$532,000		1	1	1	1										
Microfiltration: 30 mgd (30%)	$15,831,000	$1,480,000							1	1	1	1					
Microfiltration: 30 mgd (100%)	$15,831,000	$1,761,000												1	1	1	1
Electrodialysis Reversal: 9 mgd	$11,903,000	$1,697,000				1											
Electrodialysis Reversal: 30 mgd (30%)	$21,568,000	$2,238,000									1						
Electrodialysis Reversal: 30 mgd (100%)	$21,568,000	$3,908,000														1	
Nanofiltration: 9 mgd	$10,457,000	$1,455,000	1	1													
Nanofiltration: 30 mgd (30%)	$20,760,000	$2,208,000						1	1								
Nanofiltration: 30 mgd (100%)	$20,760,000	$3,855,000											1	1			
Reverse Osmosis: 9 mgd	$11,623,000	$1,630,000			1		1										
Reverse Osmosis: 30 mgd (30%)	$22,037,000	$2,424,000								1		1					
Reverse Osmosis: 30 mgd (100%)	$22,037,000	$4,560,000													1		1
Gravity Thickener: 9 mgd	$862,000	$16,000					1										
Gravity Thickener: 30 mgd (30%)	$1,147,000	$23,000										1					
Gravity Thickener: 30 mgd (100%)	$1,147,000	$24,000															1
Centrifuge: 9 mgd	$2,931,000	$194,000		1	1	1	1										
Centrifuge: 30 mgd (30%)	$4,759,000	$486,000							1	1	1	1					
Centrifuge: 30 mgd (100%)	$4,759,000	$513,000												1	1	1	1
Conventional Surge Basin Decanter: 9 mgd	$415,000	$30,000					1										
Conventional Surge Basin Decanter: 30 mgd (30%)	$1,640,000	$33,000										1					
Conventional Surge Basin Decanter: 30 mgd (100%)	$1,640,000	$57,000															1
In Plant PS: 9 mgd	$1,712,000	$101,000					1										
In Plant PS: 30 mgd (30%)	$2,957,000	$107,000										1					
In Plant PS: 30 mgd (100%)	$2,957,000	$203,000															1
Liquid Chemical NaOH: 9 mgd	$449,000	$1,215,000					1										
Liquid Chemical NaOH: 30 mgd (30%)	$1,037,000	$1,243,000										1					
Liquid Chemical NaOH: 30 mgd (100%)	$1,037,000	$4,104,000															1
Liquid Chemical H_2SO_4: 9 mgd	$439,000	$220,000					1										
Liquid Chemical H_2SO_4: 30 mgd (30%)	$470,000	$222,000										1					
Liquid Chemical H_2SO_4: 30 mgd (100%)	$470,000	$721,000															1
Liquid Chemical Alum: 9 mgd	$425,000	$118,000		1	1	1	1										
Liquid Chemical Alum: 30 mgd (30%)	$601,000	$120,000							1	1	1	1					
Liquid Chemical Alum: 30 mgd (100%)	$601,000	$381,000												1	1	1	1
Horizontal Pressure Filter: 9 mgd	$4,974,000	$176,000					1										
Microfiltration Surge Basin Decanter: 9 mgd	$851,000	$24,000		1	1	1	1										
Microfiltration Surge Basin Decanter: 30 mgd (30%)	$1,617,000	$46,000							1	1	1	1					
Microfiltration Surge Basin Decanter: 30 mgd (100%)	$1,617,000	$59,000												1	1	1	1
Subtotal Cost			**$10,457,000**	**$20,348,000**	**$21,514,000**	**$21,794,000**	**$36,399,000**	**$20,760,000**	**$43,568,000**	**$44,845,000**	**$44,376,000**	**$67,493,000**	**$20,760,000**	**$43,568,000**	**$44,845,000**	**$44,376,000**	**$67,493,000**
ADDITIONAL PROJECT COSTS:																	
Overall Sitework:	6%		$628,000	$1,221,000	$1,291,000	$1,308,000	$2,184,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000
Plant Computer System:	6%		$628,000	$1,221,000	$1,291,000	$1,308,000	$2,184,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000
Yard Electrical:	9%		$942,000	$1,832,000	$1,937,000	$1,962,000	$3,276,000	$1,869,000	$3,922,000	$4,037,000	$3,994,000	$6,075,000	$1,869,000	$3,922,000	$4,037,000	$3,994,000	$6,075,000
Yard Piping:	8%		$837,000	$1,628,000	$1,722,000	$1,744,000	$2,912,000	$1,661,000	$3,486,000	$3,588,000	$3,551,000	$5,400,000	$1,661,000	$3,486,000	$3,588,000	$3,551,000	$5,400,000
SUBTOTAL OF ADDITIONAL PROJECT COSTS:			$13,492,000	$26,250,000	$27,755,000	$28,116,000	$46,955,000	$26,782,000	$56,206,000	$57,852,000	$57,247,000	$87,068,000	$26,782,000	$56,206,000	$57,852,000	$57,247,000	$87,068,000
COST DATA ESCALATION (JAN '18 TO JAN '19)	1.0125		$13,662,000	$26,580,000	$28,103,000	$28,469,000	$47,544,000	$27,118,000	$56,911,000	$58,578,000	$57,965,000	$88,160,000	$27,118,000	$56,911,000	$58,578,000	$57,965,000	$88,160,000
CONTRACTOR MARKUPS:																	
Overhead	12%		$1,640,000	$3,190,000	$3,373,000	$3,417,000	$5,706,000	$3,255,000	$6,830,000	$7,030,000	$6,956,000	$10,580,000	$3,255,000	$6,830,000	$7,030,000	$6,956,000	$10,580,000
Subtotal:			$15,302,000	$29,770,000	$31,476,000	$31,886,000	$53,250,000	$30,373,000	$63,741,000	$65,608,000	$64,921,000	$98,740,000	$30,373,000	$63,741,000	$65,608,000	$64,921,000	$98,740,000
Profit	10%		$1,531,000	$2,977,000	$3,148,000	$3,189,000	$5,325,000	$3,038,000	$6,375,000	$6,561,000	$6,493,000	$9,874,000	$3,038,000	$6,375,000	$6,561,000	$6,493,000	$9,874,000
Subtotal:			$16,833,000	$32,747,000	$34,624,000	$35,075,000	$58,575,000	$33,411,000	$70,116,000	$72,169,000	$71,414,000	$108,614,000	$33,411,000	$70,116,000	$72,169,000	$71,414,000	$108,614,000
Mob/Bonds/Insurance	3%		$505,000	$983,000	$1,039,000	$1,053,000	$1,758,000	$1,003,000	$2,104,000	$2,166,000	$2,143,000	$3,259,000	$1,003,000	$2,104,000	$2,166,000	$2,143,000	$3,259,000
Subtotal:			$17,338,000	$33,730,000	$35,663,000	$36,128,000	$60,333,000	$34,414,000	$72,220,000	$74,335,000	$73,557,000	$111,873,000	$34,414,000	$72,220,000	$74,335,000	$73,557,000	$111,873,000
Contingency	30%		$5,202,000	$10,119,000	$10,699,000	$10,839,000	$18,100,000	$10,325,000	$21,666,000	$22,301,000	$22,068,000	$33,562,000	$10,325,000	$21,666,000	$22,301,000	$22,068,000	$33,562,000
Subtotal:			$22,540,000	$43,849,000	$46,362,000	$46,967,000	$78,433,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000
SUBTOTAL OF CONTRACTOR MARKUPS:			$22,540,000	$43,849,000	$46,362,000	$46,967,000	$78,433,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000
NON-CONSTRUCTION COSTS:																	
Permitting:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
Engineering:	10%		$2,254,000	$4,385,000	$4,637,000	$4,697,000	$7,844,000	$4,474,000	$9,389,000	$9,664,000	$9,563,000	$14,544,000	$4,474,000	$9,389,000	$9,664,000	$9,563,000	$14,544,000
Services During Construction:	8%		$1,804,000	$3,508,000	$3,709,000	$3,758,000	$6,275,000	$3,580,000	$7,511,000	$7,731,000	$7,650,000	$11,635,000	$3,580,000	$7,511,000	$7,731,000	$7,650,000	$11,635,000
Commissioning & Startup:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
Land / ROW:	1%		$226,000	$439,000	$464,000	$470,000	$785,000	$448,000	$939,000	$967,000	$957,000	$1,455,000	$448,000	$939,000	$967,000	$957,000	$1,455,000
Legal / Admin:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
SUBTOTAL OF NON-CONSTRUCTION COSTS:			$28,177,000	$54,812,000	$57,956,000	$58,712,000	$98,044,000	$55,926,000	$117,359,000	$120,797,000	$119,534,000	$181,796,000	$55,926,000	$117,359,000	$120,797,000	$119,534,000	$181,796,000
Total Capital Cost			**$28,177,000**	**$54,812,000**	**$57,956,000**	**$58,712,000**	**$98,044,000**	**$55,926,000**	**$117,359,000**	**$120,797,000**	**$119,534,000**	**$181,796,000**	**$55,926,000**	**$117,359,000**	**$120,797,000**	**$119,534,000**	**$181,796,000**
Unit Capital Cost ($/gal of capacity)			*$3.10*	*$6.10*	*$6.40*	*$6.50*	*$10.90*	*$1.90*	*$3.90*	*$4.00*	*$4.00*	*$6.10*	*$1.90*	*$3.90*	*$4.00*	*$4.00*	*$6.10*
SITE-SPECIFIC COSTS:																	
Central Site: 9 mgd	$13,113,359	$99,581	1	1	1	1	1										
Central Site: 30 mgd (30%)	$15,554,258	$113,890						1	1	1	1	1					
Central Site: 30 mgd (100%)	$15,554,258	$204,335											1	1	1	1	1
North Site: 9 mgd	$9,547,690	$74,696															
North Site: 30 mgd (30%)	$11,444,344	$92,744															
North Site: 30 mgd (100%)	$15,554,258	$204,335															
South Site: 9 mgd	$23,550,901	$338,735															
South Site: 30 mgd (30%)	$29,331,113	$425,063															
South Site: 30 mgd (100%)	$29,331,113	$801,919															
SUBTOTAL OF SITE-SPECIFIC COSTS:			$13,113,359	$13,113,359	$13,113,359	$13,113,359	$13,113,359	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258
Total Implementation Cost			**$41,290,359**	**$67,925,359**	**$71,069,359**	**$71,825,359**	**$111,157,359**	**$71,480,258**	**$132,913,258**	**$136,351,258**	**$135,088,258**	**$197,350,258**	**$71,480,258**	**$132,913,258**	**$136,351,258**	**$135,088,258**	**$197,350,258**
25-Year Bond Payment ($/yr)			$2,929,652	$4,819,471	$5,042,546	$5,096,186	$7,886,888	$5,071,700	$9,430,522	$9,674,457	$9,584,844	$14,002,486	$5,071,700	$9,430,522	$9,674,457	$9,584,844	$14,002,486
Annual O&M Cost ($/yr)			$1,572,823	$2,451,705	$2,628,900	$2,696,740	$4,622,586	$2,349,573	$4,508,303	$4,727,011	$4,538,679	$6,749,049	$4,107,668	$6,855,695	$7,569,534	$6,909,359	$13,132,415
25-Year Annual Cost ($/yr)			**$4,502,475**	**$7,271,177**	**$7,671,445**	**$7,792,925**	**$12,509,474**	**$7,421,273**	**$13,938,825**	**$14,401,468**	**$14,123,523**	**$20,751,534**	**$9,179,368**	**$16,286,217**	**$17,243,991**	**$16,494,203**	**$27,134,901**
25-Year WISE Rate Increase ($/kgal)			**$1.38**	**$2.23**	**$2.35**	**$2.39**	**$3.84**	**$2.28**	**$4.28**	**$4.42**	**$4.33**	**$6.37**	**$2.82**	**$5.00**	**$5.29**	**$5.06**	**$8.33**
Annual O&M Cost ($/yr)			$1,572,823	$2,451,705	$2,628,900	$2,696,740	$4,622,586	$2,349,573	$4,508,303	$4,727,011	$4,538,679	$6,749,049	$4,107,668	$6,855,695	$7,569,534	$6,909,359	$13,132,415
Long-Term Annual Cost ($/yr)			**$1,572,823**	**$2,451,705**	**$2,628,900**	**$2,696,740**	**$4,622,586**	**$2,349,573**	**$4,508,303**	**$4,727,011**	**$4,538,679**	**$6,749,049**	**$4,107,668**	**$6,855,695**	**$7,569,534**	**$6,909,359**	**$13,132,415**
Long-Term WISE Rate Increase ($/kgal)			**$0.48**	**$0.75**	**$0.81**	**$0.83**	**$1.42**	**$0.72**	**$1.38**	**$1.45**	**$1.39**	**$2.07**	**$1.26**	**$2.10**	**$2.32**	**$2.12**	**$4.03**

Salinity Removal Cost Summary (North Site)

			9 mgd Facility Size					30 mgd Facility Size (30% Utilization)					30 mgd Facility Size (100% Utilization)				
Unit Process	**Capital Cost**	**O&M Cost**	**RBF + NF**	**RBF + MF + NF**	**RBF + MF + RO**	**RBF + MF + EDR**	**Conventional + MF + RO**	**RBF + NF**	**RBF + MF + NF**	**RBF + MF + RO**	**RBF + MF + EDR**	**Conventional + MF + RO**	**RBF + NF**	**RBF + MF + NF**	**RBF + MF + RO**	**RBF + MF + EDR**	**Conventional + MF + RO**
Rapid Mix: 9 mgd	$654,000	$8,000					1										
Rapid Mix: 30 mgd (30%)	$935,000	$15,000										1					
Rapid Mix: 30 mgd (100%)	$935,000	$20,000															1
Flocculation: 9 mgd	$2,553,000	$117,000					1										
Flocculation: 30 mgd (30%)	$2,766,000	$84,000										1					
Flocculation: 30 mgd (100%)	$2,766,000	$93,000															1
Lamella Clarifier: 9 mgd	$2,827,000	$86,000					1										
Lamella Clarifier: 30 mgd (30%)	$4,443,000	$164,000										1					
Lamella Clarifier: 30 mgd (100%)	$4,443,000	$166,000															1
Filter: 30 mgd (30%)	$7,253,000	$106,000										1					
Filter: 30 mgd (100%)	$7,253,000	$106,000															1
Microfiltration: 9 mgd	$5,684,000	$532,000		1	1	1	1										
Microfiltration: 30 mgd (30%)	$15,831,000	$1,480,000							1	1	1	1					
Microfiltration: 30 mgd (100%)	$15,831,000	$1,761,000												1	1	1	1
Electrodialysis Reversal: 9 mgd	$11,903,000	$1,697,000				1											
Electrodialysis Reversal: 30 mgd (30%)	$21,568,000	$2,238,000									1						
Electrodialysis Reversal: 30 mgd (100%)	$21,568,000	$3,908,000														1	
Nanofiltration: 9 mgd	$10,457,000	$1,455,000	1	1													
Nanofiltration: 30 mgd (30%)	$20,760,000	$2,208,000						1	1								
Nanofiltration: 30 mgd (100%)	$20,760,000	$3,855,000											1	1			
Reverse Osmosis: 9 mgd	$11,623,000	$1,630,000			1		1										
Reverse Osmosis: 30 mgd (30%)	$22,037,000	$2,424,000								1		1					
Reverse Osmosis: 30 mgd (100%)	$22,037,000	$4,560,000													1		1
Gravity Thickener: 9 mgd	$862,000	$16,000					1										
Gravity Thickener: 30 mgd (30%)	$1,147,000	$23,000										1					
Gravity Thickener: 30 mgd (100%)	$1,147,000	$24,000															1
Centrifuge: 9 mgd	$2,931,000	$194,000		1	1	1	1										
Centrifuge: 30 mgd (30%)	$4,759,000	$486,000							1	1	1	1					
Centrifuge: 30 mgd (100%)	$4,759,000	$513,000												1	1	1	1
Conventional Surge Basin Decanter: 9 mgd	$415,000	$30,000					1										
Conventional Surge Basin Decanter: 30 mgd (30%)	$1,640,000	$33,000										1					
Conventional Surge Basin Decanter: 30 mgd (100%)	$1,640,000	$57,000															1
In Plant PS: 9 mgd	$1,712,000	$101,000					1										
In Plant PS: 30 mgd (30%)	$2,957,000	$107,000										1					
In Plant PS: 30 mgd (100%)	$2,957,000	$203,000															1
Liquid Chemical NaOH: 9 mgd	$449,000	$1,215,000					1										
Liquid Chemical NaOH: 30 mgd (30%)	$1,037,000	$1,243,000										1					
Liquid Chemical NaOH: 30 mgd (100%)	$1,037,000	$4,104,000															1
Liquid Chemical H_2SO_4: 9 mgd	$439,000	$220,000					1										
Liquid Chemical H_2SO_4: 30 mgd (30%)	$470,000	$222,000										1					
Liquid Chemical H_2SO_4: 30 mgd (100%)	$470,000	$721,000															1
Liquid Chemical Alum: 9 mgd	$425,000	$118,000		1	1	1	1										
Liquid Chemical Alum: 30 mgd (30%)	$601,000	$120,000							1	1	1	1					
Liquid Chemical Alum: 30 mgd (100%)	$601,000	$381,000												1	1	1	1
Horizontal Pressure Filter: 9 mgd	$4,974,000	$176,000					1										
Microfiltration Surge Basin Decanter: 9 mgd	$851,000	$24,000		1	1	1	1										
Microfiltration Surge Basin Decanter: 30 mgd (30%)	$1,617,000	$46,000							1	1	1	1					
Microfiltration Surge Basin Decanter: 30 mgd (100%)	$1,617,000	$59,000												1	1	1	1
Subtotal Cost			**$10,457,000**	**$20,348,000**	**$21,514,000**	**$21,794,000**	**$36,399,000**	**$20,760,000**	**$43,568,000**	**$44,845,000**	**$44,376,000**	**$67,493,000**	**$20,760,000**	**$43,568,000**	**$44,845,000**	**$44,376,000**	**$67,493,000**
ADDITIONAL PROJECT COSTS:																	
Overall Sitework:	6%		$628,000	$1,221,000	$1,291,000	$1,308,000	$2,184,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000
Plant Computer System:	6%		$628,000	$1,221,000	$1,291,000	$1,308,000	$2,184,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000
Yard Electrical:	9%		$942,000	$1,832,000	$1,937,000	$1,962,000	$3,276,000	$1,869,000	$3,922,000	$4,037,000	$3,994,000	$6,075,000	$1,869,000	$3,922,000	$4,037,000	$3,994,000	$6,075,000
Yard Piping:	8%		$837,000	$1,628,000	$1,722,000	$1,744,000	$2,912,000	$1,661,000	$3,486,000	$3,588,000	$3,551,000	$5,400,000	$1,661,000	$3,486,000	$3,588,000	$3,551,000	$5,400,000
SUBTOTAL OF ADDITIONAL PROJECT COSTS:			$13,492,000	$26,250,000	$27,755,000	$28,116,000	$46,955,000	$26,782,000	$56,206,000	$57,852,000	$57,247,000	$87,068,000	$26,782,000	$56,206,000	$57,852,000	$57,247,000	$87,068,000
COST DATA ESCALATION (JAN '18 TO JAN '19)	1.0125		$13,662,000	$26,580,000	$28,103,000	$28,469,000	$47,544,000	$27,118,000	$56,911,000	$58,578,000	$57,965,000	$88,160,000	$27,118,000	$56,911,000	$58,578,000	$57,965,000	$88,160,000
CONTRACTOR MARKUPS:																	
Overhead	12%		$1,640,000	$3,190,000	$3,373,000	$3,417,000	$5,706,000	$3,255,000	$6,830,000	$7,030,000	$6,956,000	$10,580,000	$3,255,000	$6,830,000	$7,030,000	$6,956,000	$10,580,000
Subtotal:			$15,302,000	$29,770,000	$31,476,000	$31,886,000	$53,250,000	$30,373,000	$63,741,000	$65,608,000	$64,921,000	$98,740,000	$30,373,000	$63,741,000	$65,608,000	$64,921,000	$98,740,000
Profit	10%		$1,531,000	$2,977,000	$3,148,000	$3,189,000	$5,325,000	$3,038,000	$6,375,000	$6,561,000	$6,493,000	$9,874,000	$3,038,000	$6,375,000	$6,561,000	$6,493,000	$9,874,000
Subtotal:			$16,833,000	$32,747,000	$34,624,000	$35,075,000	$58,575,000	$33,411,000	$70,116,000	$72,169,000	$71,414,000	$108,614,000	$33,411,000	$70,116,000	$72,169,000	$71,414,000	$108,614,000
Mob/Bonds/Insurance	3%		$505,000	$983,000	$1,039,000	$1,053,000	$1,758,000	$1,003,000	$2,104,000	$2,166,000	$2,143,000	$3,259,000	$1,003,000	$2,104,000	$2,166,000	$2,143,000	$3,259,000
Subtotal:			$17,338,000	$33,730,000	$35,663,000	$36,128,000	$60,333,000	$34,414,000	$72,220,000	$74,335,000	$73,557,000	$111,873,000	$34,414,000	$72,220,000	$74,335,000	$73,557,000	$111,873,000
Contingency	30%		$5,202,000	$10,119,000	$10,699,000	$10,839,000	$18,100,000	$10,325,000	$21,666,000	$22,301,000	$22,068,000	$33,562,000	$10,325,000	$21,666,000	$22,301,000	$22,068,000	$33,562,000
Subtotal:			$22,540,000	$43,849,000	$46,362,000	$46,967,000	$78,433,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000
SUBTOTAL OF CONTRACTOR MARKUPS:			$22,540,000	$43,849,000	$46,362,000	$46,967,000	$78,433,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000
NON-CONSTRUCTION COSTS:																	
Permitting:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
Engineering:	10%		$2,254,000	$4,385,000	$4,637,000	$4,697,000	$7,844,000	$4,474,000	$9,389,000	$9,664,000	$9,563,000	$14,544,000	$4,474,000	$9,389,000	$9,664,000	$9,563,000	$14,544,000
Services During Construction:	8%		$1,804,000	$3,508,000	$3,709,000	$3,758,000	$6,275,000	$3,580,000	$7,511,000	$7,731,000	$7,650,000	$11,635,000	$3,580,000	$7,511,000	$7,731,000	$7,650,000	$11,635,000
Commissioning & Startup:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
Land / ROW:	1%		$226,000	$439,000	$464,000	$470,000	$785,000	$448,000	$939,000	$967,000	$957,000	$1,455,000	$448,000	$939,000	$967,000	$957,000	$1,455,000
Legal / Admin:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
SUBTOTAL OF NON-CONSTRUCTION COSTS:			$28,177,000	$54,812,000	$57,956,000	$58,712,000	$98,044,000	$55,926,000	$117,359,000	$120,797,000	$119,534,000	$181,796,000	$55,926,000	$117,359,000	$120,797,000	$119,534,000	$181,796,000
Total Capital Cost			**$28,177,000**	**$54,812,000**	**$57,956,000**	**$58,712,000**	**$98,044,000**	**$55,926,000**	**$117,359,000**	**$120,797,000**	**$119,534,000**	**$181,796,000**	**$55,926,000**	**$117,359,000**	**$120,797,000**	**$119,534,000**	**$181,796,000**
Unit Capital Cost ($/gal of capacity)			*$3.10*	*$6.10*	*$6.40*	*$6.50*	*$10.90*	*$1.90*	*$3.90*	*$4.00*	*$4.00*	*$6.10*	*$1.90*	*$3.90*	*$4.00*	*$4.00*	*$6.10*
SITE-SPECIFIC COSTS:																	
Central Site: 9 mgd	$13,113,359	$99,581															
Central Site: 30 mgd (30%)	$15,554,258	$113,890															
Central Site: 30 mgd (100%)	$15,554,258	$204,335															
North Site: 9 mgd	$9,547,690	$74,696	1	1	1	1	1										
North Site: 30 mgd (30%)	$11,444,344	$92,744						1	1	1	1	1					
North Site: 30 mgd (100%)	$15,554,258	$204,335											1	1	1	1	1
South Site: 9 mgd	$23,550,901	$338,735															
South Site: 30 mgd (30%)	$29,331,113	$425,063															
South Site: 30 mgd (100%)	$29,331,113	$801,919															
SUBTOTAL OF SITE-SPECIFIC COSTS:			$9,547,690	$9,547,690	$9,547,690	$9,547,690	$9,547,690	$11,444,344	$11,444,344	$11,444,344	$11,444,344	$11,444,344	$15,554,258	$15,554,258	$15,554,258	$15,554,258	$15,554,258
Total Implementation Cost			**$37,724,690**	**$64,359,690**	**$67,503,690**	**$68,259,690**	**$107,591,690**	**$67,370,344**	**$128,803,344**	**$132,241,344**	**$130,978,344**	**$193,240,344**	**$71,480,258**	**$132,913,258**	**$136,351,258**	**$135,088,258**	**$197,350,258**
25-Year Bond Payment ($/yr)			$2,676,659	$4,566,478	$4,789,553	$4,843,193	$7,633,895	$4,780,091	$9,138,914	$9,382,848	$9,293,235	$13,710,877	$5,071,700	$9,430,522	$9,674,457	$9,584,844	$14,002,486
Annual O&M Cost ($/yr)			$1,547,938	$2,426,821	$2,604,015	$2,671,855	$4,597,701	$2,328,427	$4,487,157	$4,705,865	$4,517,533	$6,727,903	$4,107,668	$6,855,695	$7,569,534	$6,909,359	$13,132,415
25-Year Annual Cost ($/yr)			**$4,224,597**	**$6,993,299**	**$7,393,567**	**$7,515,047**	**$12,231,596**	**$7,108,519**	**$13,626,071**	**$14,088,714**	**$13,810,769**	**$20,438,780**	**$9,179,368**	**$16,286,217**	**$17,243,991**	**$16,494,203**	**$27,134,901**
25-Year WISE Rate Increase ($/kgal)			**$1.30**	**$2.15**	**$2.27**	**$2.31**	**$3.75**	**$2.18**	**$4.18**	**$4.32**	**$4.24**	**$6.27**	**$2.82**	**$5.00**	**$5.29**	**$5.06**	**$8.33**
Annual O&M Cost ($/yr)			$1,547,938	$2,426,821	$2,604,015	$2,671,855	$4,597,701	$2,328,427	$4,487,157	$4,705,865	$4,517,533	$6,727,903	$4,107,668	$6,855,695	$7,569,534	$6,909,359	$13,132,415
Long-Term Annual Cost ($/yr)			**$1,547,938**	**$2,426,821**	**$2,604,015**	**$2,671,855**	**$4,597,701**	**$2,328,427**	**$4,487,157**	**$4,705,865**	**$4,517,533**	**$6,727,903**	**$4,107,668**	**$6,855,695**	**$7,569,534**	**$6,909,359**	**$13,132,415**
Long-Term WISE Rate Increase ($/kgal)			**$0.48**	**$0.74**	**$0.80**	**$0.82**	**$1.41**	**$0.71**	**$1.38**	**$1.44**	**$1.39**	**$2.06**	**$1.26**	**$2.10**	**$2.32**	**$2.12**	**$4.03**

Salinity Removal Cost Summary (South Site)

			9 mgd Facility Size					30 mgd Facility Size (30% Utilization)					30 mgd Facility Size (100% Utilization)				
Unit Process	Capital Cost	O&M Cost	RBF + NF	RBF + MF + NF	RBF + MF + RO	RBF + MF + EDR	Conventional + MF + RO	RBF + NF	RBF + MF + NF	RBF + MF + RO	RBF + MF + EDR	Conventional + MF + RO	RBF + NF	RBF + MF + NF	RBF + MF + RO	RBF + MF + EDR	Conventional + MF + RO
Rapid Mix: 9 mgd	$654,000	$8,000					1										
Rapid Mix: 30 mgd (30%)	$935,000	$15,000										1					
Rapid Mix: 30 mgd (100%)	$935,000	$20,000															1
Flocculation: 9 mgd	$2,553,000	$117,000					1										
Flocculation: 30 mgd (30%)	$2,766,000	$84,000										1					
Flocculation: 30 mgd (100%)	$2,766,000	$93,000															1
Lamella Clarifier: 9 mgd	$2,827,000	$86,000					1										
Lamella Clarifier: 30 mgd (30%)	$4,443,000	$164,000										1					
Lamella Clarifier: 30 mgd (100%)	$4,443,000	$166,000															1
Filter: 30 mgd (30%)	$7,253,000	$106,000										1					
Filter: 30 mgd (100%)	$7,253,000	$106,000															1
Microfiltration: 9 mgd	$5,684,000	$532,000		1	1	1	1										
Microfiltration: 30 mgd (30%)	$15,831,000	$1,480,000							1	1	1	1					
Microfiltration: 30 mgd (100%)	$15,831,000	$1,761,000												1	1	1	1
Electrodialysis Reversal: 9 mgd	$11,903,000	$1,697,000				1											
Electrodialysis Reversal: 30 mgd (30%)	$21,568,000	$2,238,000									1						
Electrodialysis Reversal: 30 mgd (100%)	$21,568,000	$3,908,000														1	
Nanofiltration: 9 mgd	$10,457,000	$1,455,000	1	1													
Nanofiltration: 30 mgd (30%)	$20,760,000	$2,208,000						1	1								
Nanofiltration: 30 mgd (100%)	$20,760,000	$3,855,000											1	1			
Reverse Osmosis: 9 mgd	$11,623,000	$1,630,000			1		1										
Reverse Osmosis: 30 mgd (30%)	$22,037,000	$2,424,000								1		1					
Reverse Osmosis: 30 mgd (100%)	$22,037,000	$4,560,000													1		1
Gravity Thickener: 9 mgd	$862,000	$16,000					1										
Gravity Thickener: 30 mgd (30%)	$1,147,000	$23,000										1					
Gravity Thickener: 30 mgd (100%)	$1,147,000	$24,000															1
Centrifuge: 9 mgd	$2,931,000	$194,000		1	1	1	1										
Centrifuge: 30 mgd (30%)	$4,759,000	$486,000							1	1	1	1					
Centrifuge: 30 mgd (100%)	$4,759,000	$513,000												1	1	1	1
Conventional Surge Basin Decanter: 9 mgd	$415,000	$30,000					1										
Conventional Surge Basin Decanter: 30 mgd (30%)	$1,640,000	$33,000										1					
Conventional Surge Basin Decanter: 30 mgd (100%)	$1,640,000	$57,000															1
In Plant PS: 9 mgd	$1,712,000	$101,000					1										
In Plant PS: 30 mgd (30%)	$2,957,000	$107,000										1					
In Plant PS: 30 mgd (100%)	$2,957,000	$203,000															1
Liquid Chemical NaOH: 9 mgd	$449,000	$1,215,000					1										
Liquid Chemical NaOH: 30 mgd (30%)	$1,037,000	$1,243,000										1					
Liquid Chemical NaOH: 30 mgd (100%)	$1,037,000	$4,104,000															1
Liquid Chemical H_2SO_4: 9 mgd	$439,000	$220,000					1										
Liquid Chemical H_2SO_4: 30 mgd (30%)	$470,000	$222,000										1					
Liquid Chemical H_2SO_4: 30 mgd (100%)	$470,000	$721,000															1
Liquid Chemical Alum: 9 mgd	$425,000	$118,000		1	1	1	1										
Liquid Chemical Alum: 30 mgd (30%)	$601,000	$120,000							1	1	1	1					
Liquid Chemical Alum: 30 mgd (100%)	$601,000	$381,000												1	1	1	1
Horizontal Pressure Filter: 9 mgd	$4,974,000	$176,000					1										
Microfiltration Surge Basin Decanter: 9 mgd	$851,000	$24,000		1	1	1	1										
Microfiltration Surge Basin Decanter: 30 mgd (30%)	$1,617,000	$46,000							1	1	1	1					
Microfiltration Surge Basin Decanter: 30 mgd (100%)	$1,617,000	$59,000												1	1	1	1
Subtotal Cost			**$10,457,000**	**$20,348,000**	**$21,514,000**	**$21,794,000**	**$36,399,000**	**$20,760,000**	**$43,568,000**	**$44,845,000**	**$44,376,000**	**$67,493,000**	**$20,760,000**	**$43,568,000**	**$44,845,000**	**$44,376,000**	**$67,493,000**
ADDITIONAL PROJECT COSTS:																	
Overall Sitework:	6%		$628,000	$1,221,000	$1,291,000	$1,308,000	$2,184,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000
Plant Computer System:	6%		$628,000	$1,221,000	$1,291,000	$1,308,000	$2,184,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000	$1,246,000	$2,615,000	$2,691,000	$2,663,000	$4,050,000
Yard Electrical:	9%		$942,000	$1,832,000	$1,937,000	$1,962,000	$3,276,000	$1,869,000	$3,922,000	$4,037,000	$3,994,000	$6,075,000	$1,869,000	$3,922,000	$4,037,000	$3,994,000	$6,075,000
Yard Piping:	8%		$837,000	$1,628,000	$1,722,000	$1,744,000	$2,912,000	$1,661,000	$3,486,000	$3,588,000	$3,551,000	$5,400,000	$1,661,000	$3,486,000	$3,588,000	$3,551,000	$5,400,000
SUBTOTAL OF ADDITIONAL PROJECT COSTS:			$13,492,000	$26,250,000	$27,755,000	$28,116,000	$46,955,000	$26,782,000	$56,206,000	$57,852,000	$57,247,000	$87,068,000	$26,782,000	$56,206,000	$57,852,000	$57,247,000	$87,068,000
COST DATA ESCALATION (JAN '18 TO JAN '19)	1.0125		$13,662,000	$26,580,000	$28,103,000	$28,469,000	$47,544,000	$27,118,000	$56,911,000	$58,578,000	$57,965,000	$88,160,000	$27,118,000	$56,911,000	$58,578,000	$57,965,000	$88,160,000
CONTRACTOR MARKUPS:																	
Overhead	12%		$1,640,000	$3,190,000	$3,373,000	$3,417,000	$5,706,000	$3,255,000	$6,830,000	$7,030,000	$6,956,000	$10,580,000	$3,255,000	$6,830,000	$7,030,000	$6,956,000	$10,580,000
Subtotal:			$15,302,000	$29,770,000	$31,476,000	$31,886,000	$53,250,000	$30,373,000	$63,741,000	$65,608,000	$64,921,000	$98,740,000	$30,373,000	$63,741,000	$65,608,000	$64,921,000	$98,740,000
Profit	10%		$1,531,000	$2,977,000	$3,148,000	$3,189,000	$5,325,000	$3,038,000	$6,375,000	$6,561,000	$6,493,000	$9,874,000	$3,038,000	$6,375,000	$6,561,000	$6,493,000	$9,874,000
Subtotal:			$16,833,000	$32,747,000	$34,624,000	$35,075,000	$58,575,000	$33,411,000	$70,116,000	$72,169,000	$71,414,000	$108,614,000	$33,411,000	$70,116,000	$72,169,000	$71,414,000	$108,614,000
Mob/Bonds/Insurance	3%		$505,000	$983,000	$1,039,000	$1,053,000	$1,758,000	$1,003,000	$2,104,000	$2,166,000	$2,143,000	$3,259,000	$1,003,000	$2,104,000	$2,166,000	$2,143,000	$3,259,000
Subtotal:			$17,338,000	$33,730,000	$35,663,000	$36,128,000	$60,333,000	$34,414,000	$72,220,000	$74,335,000	$73,557,000	$111,873,000	$34,414,000	$72,220,000	$74,335,000	$73,557,000	$111,873,000
Contingency	30%		$5,202,000	$10,119,000	$10,699,000	$10,839,000	$18,100,000	$10,325,000	$21,666,000	$22,301,000	$22,068,000	$33,562,000	$10,325,000	$21,666,000	$22,301,000	$22,068,000	$33,562,000
Subtotal:			$22,540,000	$43,849,000	$46,362,000	$46,967,000	$78,433,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000
SUBTOTAL OF CONTRACTOR MARKUPS:			$22,540,000	$43,849,000	$46,362,000	$46,967,000	$78,433,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000	$44,739,000	$93,886,000	$96,636,000	$95,625,000	$145,435,000
NON-CONSTRUCTION COSTS:																	
Permitting:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
Engineering:	10%		$2,254,000	$4,385,000	$4,637,000	$4,697,000	$7,844,000	$4,474,000	$9,389,000	$9,664,000	$9,563,000	$14,544,000	$4,474,000	$9,389,000	$9,664,000	$9,563,000	$14,544,000
Services During Construction:	8%		$1,804,000	$3,508,000	$3,709,000	$3,758,000	$6,275,000	$3,580,000	$7,511,000	$7,731,000	$7,650,000	$11,635,000	$3,580,000	$7,511,000	$7,731,000	$7,650,000	$11,635,000
Commissioning & Startup:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
Land / ROW:	1%		$226,000	$439,000	$464,000	$470,000	$785,000	$448,000	$939,000	$967,000	$957,000	$1,455,000	$448,000	$939,000	$967,000	$957,000	$1,455,000
Legal / Admin:	2%		$451,000	$877,000	$928,000	$940,000	$1,569,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000	$895,000	$1,878,000	$1,933,000	$1,913,000	$2,909,000
SUBTOTAL OF NON-CONSTRUCTION COSTS:			$28,177,000	$54,812,000	$57,956,000	$58,712,000	$98,044,000	$55,926,000	$117,359,000	$120,797,000	$119,534,000	$181,796,000	$55,926,000	$117,359,000	$120,797,000	$119,534,000	$181,796,000
Total Capital Cost			**$28,177,000**	**$54,812,000**	**$57,956,000**	**$58,712,000**	**$98,044,000**	**$55,926,000**	**$117,359,000**	**$120,797,000**	**$119,534,000**	**$181,796,000**	**$55,926,000**	**$117,359,000**	**$120,797,000**	**$119,534,000**	**$181,796,000**
Unit Capital Cost ($/gal of capacity)			*$3.10*	*$6.10*	*$6.40*	*$6.50*	*$10.90*	*$1.90*	*$3.90*	*$4.00*	*$4.00*	*$6.10*	*$1.90*	*$3.90*	*$4.00*	*$4.00*	*$6.10*
SITE-SPECIFIC COSTS:																	
Central Site: 9 mgd	$13,113,359	$99,581															
Central Site: 30 mgd (30%)	$15,554,258	$113,890															
Central Site: 30 mgd (100%)	$15,554,258	$204,335															
North Site: 9 mgd	$9,547,690	$74,696															
North Site: 30 mgd (30%)	$11,444,344	$92,744															
North Site: 30 mgd (100%)	$15,554,258	$204,335															
South Site: 9 mgd	$23,550,901	$338,735	1	1	1	1	1										
South Site: 30 mgd (30%)	$29,331,113	$425,063						1	1	1	1	1					
South Site: 30 mgd (100%)	$29,331,113	$801,919											1	1	1	1	1
SUBTOTAL OF SITE-SPECIFIC COSTS:			$23,550,901	$23,550,901	$23,550,901	$23,550,901	$23,550,901	$29,331,113	$29,331,113	$29,331,113	$29,331,113	$29,331,113	$29,331,113	$29,331,113	$29,331,113	$29,331,113	$29,331,113
Total Implementation Cost			**$51,727,901**	**$78,362,901**	**$81,506,901**	**$82,262,901**	**$121,594,901**	**$85,257,113**	**$146,690,113**	**$150,128,113**	**$148,865,113**	**$211,127,113**	**$85,257,113**	**$146,690,113**	**$150,128,113**	**$148,865,113**	**$211,127,113**
25-Year Bond Payment ($/yr)			$3,670,222	$5,560,040	$5,783,115	$5,836,755	$8,627,457	$6,049,202	$10,408,024	$10,651,959	$10,562,346	$14,979,987	$6,049,202	$10,408,024	$10,651,959	$10,562,346	$14,979,987
Annual O&M Cost ($/yr)			$1,811,977	$2,690,860	$2,868,054	$2,935,894	$4,861,740	$2,660,746	$4,819,476	$5,038,184	$4,849,852	$7,060,221	$4,705,252	$7,453,279	$8,167,118	$7,506,943	$13,729,999
25-Year Annual Cost ($/yr)			**$5,482,199**	**$8,250,900**	**$8,651,169**	**$8,772,649**	**$13,489,197**	**$8,709,947**	**$15,227,500**	**$15,690,142**	**$15,412,197**	**$22,040,209**	**$10,754,453**	**$17,861,303**	**$18,819,076**	**$18,069,289**	**$28,709,986**
25-Year WISE Rate Increase ($/kgal)			**$1.68**	**$2.53**	**$2.65**	**$2.69**	**$4.14**	**$2.67**	**$4.67**	**$4.82**	**$4.73**	**$6.76**	**$3.30**	**$5.48**	**$5.78**	**$5.55**	**$8.81**
Annual O&M Cost ($/yr)			$1,811,977	$2,690,860	$2,868,054	$2,935,894	$4,861,740	$2,660,746	$4,819,476	$5,038,184	$4,849,852	$7,060,221	$4,705,252	$7,453,279	$8,167,118	$7,506,943	$13,729,999
Long-Term Annual Cost ($/yr)			**$1,811,977**	**$2,690,860**	**$2,868,054**	**$2,935,894**	**$4,861,740**	**$2,660,746**	**$4,819,476**	**$5,038,184**	**$4,849,852**	**$7,060,221**	**$4,705,252**	**$7,453,279**	**$8,167,118**	**$7,506,943**	**$13,729,999**
Long-Term WISE Rate Increase ($/kgal)			**$0.56**	**$0.83**	**$0.88**	**$0.90**	**$1.49**	**$0.82**	**$1.48**	**$1.55**	**$1.49**	**$2.17**	**$1.44**	**$2.29**	**$2.51**	**$2.30**	**$4.21**

Salinity Management Plan

South Metro WISE Authority

TM 2 - Brine Disposal

February 2020

Salinity Management Plan

Document Title:	TM 2 - Brine Disposal
Client Name:	South Metro WISE Authority
Project Manager:	Klint Reedy
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Denver Water

Nathan Elder, P.E.

Aurora Water

Elizabeth Carter, P.E.

Acronyms and Abbreviations

af	Acre Feet
afy	Acre Feet per Year
BWPF	Binney Water Purification Facility
CDPHE	Colorado Department of Public Health and Environment
Ci/g	Curies per Gram
COGCC	Colorado Oil and Gas Conservation Commission
DADS	Denver Arapahoe Disposal Site
ECCV	East Cherry Creek Water and Sanitation District
ft	Feet
ft bgs	Feet Below Ground Surface
I-70	Interstate 70
IWLF	Industrial Waste Landfill
gpm	Gallons per Minute
HWLF	Hazardous Waste Landfill
kgal	Kilogallon (thousands of gallons)
kWh	Kilowatt Hours
mgd	Million Gallons per Day
mg/kg	Milligram per Kilogram
O&G	Oil and Gas
O&M	Operations and Maintenance
pCi/L	Picocuries per Liter
ppm	Parts per Million
PS	Pump Station
psi	Pounds per Square Inch
PWP	Prairie Waters Project
RBF	Riverbank Filtration
RCRA	Resources Conservation and Recovery Act
SMWA	South Metro WISE Authority
Sterling	City of Sterling
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
TM	Technical Memorandum
UIC	Underground Injection Control
US EPA	United States Environmental Protection Agency
USDW	Underground Source of Drinking Water
WDA	Water Delivery Agreement
WISE	Water Infrastructure and Supply Efficiency

1. Introduction

The purpose of this study is to explore options to mitigate elevated total dissolved solids (TDS) concentrations in return flows from the South Platte River that will be delivered to the South Metro WISE Authority (SMWA) by Aurora Water and Denver Water as part of the Water Infrastructure and Supply Efficiency (WISE) project. When practical, options are configured to allow others in the region to also participate in and benefit from the salinity management solutions.

Key overall goals of this study include the following:

1. Investigate how desalination options can be configured to reduce salinity in South Platte River return flows.

2. Study options for brine disposal beyond deep-well injection.

3. Develop water blending concepts incorporating the extension of existing blending concepts and the identification of new blending concepts.

4. Gain increased insight into long-standing questions on inland salinity management and brine disposal principals.

The Salinity Management Plan ("Plan") requires numerous interrelated evaluations to be performed. To effectively manage the work effort, the Plan has been broken into the following documents:

- Project Summary
- TM 1 – Salinity Removal
- **TM 2 – Brine Disposal (this memorandum)**
- TM 3 – Water Blending

1.1 Objectives of the Brine Disposal Evaluation

In May 2018, CH2M evaluated a wide-range of brine disposal options for SMWA. CH2M's evaluation identified deep-well injection and mechanical evaporation followed by landfill disposal as two of the most feasible brine disposal alternatives. This evaluation provides a more detailed investigation of those brine disposal methods based on the specific sites and technologies discussed in **TM 1 – Salinity Removal.**

Specific objectives of this portion of the project were to:

- Identify the brine disposal methods with the lowest potential cost range
- Identify specific and plausible risks that could increase disposal costs
- Estimate the incremental increase in costs associated with each cost risk
- Provide a summary of cost ranges and water loss for each disposal method
- Identify actions and next steps that will narrow brine disposal implementation uncertainty

1.2 Relevant WISE Background

The WISE Project includes SMWA members, Denver Water and Aurora Water. Denver Water and Aurora Water deliver their reusable return flows diverted from the South Platte River to SMWA as “WISE water,” allowing SMWA members to reduce their dependence on non-renewable groundwater. WISE water is diverted from the South Platte River via the Aurora Water Prairie Waters Project (PWP) Riverbank Filtration Wells (RBF Wells) at the Aurora Water North Campus in Brighton, CO and then treated at the Binney Water Purification Facility (BWPF).

Through May 31, 2030, Denver Water and Aurora Water are required, per the WISE Water Delivery Agreement (WDA), to deliver water with a TDS concentration at or below 500 mg/L. Currently, Denver Water and Aurora Water meet this water quality goal by blending some their low TDS mountain water supplies to reduce TDS concentrations in WISE water diverted from South Platte River return flows. Following May 31, 2030, the WDA allows Denver Water and Aurora Water to deliver unblended WISE water to SMWA. Salinity in water diverted by Aurora Water’s RBF Wells can vary from below 500 mg/L of TDS during spring runoff periods to above 700 mg/L of TDS during periods with lower flow, generally in the early fall and winter. Although the water quality agreement of the WDA expires in 2030, Denver Water and Aurora Water are still required per the WDA to deliver SMWA 100,000 acre-feet (af) of WISE water over a 10-year period. The WDA asserts that deliveries of WISE water from Denver Water and Aurora Water to SMWA can range from a daily flowrate of 0 million gallons per day (mgd) to 30 mgd. If Denver Water and Aurora Water delivered WISE water at a constant rate (100,000 af over 10 years), SMWA would receive approximately 9 mgd of daily flow. The flowrate range outlined in the WDA (0 mgd to 30 mgd) and the average flowrate (9 mgd) are the design flowrate ranges utilized in this study.

1.3 Information Referenced from Accompanying TMs

This TM focuses exclusively on brine disposal technologies and the accompanying **TM 1 – Salinity Removal** focuses on salinity removal. For a complete picture of salinity removal and brine disposal the two TMs should be read together. Key information to keep in mind when reviewing this TM includes the following:

1.3.1 Information Referenced from TM 1 – Salinity Removal

- Potential desalination sites, including: North Site (near the Aurora Water PWP Pump Station (PS) #1), the Central Site (near the Aurora Water PWP PS #3), and the South Site (near the Aurora Water BWPF).

- Brine stream flowrates from the salinity removal process is 0.7 mgd for the 9 mgd desalination facility and 2.2 mgd for the 30 mgd facility.

2. Potential Brine Disposal Processes

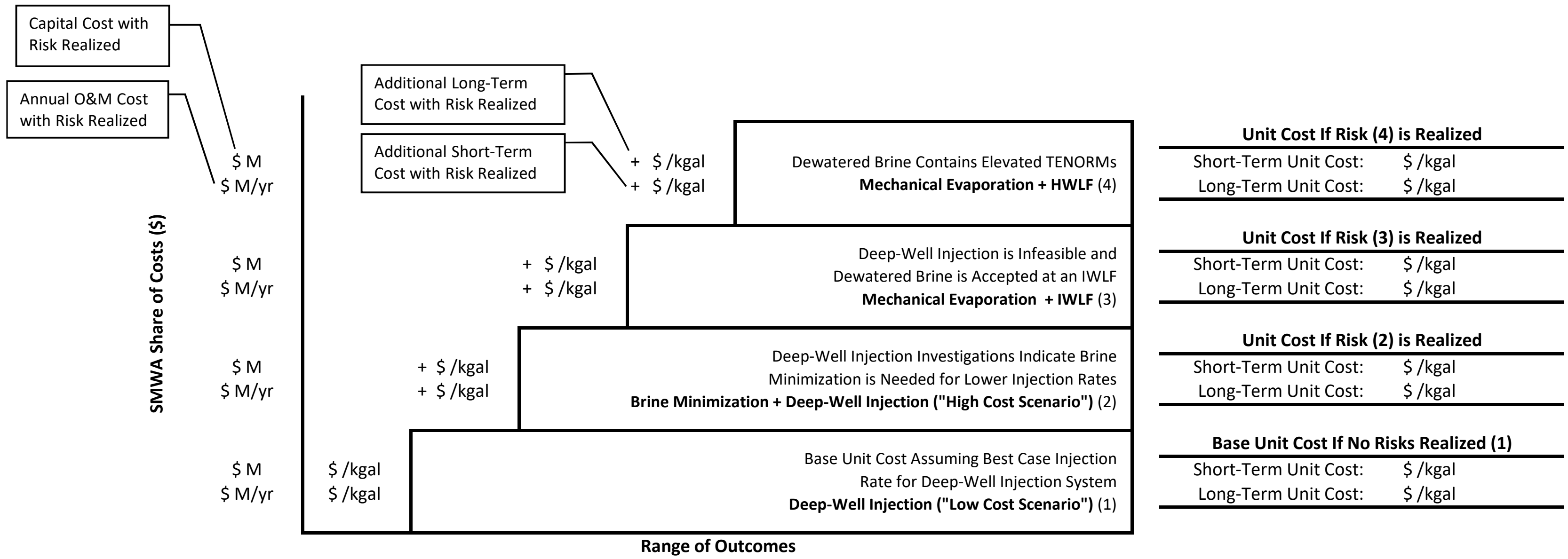
As mentioned above, previous studies completed for SMWA evaluated a long-list of potential brine disposal options. Based on recommendation of that study, this study focuses on the following three disposal methods:

- Deep-well injection
- Mechanical evaporation + brine sludge disposal at an Industrial Waste Landfill
- Mechanical evaporation + brine sludge disposal at a Hazardous Waste Landfill

Figure 1 presents a template used in this TM to provide a relative comparison of the increasing costs of the above list of potential disposal methods, where each new method is triggered because risks were realized (such as low injection rates) that require an alternate brine disposal scheme.

2.1 Discussion of Brine Disposal Processes Not Considered

Brine disposal methods not evaluated include brine discharge to a wastewater treatment plant, solar drying beds followed by solid waste disposal at a landfill, and discharge to an ocean outfall. Direct discharge to a wastewater treatment plant would only recirculate salt in the greater South Platte River watershed and consequently there is insufficient assimilative capacity to permit this disposal option. Solar drying beds would require approximately 1,000 acres of water surface area (plus adjacent area for pond access, etc.) for 10,000 afy of WISE water. Although brine misters above ponds can significantly decrease the surface area needed for passive solar evaporation, other factors like salt migration and permitting challenges removed this option from consideration for this study. Discharge to an ocean outfall was removed from consideration due to the excessive distances (greater than 700 miles) required to convey brine before disposal.



Notes:

- Costs presented within the graph area and right of the graph area would be in addition to the base WISE water rate charged by Aurora Water and Denver Water
- Future WISE water rate is unknown and therefore not shown numerically on this schematic

Risk Details:

(1) Base cost assumes that Deep-Well Injection is feasible and results in similar downhole pressures and injection rates experienced by disposal wells at ECCV's Northern Treatment Plant

(2) Additional Reverse Osmosis stages are employed for brine minimization and Deep-Well Injection downhole pressure and resulting injection rate is closer to cursory investigation based on neighboring Class II Injection Wells

(3) Deep-Well Injection is found to be unfeasible because there is not a suitable accepting geologic formation, seismic activity forces the abandonment of existing injection wells or existing injection wells experience significant fouling forcing abandonment. Therefore, mechanical dewatering is used and dewatering brine is sent to an Industrial Waste Landfill (IWLF)

(4) Constituents removed from WISE water from the salinity removal process accumulate hazardous or radioactive constituents such that dewatered brine is not accepted by an IWLF and therefore needs to be sent to a Hazardous Waste Landfill (HWLF)

2.2 Deep-Well Injection

2.2.1 Description of Process

Deep-well injection involves the sequestration of brine in deep geological formations through an injection well. A typical injection well consists of concentric pipes (pipe within a pipe) extending approximately 10,000 feet below the ground surface (ft bgs) into a highly saline and permeable geologic formation. The geologic formation must be naturally confined vertically by impermeable layers so that there is virtually no potential for contamination of freshwater aquifers.

Brine minimization (additional stages of salinity removal with reverse osmosis) can be included to reduce the volume of the concentrate stream from the primary stages of salinity removal. The brine minimization process recovers additional water (increasing the water recovery of the overall desalination process) and reduces the volume of concentrate conveyed to the injection wells. **Figure 2** shows the deep-well injection process both with and without brine minimization prior to the concentrate injection step.

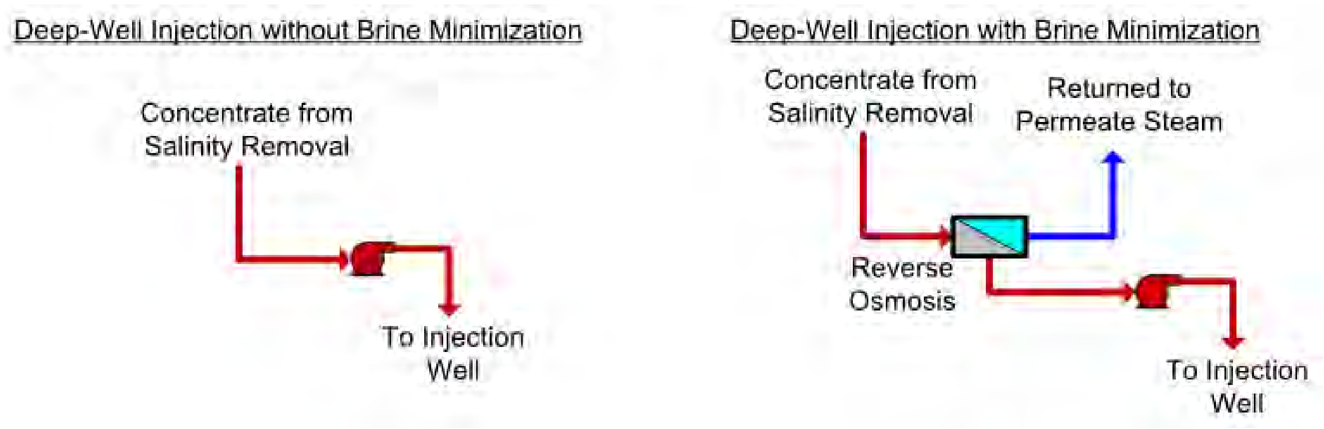


Figure 2. Deep Well-Injection Process Flow Diagrams with and without Brine Minimization

2.2.2 Regulations and Implementation Considerations

The Underground Injection Control (UIC) Permitting Program of the United States Environmental Protection Agency (US EPA) was created to prevent the contamination of freshwater aquifers from the placement of fluids underground through injection wells. The UIC rules regulate the construction, operation and closure of injection wells. The UIC classifies wells into six classes as shown in **Table 1**. In Colorado, Region 8 of the US EPA regulates the UIC Program for Class I, III, IV, V and VI injection wells and the Colorado Oil and Gas Conservation Commission (COGCC) regulates Class II Injection Wells. For disposal of brine from a SMWA desalination facility, a concentrate injection well would be permitted as a Class I well. The East Cherry Creek Valley Water and Sanitation District (ECCV) and the City of Sterling (Sterling) have been successfully operating Class I injection wells for several years.

Table 1. Classes and Descriptions of UIC Program Permits.

Class	Description
I	Industrial and municipal waste disposal wells
II	Oil and gas related injection wells
III	Injection wells for solution mining
IV	Shallow hazardous and radioactive waste injection wells
V	Wells that inject non-hazardous fluids into or above underground sources of drinking water
VI	Wells used for geologic sequestration of CO_2

The receiving formation must not be classified as an underground source of drinking water (USDW) by the US EPA. The US EPA defines an USDW as an aquifer containing water with less than 10,000 mg/L of TDS. Also, the receiving formation must be overlain by an impermeable layer to prevent migration of injected concentrate to other formations or USDWs.

USDWs were identified for each desalination site, which includes the Laramie Fox Hills Aquifer of the Denver Basin Aquifer System and the Upper Pierre Shale, which has more recently been developed as a freshwater source. The Upper Pierre Shale is part of the greater Pierre Shale, which was assumed to be able to be developed in the future as a source of water, therefore the Pierre Shale formation was considered the base of the lowermost USDW for this analysis. The approximate depths of the base of the Pierre Shale and Laramie Fox Hills Aquifer at each of the potential desalination sites were identified based on well logs for nearby wells from Class II Injection Well Permits as shown in **Table 2**.

Table 2. Estimated USDWs for Each Desalination Site

Desalination Site	USDW Aquifer Formation	Base Depth (ft bgs [1])
North Site	Laramie Fox Hills Aquifer	900
	Pierre Shale	4,500
Central Site	Laramie Fox Hills Aquifer	2,000
	Pierre Shale	5,500
South Site	Laramie Fox Hills Aquifer	2,100
	Pierre Shale	7,648

[1] feet below ground surface

2.2.3 Basis of Cost Estimate Design Assumptions

The US EPA limits the allowable injection pressure for a disposal well to less than the estimated natural pressures that would fracture the subsurface rock formation. During preliminary investigations, exploratory wells would be drilled to estimate the characteristics of underlying formations at varying depths. These characteristics are used to determine the natural fracture pressure of formations. Next, the allowable well injection flow rate is the estimated flow rate that could be sustained while keeping pressures in the receiving formations below the natural fracture pressure.

Table 3 summarizes the injection pressure and flow rates for select existing injection wells along the Front Range of Colorado. **Figure 3** shows the general location of these reference injection wells relative to the South, Central and North Sites.

Table 3. Characteristics of Select Existing Injection Wells

Owner	ECCV	Sterling	O&G (North)	O&G (South)
Data Source	(1)	(1)	(2)	(2)
UIC Injection Well Classification	Class I	Class I	Class II	Class II
Estimated Well Depth (ft bgs)	10,000	7,000	9,200	8,500
Fracture Gradient (psi/ft bgs)	Not Available		0.65	0.65
Max Downhole Pressure (psi)	Not Available		1,997	1,845
Observed/Estimated Top Well Pressure (psi)	1,500	475	1,500	1,800
Observed/Estimated Injection Rate (gpm)	450	475	200	130
Observed/Estimated Injection Rate (mgd)	0.65	0.68	0.29	0.19

Note: Information presented for the ECCV and Sterling Injection Well systems was estimated based on information from the US EPA, while information presented from O&G Injection Wells are estimates based on aggregated information from permits of several nearby injection wells.

(1) US EPA Region 8 UIC Permit Database, 2019

(2) COGCC Online Database, 2018

Utilizing observed injection rates from **Table 3**, an estimate of the potential number of injection wells for SMWA can be made as shown in **Table 4**.

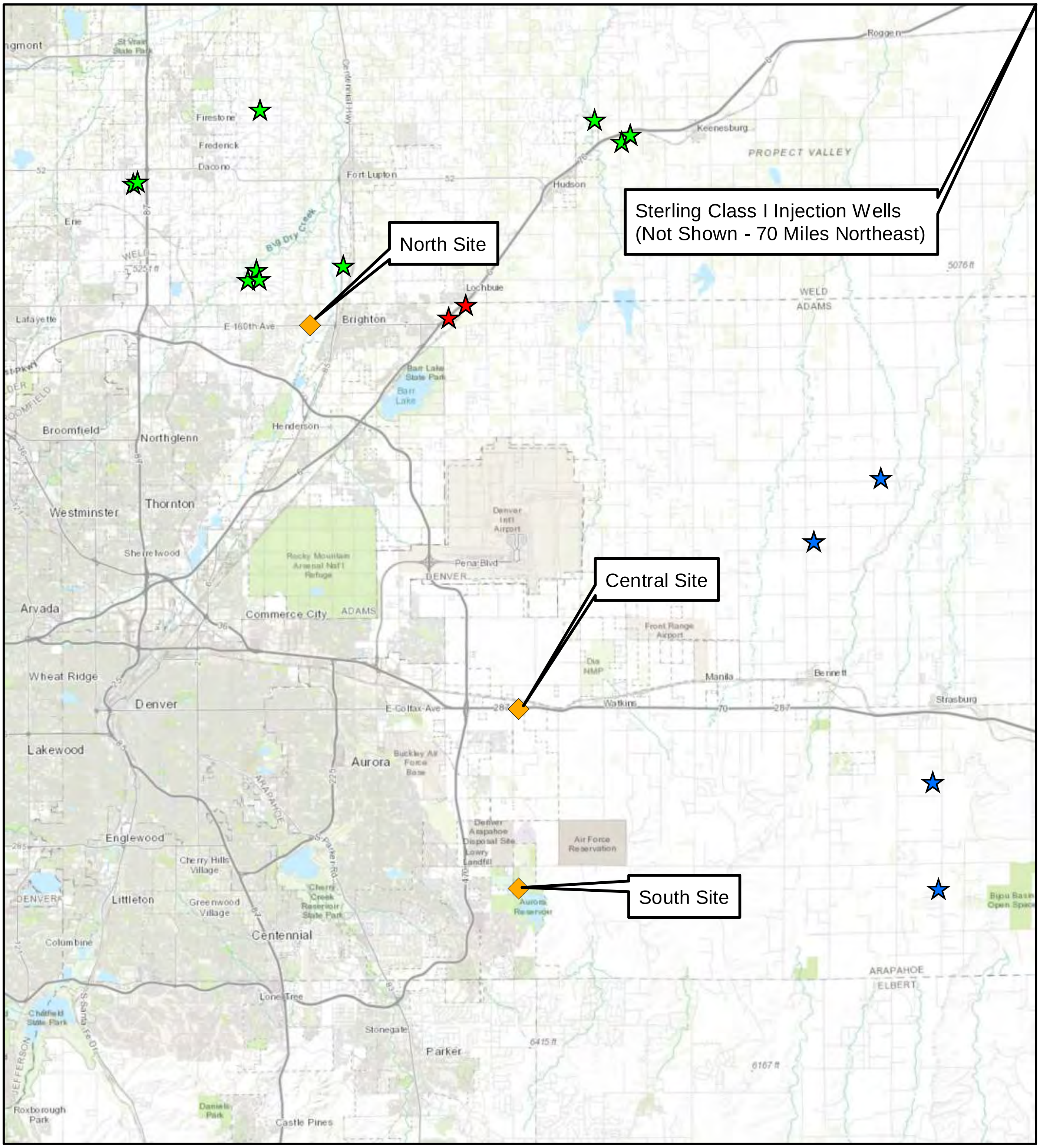
Table 4. Number of Injection Wells Needed Based on Reference Injection Wells.

Reference Site	ECCV	Sterling	O&G (North)	O&G (South)
Reference Injection Rate (mgd)	0.65	0.68	0.29	0.19
Required Wells for 9 mgd (w/o Brine Minimization)	2	1	3	4
Required Wells for 9 mgd (w/ Brine Minimization)	1	1	2	2
Required Wells or 30 mgd (w/o Brine Minimization)	4	4	8	12
Required Wells for 30 mgd (w/ Brine Minimization)	2	2	4	6

Two costs scenarios were developed using injection well information from **Tables 3** and **4**. The lowest-cost scenario would be if injection wells performed like the ECCV injection well system, therefore the “Low Cost Scenario” was developed from the injection well performance of the ECCV system. Conversely, if initial estimates based on nearby Class II Injection Wells (O&G North and South) are realized, the addition of brine minimization would likely be needed to avoid the need to construct upwards of 12 injection wells. Therefore, the “High Cost Scenario” was designed from injection well performance estimates from nearby Class II Injection Wells preceded by a brine minimization process. **Table 5** summarizes the parameters used for each cost scenario. The Sterling system was not used as a design basis for a SMWA deep-well injection system as Sterling is at least 100 miles from any potential SMWA desalination facility site.

Table 5. Basis of Cost Estimate Design Assumptions for Deep-Well Injection Cost Scenarios.

Parameter	Low Cost Scenario	High Cost Scenario		
	All Sites	**North Site**	**Central Site**	**South Site**
Reference System	ECCV	O&G (North)	O&G (South)	
Process	Deep-Well Injection	Brine Minimization and Deep-Well Injection		
Required Wells for 9 mgd	2	2	2	
Required Wells for 30 mgd	4	4	6	



LEGEND

- ECCV Class I Injection Wells
- Oil & Gas Class II Injection Wells (North Group)
- Oil & Gas Class II Injection Wells (South Group)
- Desalination Sites

N

0 5 10
Miles

FIGURE 3
Locations of Reference Injection Wells
TM 2 - Brine Disposal
WISE Salinity Management Plan

2.2.4 Risks

Although deep-well injection is an effective and commonly used technique for brine/wastewater disposal, there are some risks that impact the sustainability of an injection well system. These generally include:

- **Fissures:** Subsurface geology can have unknown fissures and other small faults that can allow the waste stream to migrate into overlying or neighboring drinking water aquifers that were initially estimated to be separated from the receiving formations by impermeable layers. If this condition occurs, the disposal permit could be revoked.

- **Well Fouling:** Constituents in the injected waste stream and constituents in groundwater of the receiving formation can exhibit complex geochemical reactions that can cause fouling due to mineralization in the receiving formation. If this condition occurs, it may be possible to adjust the chemistry of the brine stream or it could result in unusable injection wells.

- **Seismic Activity:** Certain seismic activity has been linked to injection of waste liquids into the subsurface. According to the Earthquake Center at the United States Geological Survey, injection activities may reactivate non-active faults and induce significant seismicity in the region surrounding the injection well. Of the 21 areas within the continental United States where injection of waste fluid has been linked to induced earthquakes, five are within Colorado. These areas include:

    - The Rocky Mountain Arsenal where, over 1,500 low-magnitude earthquakes were recorded due to wastewater fluid injection through one injection well completed to approximately 12,000 ft bgs in the 1960s.

    - Greeley where, magnitude 3.3 and 2.6 earthquakes occurred in 2014. These earthquakes were believed to be induced by wastewater injection nearby. The injection operation was halted following the earthquakes but resumed two months later.

    - Paradox Valley Unit along the Dolores River operated as part of the Colorado River Salinity Control Program by the United States Bureau of Reclamation began in 1995 at 345 gpm under 4,900 psi to a receiving formation approximately 15,000 ft bgs. Earthquakes were recorded as early as 1996 and minor earthquakes occurred through 1999 and into 2000 with magnitudes between 3 and 4.

    - Raton Basin on the Colorado, New Mexico border has more than 22 Class II injection wells that inject waste fluid to approximately 4,000 – 5,000 ft bgs without any downhole pressure. The area has a history of earthquakes from 2001 to 2011 that are suspected to be caused by injection activity.

Although the number of earthquakes occurring due to deep well injection is relatively small considering the number of operating injection wells, seismicity might be a risk because if an injection well is found to cause a seismic event, the injection well can be shut down for an interim period or permanently, which would force SMWA to use an alternate brine disposal method.

Note that Aurora Water has recently request local land use permit authorities not allow deep-well injection within 4 miles of Aurora Water facilities due to concerns of potential damage related to seismic activity. The representative site configurations developed in the Plan (mentioned in Section 1.3 and introduced in the accompanying **TM 1 – Salinity Removal**) were developed prior to being made aware of the requested exclusion zone and example site layouts with injection wells do include wells within that zone. Therefore, some additional small diameter (8-inch to 12-inch) pipeline costs may be incurred to locate wells in different locations than originally assumed.

2.3 Mechanical Evaporation

The first step in the mechanical evaporation and landfill disposal processes is mechanical evaporation, which would be used to remove enough water from the concentrate stream that the product brine sludge consists of mostly salts and other removed constituents. The goal is to produce a dewatered brine sludge that landfills would accept.

2.3.1 Description of Process

Many different options for mechanical evaporation equipment exist, including:

- Singe-effect evaporator
- Multiple-effect evaporator
- Vapor compression evaporator
- Vertical tube falling film concentrator
- Horizontal tube spray film concentrator
- Forced-circulation crystallizer

Typically, a vertical tube falling film concentrator (vertical concentrator) followed by a forced-circulation crystallizer (crystallizer) would be implemented to accomplish evaporation of water from a municipal brine stream. A plate filter press would be used following the evaporation steps to remove remaining free liquids to produce a wet brine sludge that would be accepted at a landfill as solid waste. **Figure 4** shows a process flow diagram for the entire brine dewatering process using mechanical evaporation. This arrangement of evaporation equipment is typically the most cost efficient of the options listed above. Therefore, it is used for all analyses in this investigation using mechanical evaporation as part of the brine disposal process.

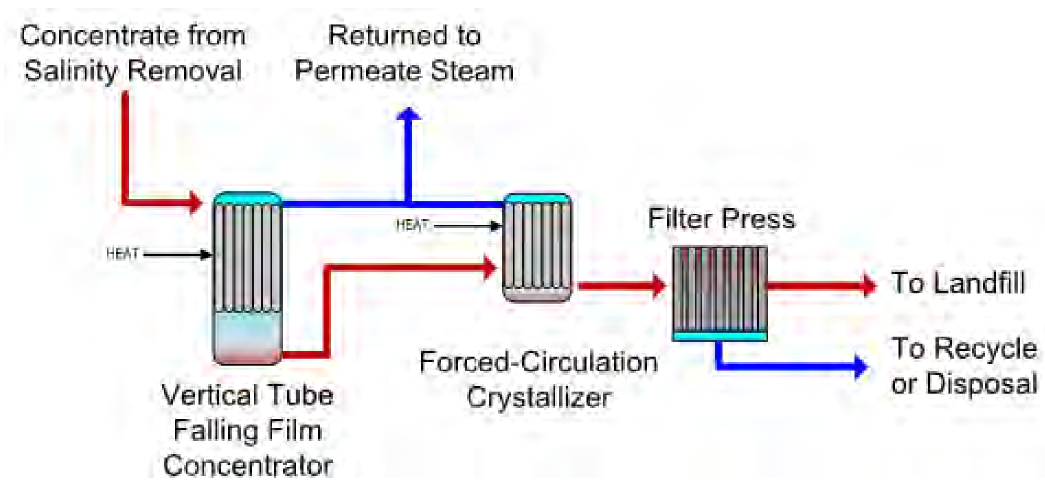


Figure 4. Mechanical Evaporation Process Flow Diagram

2.3.2 Regulations and Implementation Considerations

Mechanical evaporation equipment itself is not directly impacted by specific regulations other than those pertaining to the disposal of brine sludge, which is discussed in the following section. It is important to note that (as described in more detail below), the size and appearance of the equipment is unlikely to be permitted in locations that are not designated as industrial land use areas.

2.3.3 Basis of Cost Estimate Design Assumptions

A preliminary design of a mechanical evaporator process, including a vertical concentrator followed by a crystallizer with a plate filter press, was developed to treat the concentrate stream of 0.7 mgd and 2.2 mgd from the 9 mgd and 30 mgd desalination facility sizes, respectively. **Table 6** presents the assumed design parameters for the mechanical evaporator process.

Mechanical evaporation is a physical process much like salinity removal and should be piloted prior to implementation to understand how different processes and equipment can improve optimization of the evaporation process. Additionally, materials used in construction of mechanical evaporation equipment are sensitive to the quality of the concentrate fed to these systems, so equipment manufacturers should be engaged during final design of the system.

Table 6. Mechanical Evaporation Design Parameters

Design Parameter	9 MGD Size	30 MGD Size
Disposal System Peak Concentrate Feed Flowrate	0.7 mgd	2.2 mgd
Vertical Concentrator Height	100 ft	115 ft
Brine Crystallizer Peak Feed Flowrate	35 gpm	100 gpm
Brine Crystallizer Height	65 ft	70 ft
Peak Brine Sludge Production Rate	17 tons/day	52 tons/day
Disposal Rate for Peak Brine Sludge Production Rate	6 truckloads/week	17 truckloads/week

2.3.4 Risks

Mechanical evaporation is not a common process utilized at a water treatment plant and therefore presents the following risks:

- **Land Use Approvals:** As noted in **Table 6**, the vertical concentrator and crystallizer are between 100 ft and 115 ft, and 65 ft and 70 ft tall, respectively. **Figure 5** shows an example of what these evaporator columns could look like if constructed. This type of equipment may limit potential sites to predominantly industrial areas.

- **Operational Complexity:** Evaporators and crystallizers are relatively complex to operate compared to other water treatment processes and therefore can be less efficient if not optimized. Less-than-optimal operations may increase operating costs or cause produced brine sludge to fail landfill acceptability tests for water content forcing SMWA to recirculate sludge or pay a higher disposal cost.

- **Power Costs:** Mechanical evaporators and crystallizers require approximately 70 – 90 Kilowatt Hours (kWh) and 250 kWh of power each per 1,000 gallons fed into each process, respectively. O&M costs are therefore very sensitive to the local price of electricity and can dramatically increase with slight increases in power costs.

Figure 5. Example of the Vertical Evaporator Appearance.

Evaporators would look like the stacks with a thicker diameter shown in the foreground of the picture.

2.4 Landfill Disposal of Brine Solids

Brine sludge would be stored at the treatment plant site in roll-off dumpsters or similar containers and then transported to a landfill by a waste management company for landfill disposal. Depending on characterization, the brine sludge can be disposed of in industrial waste landfills (IWLFs) or hazardous waste landfills (HWLFs). Note that most large municipal solid waste landfill sites also accept industrial waste.

2.4.1 Regulations and Implementation Considerations

Landfills are distinguished by the type of wastes a facility is permitted to accept. IWLFs, accepting non-hazardous wastes, are governed by the Resource Conservation and Recovery Act (RCRA) Subtitle D. HWLFs are governed under RCRA Subtitle C as part of the rules for production, transportation and disposal of hazardous wastes.

Toxicity: Hazard waste classification tests are used to determine whether a solid waste is hazardous or non-hazardous. The basic criteria for determining the classification of a waste as hazardous or non-hazardous under RCRA are ignitability, corrosivity, reactivity and toxicity. Brine sludge is not anticipated to be ignitable, corrosive or reactive at levels that would classify it as hazardous. Toxicity is determined through the Toxicity Characteristic Leaching Procedure (TCLP), which is a test to determine if toxic constituents will leach from soil (or, in this case, brine sludge). If dried brine fails the TCLP test, it is classified as a hazardous waste. Relevant constituents to this application from TCLP tests include the “RCRA 8” metals of arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.

Solids Content: Another widely used criterion for disposal at landfills is solids content. Some waste providers can accept liquid wastes but charge the producer to dewater liquids prior to disposal at a landfill. Preliminary analysis shows it would be more economical to remove the water from the concentrate stream at the desalination facility, and based on cursory discussions with industrial and hazardous waste acceptors, there is not a facility in Colorado that currently has the equipment capacity to accept the volume of brine expected to be generated from the SMWA desalination facility. Furthermore, coordinating hauling of multiple tankers of liquid concentrate per day, combined with the cost to construct the required equipment, likely makes this option infeasible. Therefore, the concentrate stream must be dewatered to the standards that landfill operators use to determine acceptability. If solids are not dried sufficiently, the landfill will charge an additional fee for disposal or may refuse to accept waste. Through landfill operator interviews (included in **Appendix A – Landfill Operator Interviews**), it was determined that local landfill operators use the Paint Filter Liquids Test to determine the water content of the waste. In the Paint Filter Liquids Test, a representative sample of waste is placed above a paint filter, and if any liquid passes through the filter, the waste fails and will either not be accepted by landfills or will incur additional costs for disposal.

Technologically Enhanced Naturally Occurring Radioactive Material (TENORM): Salinity removal processes presented in the accompanying **TM 1 – Salinity Removal** all have the potential to remove radionuclides, which are naturally present in source water in Colorado. Once removed from the water, the concentrated levels of radionuclides are categorized as TENORM. Regulation of TENORM in drinking water residuals is not clearly explained in the Federal or State regulations and overlaps regulatory programs. Colorado RCRA Subtitle D regulations state that if the total alpha activity in the residuals exceeds 40 picocuries per liter (pCi/L), the level assumed to be the natural “background” level, then the Colorado Department of Public Health and Environment’s (CDPHE’s) Hazardous Materials and Waste Management Division must be contacted. Pilot testing would be required to determine if brine sludge from the SMWA desalination facility might trigger TENORM disposal requirements.

At this preliminary stage, the waste classification of brine sludge that would be created from the SMWA desalination facility is unknown. However, **Table 7** provides a summary of key considerations based on historical constituents in the South Platte River water captured and conveyed by the Prairie Waters Project system. **Table 7** also provides a worst-case estimate of constituents of concern in brine sludge produced from the SMWA desalination process.

Table 7. Worst-Case Brine Sludge Waste Characterization Estimate.

Waste Classification	Constituent	DADS Landfill Acceptance Threshold	Deer Trail Facility Acceptance Threshold	Max Estimated Level in SMWA Brine Sludge (1)
Toxicity	Arsenic	100 ppm	above 100 ppm (2)	5 ppm
Toxicity	Barium	200 ppm	above 200 ppm (2)	133 ppm
Toxicity	Cadmium	20 ppm	above 20 ppm (2)	Below Detection Limit (3)
Toxicity	Chromium	120 ppm	above 120 ppm (2)	No Data (4)
Toxicity	Lead	100 ppm	above 100 ppm (2)	9 ppm
Toxicity	Mercury	4 ppm	above 40 ppm (2)	No Data (4)
Toxicity	Selenium	20 ppm	above 20 ppm (2)	4 ppm
Toxicity	Silver	100 ppm	above 100 ppm (2)	No Data (4)
Radioactivity	Total Activity	40 pCi/g	2,000 pCi/g	97 pCi/g
Radioactivity	Uranium	3 pCi/g	355 pCi/g	17 pCi/g (5)
Radioactivity	Combined Radium	6 pCi/g	222 pCi/g	8 pCi/g

(1) Based on South Platte water quality presented in CH2MHILL (2011).

(2) The Deer Trail Facility can accept waste above limits shown. However, wastes are individually assessed for acceptability by landfill operators and therefore alternative options to landfill disposal may be required.

(3) Cadmium was not detected in water quality samples from CH2MHILL (2011).

(4) Chromium, Mercury, or Silver were not included as part of the CH2MHILL (2011) analysis.

(5) Estimated value is equivalent to 24 mg/kg (ppm) of Uranium (estimated from the Specific Activity of Natural Uranium of 7.1×10^{-7} Ci/g).

Additionally, a Paint Filter Liquids Test would need to be conducted to ensure that no free liquids are present in the brine sludge following the plate filter press. It is anticipated that the mechanical evaporation and plate filter press concentrate handling process will be able to remove enough water from the concentrate stream such that the brine sludge produced from the plate filter press will pass a Paint Filter Liquids Test and be considered solid waste by landfills.

Based on the results of the cursory waste characterization analysis presented in **Table 7**, brine sludge from the desalination and mechanical dewatering process would not be considered hazardous but could contain elevated TENORM such that it would not be accepted at the Denver Area Disposal Site (DADS) Landfill and would have taken to the Deer Trail Facility for disposal.

2.4.2 Basis of Cost Estimate Design Assumptions

Landfill disposal was investigated for three regional waste management providers. It should be noted that although each facility accepts waste with TENORM, each facility is permitted to accept different levels of waste constituents that contribute to TENORM.

Table 8. Summary of Disposal Facilities Investigated for Brine Sludge.

Facility	Operator	Type of Waste Accepted
DADS Landfill	Waste Management	Non-Hazardous and TENORM
Deer Trail Facility	Clean Harbors	Hazardous and TENORM

As shown, brine sludge that would not trigger hazardous waste except for TENORM could be taken to the DADS Landfill depending on the level of TENORM constituents present. Locations of the DADS Landfill and Deer Trail Facility are shown in subsequent sections. Interviews with each waste provider were conducted and are included in **Appendix A – Landfill Operator Interviews**.

By treating 10,000 afy of WISE water on average, it is estimated that 6 truckloads per week would be required to transport the brine sludge away from the desalination facility. If SMWA desalination facility is operated as a regional facility (closer to 30 mgd) for extended periods, up to 17 truckloads per week could be required to dispose of the brine sludge produced.

2.4.3 **Risks**

Risks associated with landfill disposal are summarized below:

- **"At-Will Agreements":** Typically, a waste producer enters into general services agreements with a waste management company where the agreement describes waste acceptance criteria and payment terms. These agreements have various term limits. General service agreements are typically "at will," meaning that either party can remove themselves from the agreement at any time for any reason. Therefore, without negotiating a non-standard agreement, there is a risk that a given waste management operator could decide to no longer accept the brine sludge with relatively short notice. Also, the price for disposal could change with every new agreement depending on the duration.

- **"Indemnity Clauses":** If the waste producer delivers conforming non-hazardous waste to a disposal facility, the producer is generally not liable for damages incurred by the landfill operator for accepting the non-hazardous waste. For example, if future environmental regulations require stricter disposal of brine waste, the waste management operator would indemnify SMWA from paying for damages associated with previously accepting SMWA brine waste. However, if it is found that SMWA delivered non-conforming (i.e. hazardous or elevated TENORM) waste to the waste management facility, then SMWA would be liable for damages incurred by the waste management company because of breaching contractual agreements.

  For this reason, it is recommended that a rigorous waste classification program be implemented to confirm that waste meets criteria to be accepted at the DADS Landfill or Deer Trail Facility.

  Indemnity does not apply to hazardous wastes. The generator of hazardous waste always carries liability for hazardous waste produced per RCRA Subtitle C.

- **Limits of TENORM Acceptance:** Although it is not assumed to be likely based on estimates presented in **Table 7**, it is possible that radionuclides could be concentrated such that they break the threshold for acceptance at the Deer Trail Facility. If this were the case, then the brine waste would need to be disposed of in a low-level radioactive waste disposal site. There are no low-level radioactive waste disposal sites within Colorado. The closest facility being the Clive Disposal Facility, approximately 75 miles west of Salt Lake City in Utah.

3. Site-Specific Considerations

Site-specific considerations include estimated sustainable injection rates, vicinity to neighboring communities for concerns of mechanical evaporation aesthetics and proximity to landfills for haulage costs of dewatered brine.

3.1 Deep-Well Injection

As described in earlier sections of this TM, between one and four injection wells could be required for a 9 mgd desalination facility depending on the level of brine concentration achieved and the sustainable injection rate realized. Between two and twelve injection wells could be required for a 30 mgd desalination facility. **TM 1 – Salinity Removal** includes conceptual layouts of the salinity removal facilities and shows potential locations for up to four injection wells for each site.

Table 9 and **Table 10** show the parameters used in the cost estimate for the deep-well injection systems at each potential salinity removal location. A more detailed analysis should be conducted to confirm or improve the injection interval, downhole injection pressure and injection rate that would occur at each site. It was assumed that each additional injection well be between 0.75 miles and 1 mile from neighboring wells and therefore would need approximately 4,600 ft of pipe to convey brine sludge from the desalination process to each injection well. Additional investigations should be conducted to determine an appropriate surface distance between each injection well, which will be based on site specific geological conditions and resulting areas of influence of each injection well.

Table 9. 9 MGD Desalination Facility Deep-Well Injection Cost Estimate Parameters.

Site	Low Cost Scenario			High Cost Scenario		
	Number of Wells	Well Depth	Downhole Pressure	Number of Wells	Well Depth	Downhole Pressure
North	2	10,000 ft bgs	1,500 psi	2	9,200 ft bgs	1,900 psi
Central	2	10,000 ft bgs	1,500 psi	2	8,500 ft bgs	1,800 psi
South	2	10,000 ft bgs	1,500 psi	2	8,500 ft bgs	1,800 psi

Table 10. 30 MGD Desalination Facility Deep-Well Injection Cost Estimate Parameters.

Site	Low Cost Scenario			High Cost Scenario		
	Number of Wells	Well Depth	Downhole Pressure	Number of Wells	Well Depth	Downhole Pressure
North	4	10,000 ft bgs	1,500 psi	4	9,200 ft bgs	1,900 psi
Central	4	10,000 ft bgs	1,500 psi	6	8,500 ft bgs	1,800 psi
South	4	10,000 ft bgs	1,500 psi	6	8,500 ft bgs	1,800 psi

3.2 Mechanical Evaporation

Getting land use approval for mechanical evaporation equipment is a critical consideration for all three sites as summarized below:

- **North Site:** This site is located along the South Platte River in a region that is largely currently undeveloped. However, there are residential neighborhoods approximately 0.5 miles to the southwest. Further diligence should be completed to determine if SMWA would have the option to install a mechanical evaporator at this site.

- **Central Site:** Originally, a parcel located directly south of the PWP PS #3 was selected for the central site. However, this site has existing residential developments on three sides and planned residential development on the fourth side. For this reason, the abandoned airport site further east along Interstate 70 (I-70) was selected as a representative central site. It is important to note that the selected site is tentatively planned for more commercial and mixed-use development and further diligence should be completed to determine if this site is feasible or if an alternate site (possibly across I-70) is required.

- **South Site:** This site is located on City of Aurora property and across from City of Aurora Parks and Open space. It is assumed that locating salinity removal facilities that can be housed in buildings that would meet the aesthetic requirements of the area is feasible. However, further diligence should be completed to determine if SMWA would have the option to install a mechanical evaporator at this site.

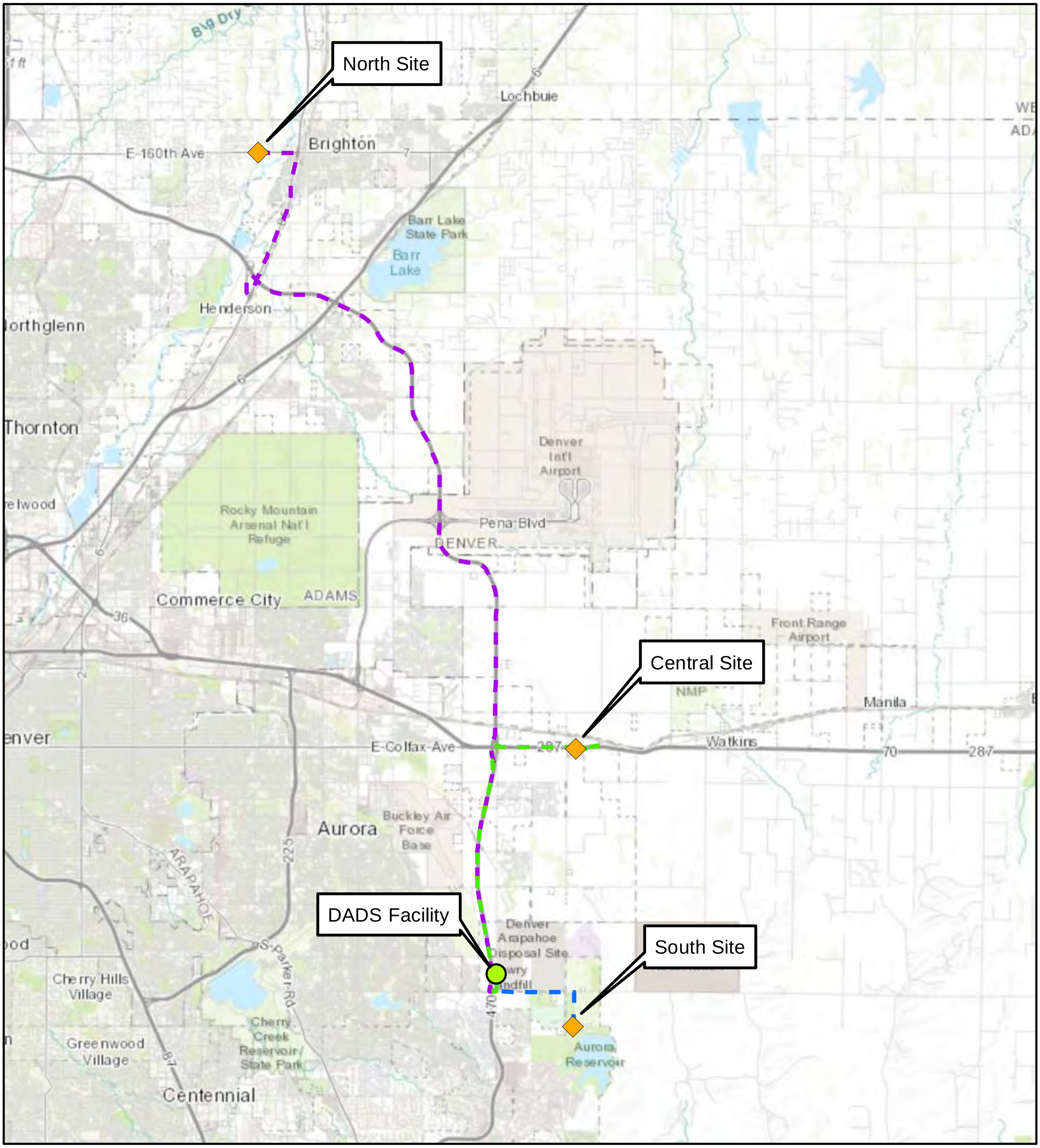
3.3 Landfill Disposal

The proximity of a potential desalination site to the DADS Landfill or Deer Trail Facility will affect the haulage cost to transport brine sludge from a desalination facility site. As described below, specific travel routs are required for heavy trucks and alternate routes are required for heavy trucks transporting hazardous materials. **Table 11** summarizes the assumed haul distances from each of the evaluated SMWA desalination sites.

Table 11. Haulage Distances from Each Desalination Facility Site to Investigated Landfills.

Site	Round Trip Distance to the DADS Landfill (Non-Hazardous Waste)	Round Trip Distance to the Deer Trail Facility (Hazardous Waste)
North	74 miles	172 miles
Central	18 miles	108 miles
South	10 miles	124 miles

Figure 6 shows waste transportation routes that were found by the ArcMap Plan Routes tool for Trucking Distance, which finds trucking routes from an origin point to a destination point to optimize travel distance while following rules applicable to heavy trucks. As part of regulations governing hazardous wastes, the state of Colorado has designated specific routes on which hazardous waste can be transported. The ArcMap Plan Routes tool for trucking distance was again used to optimize the travel distance for trucking brine sludge from desalination facilities to the Deer Trail Facility. However, in this case, large highways (E-470 and 6th Avenue West of E-470) were blocked because they are not part of the designated hazardous waste routes specified by the State of Colorado. **Figure 7** shows waste transportation routes for transporting hazardous wastes from desalination facility locations to the Deer Trail Facility for brine disposal.



LEGEND

- Disposal Location
- Desalination Sites
- South Site to DADS Facility
- North Site to DADS Facility
- Central Site to DADS Facility

FIGURE 6
Non-Hazardous Waste Transportation Routes
TM 2 - Brine Disposal
WISE Salinity Management Plan

N

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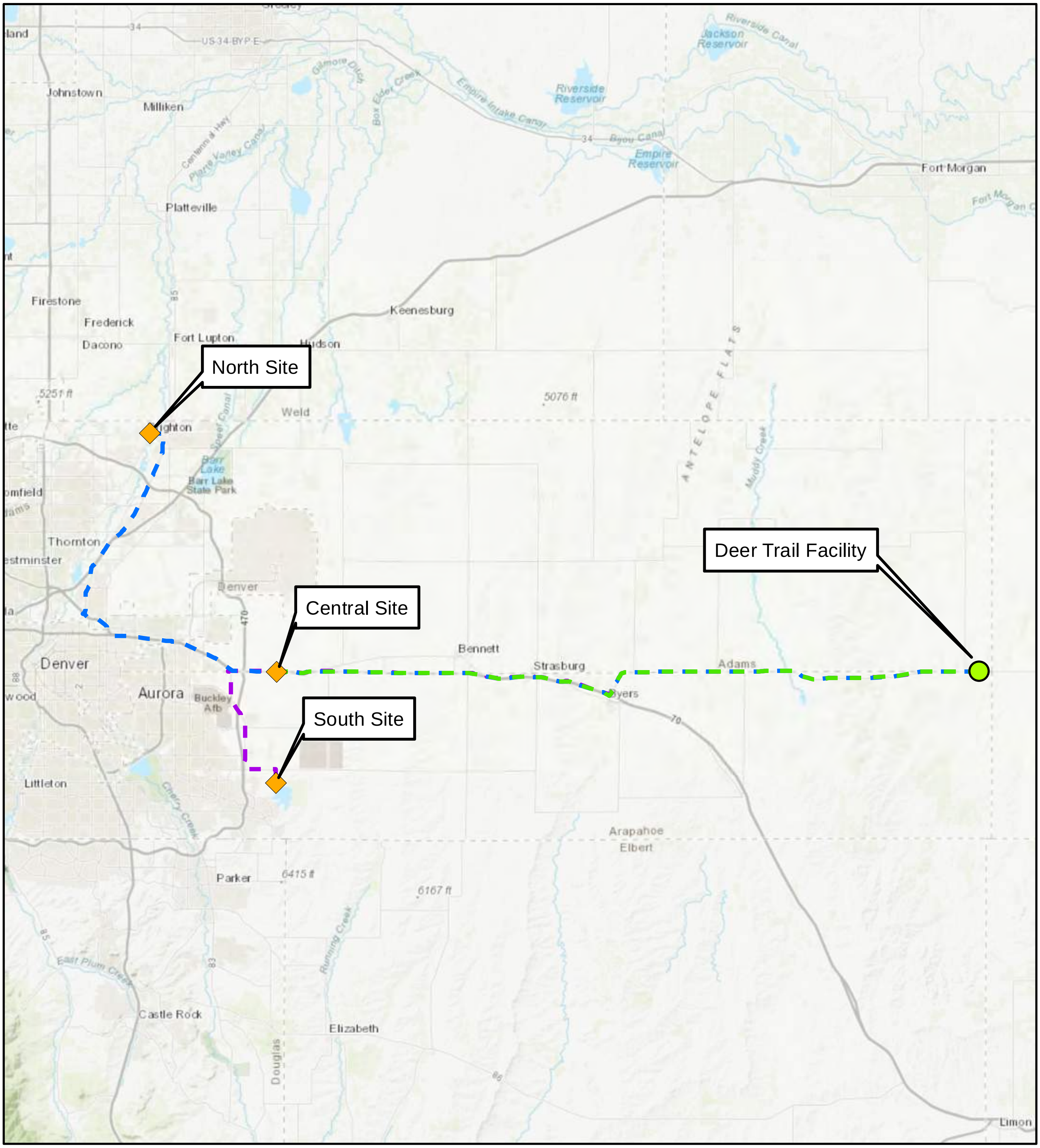

LEGEND

- Disposal Location
- Desalination Sites
- North Site to Deer Trail Facility
- Central Site to Deer Trail Facility
- South Site to Deer Trail Facility

N

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FIGURE 7
Hazardous Waste Transportation Routes
TM 2 - Brine Disposal
WISE Salinity Management Plan

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JACOBS

4. Brine Disposal Costs

Desalination facility costs are presented graphically using the template shown in **Figure 1**. Brine disposal processes were designed assuming that 0.7 mgd and 2.2 mgd of concentrate flow is produced from salinity removal processes for the 9 mgd and 30 mgd desalination facilities, respectively.

4.1.1 Brine Disposal Cost Assumptions

Costs for each desalination process and facility size were developed with the following assumptions:

- Costs were developed and reported in January 2019 dollars (Engineering News Record Construction Cost Index from Denver, CO = 7,505.86).
- Unit costs were obtained from 2018 R.S. Means (adjusted to Denver, CO) and Jacobs' historical unit cost database. Costs were adjusted to January 2019 dollars based on applicable Engineering News Record Construction Cost Indices.
- Equipment costs were based on R.S. Means rates and local equipment vendor quotes. This estimate does not include escalation. Costs were based on market research of web-based cost indices.
- Allowances of 6 percent for overall site work, 6 percent for the plant computer system, 9 percent for yard electrical and 8 percent for yard piping was applied to develop a complete desalination facility Construction Cost.
- Contractor overhead at 12 percent was applied to the Construction Cost.
- Contractor profit of 10 percent was applied to the subtotal of the Construction Cost and Overhead.
- Mobilization/Bonds/Insurance at 3 percent was applied to the subtotal of the Construction Cost, Overhead and Profit.
- A contingency of 30 percent was applied to the subtotal of Construction Costs, Profit, Overhead, and Mobilization/Bonds/Insurance.
- Allowances of 10 percent for engineering, 5 percent for legal, 5 percent for administrative and 5 percent for construction management (totaling 25 percent) were applied to the subtotal of Construction Costs, Profit, Overhead, Mobilization/Bonds/Insurance and Contingency.

The 30 percent contingency has been included in this estimate as a provision for unforeseeable additional costs within the general bounds of the scope, particularly where previous experience has shown that unforeseen events that would increase costs are likely to occur. Additional allowances for finishes, instrumentation and controls, mechanical and electrical items specific to each process can be found in detailed cost estimates presented in **Appendix B – Cost Appendix**.

Annual operations and maintenance costs (O&M) costs for the brine disposal process for the 9 mgd desalination facility assume a 100 percent annual utilization (i.e. the plant runs continuously with no downtime). Annual O&M costs for the brine disposal process for the 30 mgd facility assumes a 30 percent annual utilization. On a long-term basis, WISE water flow through the facility would be 9 mgd of the 30 mgd capacity.

Costs for brine disposal systems for the 9 and 30 mgd facilities are presented on **Figure 8** and **Figure 9**, respectively for the Central Site as an indication of site-specific costs. The Central Site was used as a representative site for cost estimates of the three potential desalination sites. In general, site specific costs did not drastically change costs among sites. Costs were similar to costs presented for the Central Site for the North and South Sites. Costs are shown from low to high where the lowest cost would be realized if initial investigations showed that injection wells could sustain higher injection rates at lower injection pressures and the high costs would be realized if dewatered brine were hazardous.

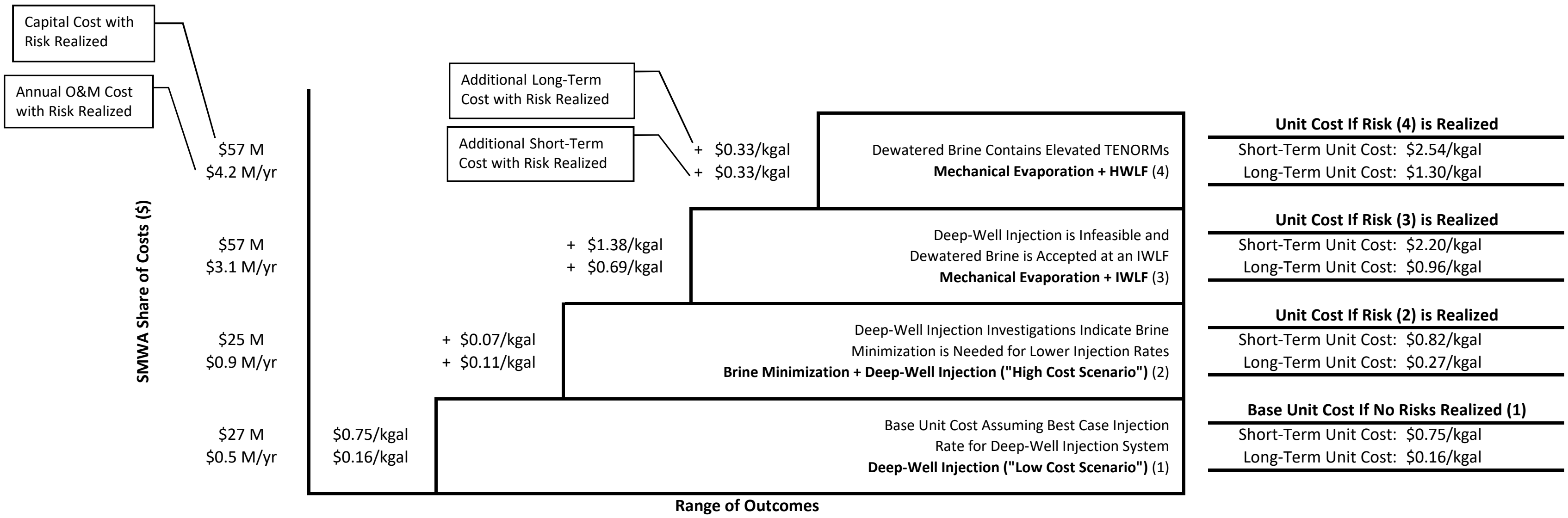
Desalination facility costs are presented in three different formats on **Figure 8** and **Figure 9**:

- Capital and Annual O&M Costs
- Unit Cost Impacts to the WISE Water Rate
- Incremental Unit Cost Impacts to the WISE Water Rate for each cost risk.

Capital and Annual O&M costs are presented on the left y-axis of each figure (capital cost is listed above the annual O&M cost for each brine disposal process).

Unit Costs are presented to the right y-axis of each figure. It is important to note that these unit ($/kgal) costs would be ***in addition*** to the future WISE Water Rate. Unit costs are presented for two different time frames: short-term and long-term. The short-term costs include the repayment of a 25-year bond at 5 percent interest financing brine disposal capital costs plus the annual O&M costs to dispose of brine from treating 10,000 afy of WISE water. The long-term unit cost is only the annual O&M costs to dispose of brine from treating 10,000 afy of WISE water.

Incremental Unit Costs are also presented to show the incremental cost impact of realizing a given cost risk.



Notes:
- Costs presented within the graph area and right of the graph area would be in addition to the base WISE water rate charged by Aurora Water and Denver Water
- Future WISE water rate is unknown and therefore not shown numerically on this schematic
- Costs presented are for brine disposal processes at the Central Site. Costs for other sites can be found in **Appendix B - Cost Appendix**

Risk Details:

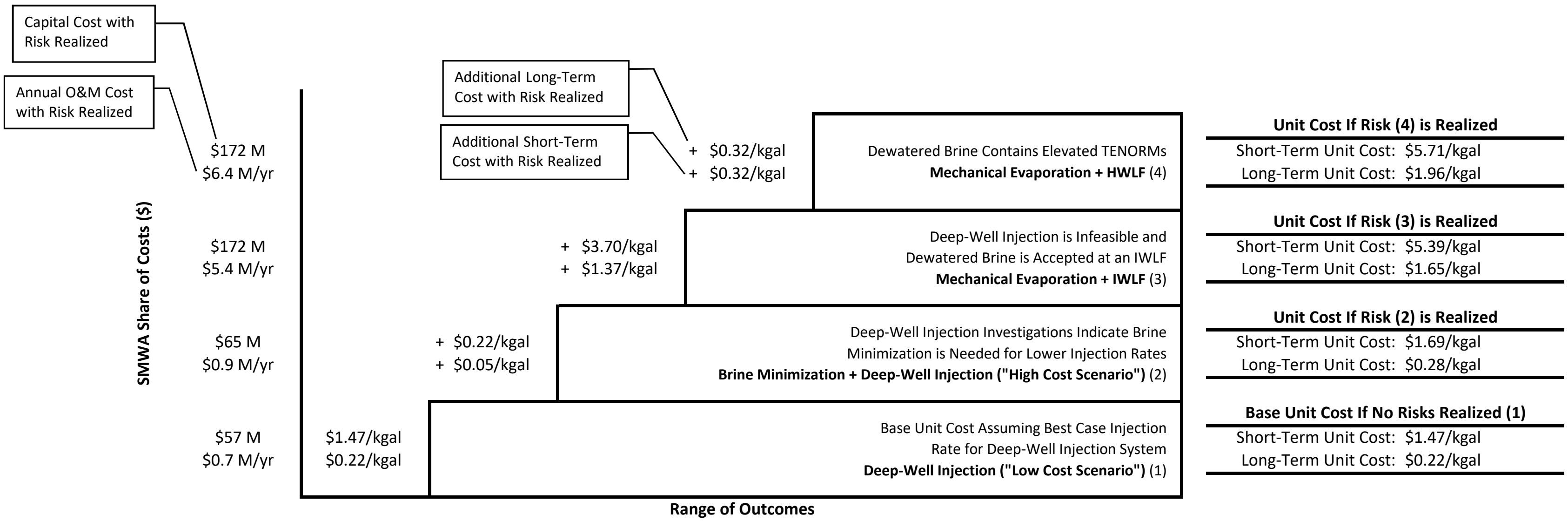
(1) Base cost assumes that Deep-Well Injection is feasible and results in similar downhole pressures and injection rates experienced by disposal wells at ECCV's Northern Treatment Plant

(2) Additional Reverse Osmosis stages are employed for brine minimization and Deep-Well Injection downhole pressure and resulting injection rate is closer to cursory investigation based on neighboring Class II Injection Wells

(3) Deep-Well Injection is found to be unfeasible because there is not a suitable accepting geologic formation, seismic activity forces the abandonment of existing injection wells or existing injection wells experience significant fouling forcing abandonment. Therefore, mechanical dewatering is used and dewatering brine is sent to an Industrial Waste Landfill (IWLF)

(4) Constituents removed from WISE water from the salinity removal process accumulate hazardous or radioactive constituents such that dewatered brine is not accepted by an IWLF and therefore needs to be sent to a Hazardous Waste Landfill (HWLF)

Unit Cost Impacts to the WISE Water Rate for Brine Disposal Processes (9 mgd Facility)



Notes:

- Costs presented within the graph area and right of the graph area would be in addition to the base WISE water rate charged by Aurora Water and Denver Water
- Future WISE water rate is unknown and therefore not shown numerically on this schematic
- Costs presented are for brine disposal processes at the Central Site. Costs for other sites can be found in **Appendix B - Cost Appendix**

Risk Details:

(1) Base cost assumes that Deep-Well Injection is feasible and results in similar downhole pressures and injection rates experienced by disposal wells at ECCV's Northern Treatment Plant

(2) Additional Reverse Osmosis stages are employed for brine minimization and Deep-Well Injection downhole pressure and resulting injection rate is closer to cursory investigation based on neighboring Class II Injection Wells

(3) Deep-Well Injection is found to be unfeasible because there is not a suitable accepting geologic formation, seismic activity forces the abandonment of existing injection wells or existing injection wells experience significant fouling forcing abandonment. Therefore, mechanical dewatering is used and dewatering brine is sent to an Industrial Waste Landfill (IWLF)

(4) Constituents removed from WISE water from the salinity removal process accumulate hazardous or radioactive constituents such that dewatered brine is not accepted by an IWLF and therefore needs to be sent to a Hazardous Waste Landfill (HWLF)

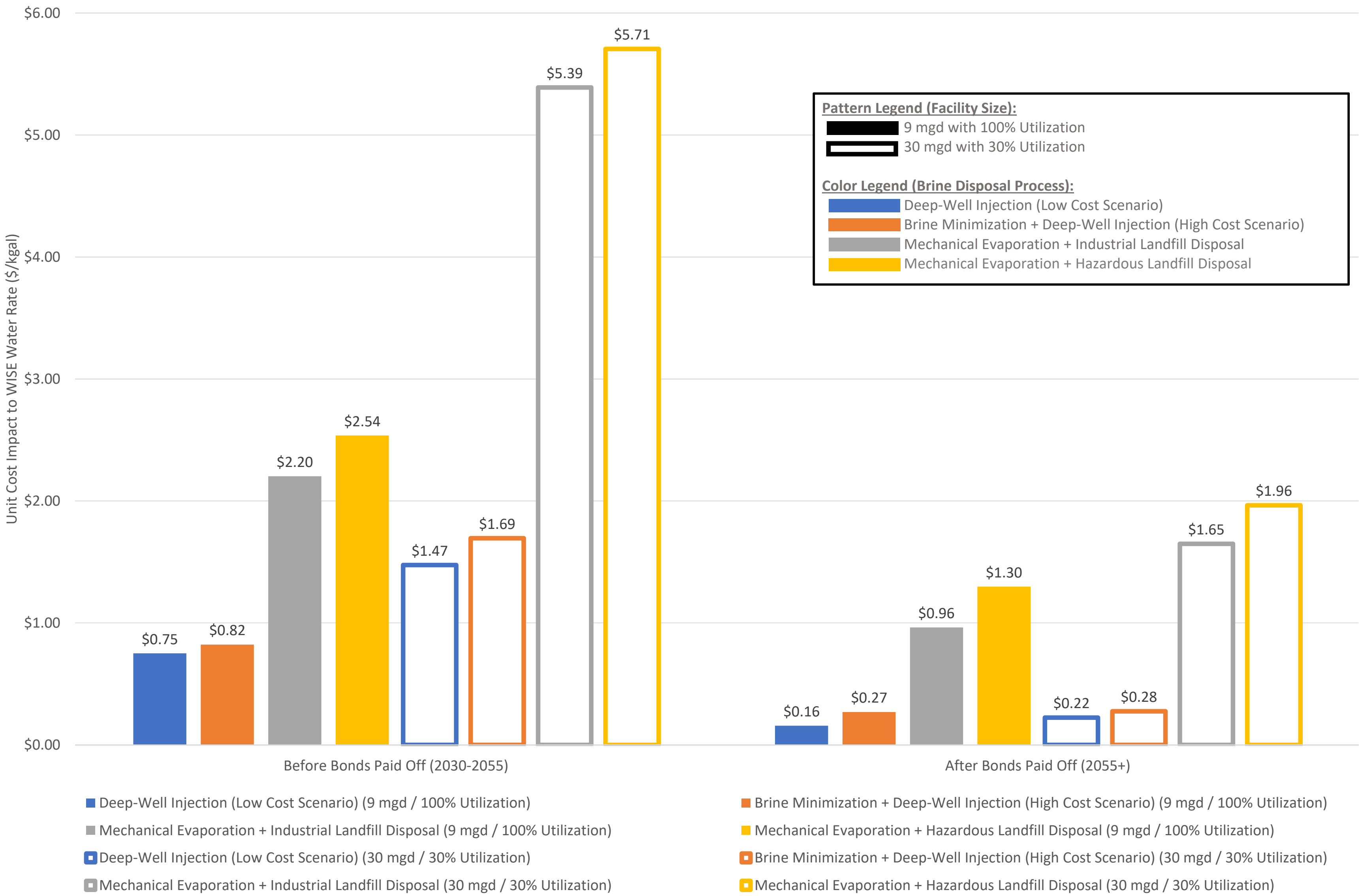
Unit Cost Impacts to the WISE Water Rate for Brine Disposal Processes (30 mgd Facility)

5. Summary of Findings

Brine disposal processes investigated could be implemented to dispose of brine waste from a new SMWA desalination facility. However, there are significant cost uncertainties based on a wide range of costs presented among brine disposal processes. In addition to the cost uncertainties, the following section outlines potential next steps to reduce cost uncertainty of injection wells. There is a wide range of estimated water loss among brine disposal processes. Water losses associated with deep-well injection without brine minimization are estimated to be approximately 8 percent, while water losses estimated for deep-well injection following brine minimization are approximately 4 percent. Water losses estimated for mechanical evaporation and brine sludge disposal at a landfill are approximately 0.2 percent.

Figure 10 presents unit cost impacts to the WISE water rate before (short-term) and after (long-term) bonds financing capital costs would be paid off for all brine disposal processes investigated. The lowest unit cost option would be implementation of a deep-well injection system that experiences sustainable injection rates similar to the existing ECCV system. However, this option also has the highest water loss (8 percent) among brine disposal processes investigated. The unit cost to send brine sludge to an Industrial Waste Landfill is between two and four times more expensive than deep-well injection, depending on the sustainable injection rate. The additional unit cost to send brine to a Hazardous Waste Landfill is between 5 and 15 percent more expensive than sending the brine waste to the Industrial Waste Landfill depending on the facility size.

Unit costs presented in **Figure 10** would be the additional unit cost above the future WISE water rate and would also need to include costs for salinity removal presented in the accompanying **TM 1 – Salinity Removal**. The **Project Summary** presents a holistic summary of costs associated with desalination options (salinity removal and brine disposal).



Note:
Costs presented are for brine disposal processes at the Central Site. Costs for other sites can be found in **Appendix B - Cost Appendix**

WISE Salinity Management Plan	JACOBS	**TM 2 - Brine Disposal** **Unit Cost Impacts to the WISE Water Rate for Evaluated Brine Disposal Processes**	**Figure 10**

6. Injection Well Geophysical and Geochemical Testing

As deep-well injection is the most cost-effective potential brine disposal method, the following next steps are recommended to further define the feasibility of deep-well injection.

1. Perform a fatal flaw assessment of the ability to acquire land at or near the proposed central site.

2. Get permission from a local land owner near the proposed central site to construct an exploratory injection well boring to better understand if a suitable injection zone exists beneath the site. Data collected from the exploratory boring will be used to characterize the native water chemistry and permeability of the formations underlying the site. A select list of exploratory injection well boring activities includes:

    - Drill a test hole to total depth of proposed injection zone. Log the hole, collect lithology samples and perform sieve analysis on select samples.

    - Perform geophysical logging on the test hole including electric resistivity, gamma ray and spontaneous potential to confirm depth and thickness of potential injection zones.

    - Perform sidewall cores or collect continuous cores. Final number of cores and depths of cores will be selected based on the target injection interval.

    - Perform isolated aquifer zone tests or straddle packer testing and collect hydraulic and water samples. Final number and intervals for isolated aquifer zone tests will be selected based on the target injection interval.

    - Decommission/abandon test hole.

3. Identify potential zones to be used for disposal.

4. Perform numerical modeling of injection well performance.

5. Update preliminary cost assumptions including:

    - Refine number of wells, depth, injection pressure, injection rate.

    - Perform UIC Area of Review per the US EPA UIC regulations, which requires the injection well permit applicant to review of the surrounding area to for aquifer penetrations such as other wells that might allow injected fluid to migrate up into an overlying USDW. If wells that penetrate a confining unit are identified, investigate feasibility and costs of corrective actions to address improperly completed or plugged wells within the area.

    - Identify local site regulators (i.e. county rules and regulations) and identify additional design elements and associated costs that may be required.

If the above actions identify a site that can be acquired and a formation suitable for deep-well injection, then land acquisition should be considered.

References

Brown, D., Rynders, T., Stillwell, C., Douglass, C. and Niebur, S. (2017) Brackish Water Reverse Osmosis: A Proven Cost-Effective Renewable Water Supply. Journal AWWA. 109:2.

CH2MHILL (Nov., 2011) *North Campus Water Quality Monitoring River Bank Filtration Final Monitoring Report and Long Term Performance Monitoring Recommendations*.

Appendix A. Landfill Operator Interviews

JACOBS

Meeting Minutes

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Subject	**Landfill Operator Interview - Clean Harbors**
Project	WISE Salinity Management Plan
Prepared by	Jacobs
Participants	Mike Hall – Clean Harbors George Cebula – Clean Harbors Jack Greene – Jacobs

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Q: Do you currently accept brine waste at your Deer Trail, CO RCRA Subtitle C Landfill? What is the facility's expected lifespan? Do you have plans to expand?

- We can accept brine waste in both solidified and liquid forms. We can typically accept about 30,000 – 40,000 gallons per day in liquid form and 400 tons or more of solid material for direct landfill on a daily basis.

- The facility has an expected lifespan of a 30 years as currently permitted but could be expanded as needed on site property for many more years of operation.

Q: What transportation infrastructure is near your Deer Trail, CO facility? Is it accessible by rail, or are most deliveries made via truck?

- There is no rail infrastructure within our plant or in close proximity that could be used for shipments of liquid or solid material from the greater Denver area and most deliveries are made by truck from the surrounding Denver area.

Q: Do you serve large industrial producers or smaller individual users? Do you do contracts with them or are agreements done "by-load"? Who carries the liability?

- We serve all sizes of producers.

- Contract length terms are whatever the generator prefers.

- With hazardous waste, the liability always stays with the generator.

Q: What types of tests do you look for to determine the acceptability of waste? What is the process?

- Pesticides, PCBs, Volatiles, Semi-Volatiles, Total Metals, RCRA Metals, TCLP, Ignitability, Corrosivity and Radionuclides per RCRA sampling standards.

Q: Do you anticipate a problem with brine waste on your leachate treatment systems?

- Leachate water is treated, which will manage the risk of addition salts to the landfill

Q: Will Clean Harbors be able to handle 0.66 mgd or 2.2 mgd of liquid waste?

- This amount of liquid waste would overwhelm our Deer Trail facility and would need to be shipped to our Oklahoma or Utah Subtitle C landfills both of which have rail capabilities near them. This would increase the price of shipping, or we could build a solids handling process specifically for this waste. We could get our Water Treatment Specialists involved, but we know Jacobs also provides those services. Given the volume of liquids, it may be more efficient for the treatment plant(s) to solidify/evaporate produced brine rather than attempt to ship liquids. Much more information would be required to determine the economic/feasibility of any such endeavor.

JACOBS

Meeting Minutes

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Subject	**Landfill Operator Interview - Waste Management**
Project	WISE Salinity Management Plan
Prepared by	Jacobs
Participants	Jeff Sprowls – Waste Management Jack Greene – Jacobs

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Q: Do you currently accept brine waste? What the facility's expected lifespan? Do you have plans to expand?

- Brine waste hasn't been traditionally accepted, but not necessarily something that we wouldn't be able to accept. There is an industrial waste collection site outside of Bennett, CO that can accept liquid or slurry waste and solidify it, but the cost is generally higher. The volume estimated is significant but may not be unmanageable.

- The lifespan of the Denver Arapahoe Disposal Site (DADS) is currently approximately 120 years, but the lifespan is shrinking with increasing population growth in the Denver Metro Area.

Q: What infrastructure is near your area? Is it accessible by rail, or are most deliveries made via truck?

- There is no rail infrastructure near the DADS facility, so all deliveries are made by trucks.

- At our liquid waste facility in Bennett, CO, there is rail infrastructure near there, but we have discontinued our lease of it due to low use.

Q: Do you serve large industrial producers or smaller individual users? Do you do contracts with them or are agreements done "by-load"? Who carries the liability?

- We do agreements based on general services agreements, which spells out our acceptance criteria and payment terms.

- Liability is handled as part of indemnity, so as long as the producer delivers conforming waste, the producer is not liable for any damages incurred by WM on future environmental regulations (for example).

- Estimated current costs are below (with an estimated annual escalation of 5%):

    - Waste that contains free liquids is more expensive at $1.06/gallon or $167 per cubic yard

    - Waste that passes a paint filter test for free liquids is $47.50/ton

- Generally, solidification costs are expected to increase significantly in the next decade.

Q: What types of tests do you look for to determine the acceptability of waste? What is the process?

- Paint Filter Test for free liquids – anything with liquids will be subject to additional processing and solidification by WM for final disposal.
- “RCRA 8” metals – arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver. Waste should be tested using the Toxicity Characteristic Leachate Procedure to ensure compliance.
- Along with other water/wastewater treatment wastes, background testing based on EPA methods are needed to deem waste non-hazardous and non-radiological.
  - 40 pCi/g total
  - 6 pCi/g of combined Radium
  - 3 pCi/g of Uranium or Thorium
- We are often concerned with water and wastewater sludge containing radionuclides or have radiation present, if the producer cannot prove that the waste will also be below 40 pCi/g, we require tests for combined Radium and Uranium and Thorium for acceptance
- New tests are required (on an interval determined by CDPHE)

Q: Do you anticipate a problem with brine waste on your leachate treatment systems?

- Leachate problems as a result of brine are not anticipated. If leachate is collected it will be tested and properly managed.

Q: Will Waste Management be able to handle 0.66 mgd or 2.2 mgd of liquid waste?

- The DADS facility cannot accept the anticipated volume. This amount would overwhelm our facility.

Appendix B. Cost Appendix

Brine Disposal Cost Summary (Central Site)

			9 mgd Facility Size				30 mgd Facility Size (30% Utilization)				30 mgd Facility Size (100% Utilization)			
Unit Process	**Capital Cost**	**O&M Cost**	**Deep-Well Injection (Low Cost)**	**Deep-Well Injection (High Cost)**	**Mechanical Evaporation + IWLF**	**Mechanical Evaporation + HWLF**	**Deep-Well Injection (Low Cost)**	**Deep-Well Injection (High Cost)**	**Mechanical Evaporation + IWLF**	**Mechanical Evaporation + HWLF**	**Deep-Well Injection (Low Cost)**	**Deep-Well Injection (High Cost)**	**Mechanical Evaporation + IWLF**	**Mechanical Evaporation + HWLF**
Deep-Well Injection (Low Cost): 9 mgd	$7,789,000	$315,000		1										
Deep-Well Injection (Low Cost): 30 mgd (30%)	$21,098,000	$881,000										1		
Mechanical Evaporation: 9 mgd - IWLF	$21,127,000	$3,099,000			1									
Mechanical Evaporation: 30 mgd (100%) - IWLF	$63,783,000	$9,712,000											1	
Mechanical Evaporation: 9 mgd - HWLF	$21,127,000	$4,177,000				1								
Mechanical Evaporation: 30 mgd (100%) - HWLF	$63,783,000	$13,100,000												1
Deep-Well Injection (Low Cost): 30 mgd (100%)	$21,098,000	$434,000						1						
Mechanical Evaporation: 30 mgd (30%) - IWLF	$63,783,000	$5,305,000							1					
Mechanical Evaporation: 30 mgd (30%) - HWLF	$63,783,000	$6,321,000								1				
Deep-Well Injection (High Cost): 9 mgd	$10,111,000	$507,000	1											
Deep-Well Injection (High Cost): 30 mgd (100%)	$21,318,000	$1,468,000									1			
Deep-Well Injection (High Cost): 30 mgd (30%)	$21,318,000	$721,000					1							
Chemical Feed (HCl): 9 mgd	$667,000	$12,000		1										
Chemical Feed (HCl): 30 mgd (30%)	$1,406,000	$25,000						1						
Chemical Feed (HCl): 30 mgd (100%)	$1,406,000	$26,000										1		
Brine Minimization: 9 mgd	$963,000	$541,000		1										
Brine Minimization: 30 mgd (30%)	$1,673,000	$429,000						1						
Brine Minimization: 30 mgd (100%)	$1,673,000	$873,000										1		
Subtotal Cost			**$10,111,000**	**$9,419,000**	**$21,127,000**	**$21,127,000**	**$21,318,000**	**$24,177,000**	**$63,783,000**	**$63,783,000**	**$21,318,000**	**$24,177,000**	**$63,783,000**	**$63,783,000**
ADDITIONAL PROJECT COSTS:														
Overall Sitework:	6%		$607,000	$566,000	$1,268,000	$1,268,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000
Plant Computer System:	6%		$607,000	$566,000	$1,268,000	$1,268,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000
Yard Electrical:	9%		$910,000	$848,000	$1,902,000	$1,902,000	$1,919,000	$2,176,000	$5,741,000	$5,741,000	$1,919,000	$2,176,000	$5,741,000	$5,741,000
Yard Piping:	8%		$809,000	$754,000	$1,691,000	$1,691,000	$1,706,000	$1,935,000	$5,103,000	$5,103,000	$1,706,000	$1,935,000	$5,103,000	$5,103,000
SUBTOTAL OF ADDITIONAL PROJECT COSTS:			$13,044,000	$12,153,000	$27,256,000	$27,256,000	$27,503,000	$31,190,000	$82,281,000	$82,281,000	$27,503,000	$31,190,000	$82,281,000	$82,281,000
COST DATA ESCALATION (JAN '18 TO JAN '19)	1.0125		$13,208,000	$12,306,000	$27,598,000	$27,598,000	$27,848,000	$31,582,000	$83,313,000	$83,313,000	$27,848,000	$31,582,000	$83,313,000	$83,313,000
CONTRACTOR MARKUPS:														
Overhead	12%		$1,585,000	$1,477,000	$3,312,000	$3,312,000	$3,342,000	$3,790,000	$9,998,000	$9,998,000	$3,342,000	$3,790,000	$9,998,000	$9,998,000
Subtotal:			$14,793,000	$13,783,000	$30,910,000	$30,910,000	$31,190,000	$35,372,000	$93,311,000	$93,311,000	$31,190,000	$35,372,000	$93,311,000	$93,311,000
Profit	10%		$1,480,000	$1,379,000	$3,091,000	$3,091,000	$3,119,000	$3,538,000	$9,332,000	$9,332,000	$3,119,000	$3,538,000	$9,332,000	$9,332,000
Subtotal:			$16,273,000	$15,162,000	$34,001,000	$34,001,000	$34,309,000	$38,910,000	$102,643,000	$102,643,000	$34,309,000	$38,910,000	$102,643,000	$102,643,000
Mob/Bonds/Insurance	3%		$489,000	$455,000	$1,021,000	$1,021,000	$1,030,000	$1,168,000	$3,080,000	$3,080,000	$1,030,000	$1,168,000	$3,080,000	$3,080,000
Subtotal:			$16,762,000	$15,617,000	$35,022,000	$35,022,000	$35,339,000	$40,078,000	$105,723,000	$105,723,000	$35,339,000	$40,078,000	$105,723,000	$105,723,000
Contingency	30%		$5,029,000	$4,686,000	$10,507,000	$10,507,000	$10,602,000	$12,024,000	$31,717,000	$31,717,000	$10,602,000	$12,024,000	$31,717,000	$31,717,000
Subtotal:			$21,791,000	$20,303,000	$45,529,000	$45,529,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000
SUBTOTAL OF CONTRACTOR MARKUPS:			$21,791,000	$20,303,000	$45,529,000	$45,529,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000
NON-CONSTRUCTION COSTS:														
Permitting:	2%		$436,000	$407,000	$911,000	$911,000	$919,000	$1,043,000	$2,749,000	$2,749,000	$919,000	$1,043,000	$2,749,000	$2,749,000
Engineering:	10%		$2,180,000	$2,031,000	$4,553,000	$4,553,000	$4,595,000	$5,211,000	$13,744,000	$13,744,000	$4,595,000	$5,211,000	$13,744,000	$13,744,000
Services During Construction:	8%		$1,744,000	$1,625,000	$3,643,000	$3,643,000	$3,676,000	$4,169,000	$10,996,000	$10,996,000	$3,676,000	$4,169,000	$10,996,000	$10,996,000
Commissioning & Startup:	2%		$436,000	$407,000	$911,000	$911,000	$919,000	$1,043,000	$2,749,000	$2,749,000	$919,000	$1,043,000	$2,749,000	$2,749,000
Land / ROW:	1%		$218,000	$204,000	$456,000	$456,000	$460,000	$522,000	$1,375,000	$1,375,000	$460,000	$522,000	$1,375,000	$1,375,000
Legal / Admin:	2%		$436,000	$407,000	$911,000	$911,000	$919,000	$1,043,000	$2,749,000	$2,749,000	$919,000	$1,043,000	$2,749,000	$2,749,000
SUBTOTAL OF NON-CONSTRUCTION COSTS:			$27,241,000	$25,384,000	$56,914,000	$56,914,000	$57,429,000	$65,133,000	$171,802,000	$171,802,000	$57,429,000	$65,133,000	$171,802,000	$171,802,000
Total Capital Cost			**$27,241,000**	**$25,384,000**	**$56,914,000**	**$56,914,000**	**$57,429,000**	**$65,133,000**	**$171,802,000**	**$171,802,000**	**$57,429,000**	**$65,133,000**	**$171,802,000**	**$171,802,000**
Unit Capital Cost ($/gal of desalination facility capacity)			*$3.00*	*$2.80*	*$6.30*	*$6.30*	*$1.90*	*$2.20*	*$5.70*	*$5.70*	*$1.90*	*$2.20*	*$5.70*	*$5.70*
25-Year Bond Payment ($/yr)			$1,932,816	$1,801,057	$4,038,188	$4,038,188	$4,074,729	$4,621,346	$12,189,774	$12,189,774	$4,074,729	$4,621,346	$12,189,774	$12,189,774
Annual O&M Cost ($/yr)			$513,357	$878,883	$3,137,854	$4,229,369	$730,040	$899,133	$5,371,512	$6,400,250	$1,486,405	$1,802,317	$9,833,765	$13,264,242
25-Year Annual Cost ($/yr)			**$2,446,172**	**$2,679,940**	**$7,176,042**	**$8,267,558**	**$4,804,768**	**$5,520,480**	**$17,561,286**	**$18,590,024**	**$5,561,134**	**$6,423,663**	**$22,023,539**	**$25,454,016**
25-Year WISE Water Rate Increase ($/kgal)			**$0.75**	**$0.82**	**$2.20**	**$2.54**	**$1.47**	**$1.69**	**$5.39**	**$5.71**	**$1.71**	**$1.97**	**$6.76**	**$7.81**
Annual O&M Cost ($/yr)			$513,357	$878,883	$3,137,854	$4,229,369	$730,040	$899,133	$5,371,512	$6,400,250	$1,486,405	$1,802,317	$9,833,765	$13,264,242
Long-Term Annual Cost ($/yr)			**$513,357**	**$878,883**	**$3,137,854**	**$4,229,369**	**$730,040**	**$899,133**	**$5,371,512**	**$6,400,250**	**$1,486,405**	**$1,802,317**	**$9,833,765**	**$13,264,242**
Long-Term WISE Water Rate Increase ($/kgal)			**$0.16**	**$0.27**	**$0.96**	**$1.30**	**$0.22**	**$0.28**	**$1.65**	**$1.96**	**$0.46**	**$0.55**	**$3.02**	**$4.07**

Brine Disposal Cost Summary (North Site)

			9 mgd Facility Size				30 mgd Facility Size (30% Utilization)				30 mgd Facility Size (100% Utilization)			
Unit Process	Capital Cost	O&M Cost	Deep-Well Injection (Low Cost)	Deep-Well Injection (High Cost)	Mechanical Evaporation + IWLF	Mechanical Evaporation + HWLF	Deep-Well Injection (Low Cost)	Deep-Well Injection (High Cost)	Mechanical Evaporation + IWLF	Mechanical Evaporation + HWLF	Deep-Well Injection (Low Cost)	Deep-Well Injection (High Cost)	Mechanical Evaporation + IWLF	Mechanical Evaporation + HWLF
Deep-Well Injection (Low Cost): 9 mgd	$9,091,000	$330,000		1										
Deep-Well Injection (Low Cost): 30 mgd (30%)	$17,985,000	$936,000										1		
Mechanical Evaporation: 9 mgd - IWLF	$21,127,000	$3,169,000			1									
Mechanical Evaporation: 30 mgd (100%) - IWLF	$63,783,000	$9,932,000											1	
Mechanical Evaporation: 9 mgd - HWLF	$21,127,000	$4,257,000				1								
Mechanical Evaporation: 30 mgd (100%) - HWLF	$63,783,000	$13,352,000												1
Deep-Well Injection (Low Cost): 30 mgd (100%)	$17,985,000	$463,000						1						
Mechanical Evaporation: 30 mgd (30%) - IWLF	$63,783,000	$5,371,000							1					
Mechanical Evaporation: 30 mgd (30%) - HWLF	$63,783,000	$6,397,000								1				
Deep-Well Injection (High Cost): 9 mgd	$10,111,000	$507,000	1											
Deep-Well Injection (High Cost): 30 mgd (100%)	$21,318,000	$1,468,000									1			
Deep-Well Injection (High Cost): 30 mgd (30%)	$21,318,000	$721,000					1							
Chemical Feed (HCl): 9 mgd	$667,000	$12,000		1										
Chemical Feed (HCl): 30 mgd (30%)	$1,406,000	$25,000						1						
Chemical Feed (HCl): 30 mgd (100%)	$1,406,000	$26,000										1		
Brine Minization: 9 mgd	$963,000	$541,000		1										
Brine Minization: 30 mgd (30%)	$1,673,000	$429,000						1						
Brine Minization: 30 mgd (100%)	$1,673,000	$873,000										1		
Subtotal Cost			**$10,111,000**	**$10,721,000**	**$21,127,000**	**$21,127,000**	**$21,318,000**	**$21,064,000**	**$63,783,000**	**$63,783,000**	**$21,318,000**	**$21,064,000**	**$63,783,000**	**$63,783,000**
ADDITIONAL PROJECT COSTS:														
Overall Sitework:	6%		$607,000	$644,000	$1,268,000	$1,268,000	$1,280,000	$1,264,000	$3,827,000	$3,827,000	$1,280,000	$1,264,000	$3,827,000	$3,827,000
Plant Computer System:	6%		$607,000	$644,000	$1,268,000	$1,268,000	$1,280,000	$1,264,000	$3,827,000	$3,827,000	$1,280,000	$1,264,000	$3,827,000	$3,827,000
Yard Electrical:	9%		$910,000	$965,000	$1,902,000	$1,902,000	$1,919,000	$1,896,000	$5,741,000	$5,741,000	$1,919,000	$1,896,000	$5,741,000	$5,741,000
Yard Piping:	8%		$809,000	$858,000	$1,691,000	$1,691,000	$1,706,000	$1,686,000	$5,103,000	$5,103,000	$1,706,000	$1,686,000	$5,103,000	$5,103,000
SUBTOTAL OF ADDITIONAL PROJECT COSTS:			$13,044,000	$13,832,000	$27,256,000	$27,256,000	$27,503,000	$27,174,000	$82,281,000	$82,281,000	$27,503,000	$27,174,000	$82,281,000	$82,281,000
COST DATA ESCALATION (JAN '18 TO JAN '19)	1.0125		$13,208,000	$14,006,000	$27,598,000	$27,598,000	$27,848,000	$27,515,000	$83,313,000	$83,313,000	$27,848,000	$27,515,000	$83,313,000	$83,313,000
CONTRACTOR MARKUPS:														
Overhead	12%		$1,585,000	$1,681,000	$3,312,000	$3,312,000	$3,342,000	$3,302,000	$9,998,000	$9,998,000	$3,342,000	$3,302,000	$9,998,000	$9,998,000
Subtotal:			$14,793,000	$15,687,000	$30,910,000	$30,910,000	$31,190,000	$30,817,000	$93,311,000	$93,311,000	$31,190,000	$30,817,000	$93,311,000	$93,311,000
Profit	10%		$1,480,000	$1,569,000	$3,091,000	$3,091,000	$3,119,000	$3,082,000	$9,332,000	$9,332,000	$3,119,000	$3,082,000	$9,332,000	$9,332,000
Subtotal:			$16,273,000	$17,256,000	$34,001,000	$34,001,000	$34,309,000	$33,899,000	$102,643,000	$102,643,000	$34,309,000	$33,899,000	$102,643,000	$102,643,000
Mob/Bonds/Insurance	3%		$489,000	$518,000	$1,021,000	$1,021,000	$1,030,000	$1,017,000	$3,080,000	$3,080,000	$1,030,000	$1,017,000	$3,080,000	$3,080,000
Subtotal:			$16,762,000	$17,774,000	$35,022,000	$35,022,000	$35,339,000	$34,916,000	$105,723,000	$105,723,000	$35,339,000	$34,916,000	$105,723,000	$105,723,000
Contingency	30%		$5,029,000	$5,333,000	$10,507,000	$10,507,000	$10,602,000	$10,475,000	$31,717,000	$31,717,000	$10,602,000	$10,475,000	$31,717,000	$31,717,000
Subtotal:			$21,791,000	$23,107,000	$45,529,000	$45,529,000	$45,941,000	$45,391,000	$137,440,000	$137,440,000	$45,941,000	$45,391,000	$137,440,000	$137,440,000
SUBTOTAL OF CONTRACTOR MARKUPS:			$21,791,000	$23,107,000	$45,529,000	$45,529,000	$45,941,000	$45,391,000	$137,440,000	$137,440,000	$45,941,000	$45,391,000	$137,440,000	$137,440,000
NON-CONSTRUCTION COSTS:														
Permitting:	2%		$436,000	$463,000	$911,000	$911,000	$919,000	$908,000	$2,749,000	$2,749,000	$919,000	$908,000	$2,749,000	$2,749,000
Engineering:	10%		$2,180,000	$2,311,000	$4,553,000	$4,553,000	$4,595,000	$4,540,000	$13,744,000	$13,744,000	$4,595,000	$4,540,000	$13,744,000	$13,744,000
Services During Construction:	8%		$1,744,000	$1,849,000	$3,643,000	$3,643,000	$3,676,000	$3,632,000	$10,996,000	$10,996,000	$3,676,000	$3,632,000	$10,996,000	$10,996,000
Commissioning & Startup:	2%		$436,000	$463,000	$911,000	$911,000	$919,000	$908,000	$2,749,000	$2,749,000	$919,000	$908,000	$2,749,000	$2,749,000
Land / ROW:	1%		$218,000	$232,000	$456,000	$456,000	$460,000	$454,000	$1,375,000	$1,375,000	$460,000	$454,000	$1,375,000	$1,375,000
Legal / Admin:	2%		$436,000	$463,000	$911,000	$911,000	$919,000	$908,000	$2,749,000	$2,749,000	$919,000	$908,000	$2,749,000	$2,749,000
SUBTOTAL OF NON-CONSTRUCTION COSTS:			$27,241,000	$28,888,000	$56,914,000	$56,914,000	$57,429,000	$56,741,000	$171,802,000	$171,802,000	$57,429,000	$56,741,000	$171,802,000	$171,802,000
Total Capital Cost			**$27,241,000**	**$28,888,000**	**$56,914,000**	**$56,914,000**	**$57,429,000**	**$56,741,000**	**$171,802,000**	**$171,802,000**	**$57,429,000**	**$56,741,000**	**$171,802,000**	**$171,802,000**
Unit Capital Cost ($/gal of desalination facility capacity)			*$3.00*	*$3.20*	*$6.30*	*$6.30*	*$1.90*	*$1.90*	*$5.70*	*$5.70*	*$1.90*	*$1.90*	*$5.70*	*$5.70*
25-Year Bond Payment ($/yr)			$1,932,816	$2,049,675	$4,038,188	$4,038,188	$4,074,729	$4,025,913	$12,189,774	$12,189,774	$4,074,729	$4,025,913	$12,189,774	$12,189,774
Annual O&M Cost ($/yr)			$513,357	$894,071	$3,208,732	$4,310,372	$730,040	$928,497	$5,438,339	$6,477,203	$1,486,405	$1,858,006	$10,056,523	$13,519,402
25-Year Annual Cost ($/yr)			**$2,446,172**	**$2,943,745**	**$7,246,920**	**$8,348,561**	**$4,804,768**	**$4,954,410**	**$17,628,113**	**$18,666,977**	**$5,561,134**	**$5,883,920**	**$22,246,297**	**$25,709,176**
25-Year WISE Water Rate Increase ($/kgal)			**$0.75**	**$0.90**	**$2.22**	**$2.56**	**$1.47**	**$1.52**	**$5.41**	**$5.73**	**$1.71**	**$1.81**	**$6.83**	**$7.89**
Annual O&M Cost ($/yr)			$513,357	$894,071	$3,208,732	$4,310,372	$730,040	$928,497	$5,438,339	$6,477,203	$1,486,405	$1,858,006	$10,056,523	$13,519,402
Long-Term Annual Cost ($/yr)			**$513,357**	**$894,071**	**$3,208,732**	**$4,310,372**	**$730,040**	**$928,497**	**$5,438,339**	**$6,477,203**	**$1,486,405**	**$1,858,006**	**$10,056,523**	**$13,519,402**
Long-Term WISE Water Rate Increase ($/kgal)			**$0.16**	**$0.27**	**$0.98**	**$1.32**	**$0.22**	**$0.28**	**$1.67**	**$1.99**	**$0.46**	**$0.57**	**$3.09**	**$4.15**

Brine Disposal Cost Summary (South Site)														
			9 mgd Facility Size				30 mgd Facility Size (30% Utilization)				30 mgd Facility Size (100% Utilization)			
Unit Process	Capital Cost	O&M Cost	Deep-Well Injection (Low Cost)	Deep-Well Injection (High Cost)	Mechanical Evaporation + IWLF	Mechanical Evaporation + HWLF	Deep-Well Injection (Low Cost)	Deep-Well Injection (High Cost)	Mechanical Evaporation + IWLF	Mechanical Evaporation + HWLF	Deep-Well Injection (Low Cost)	Deep-Well Injection (High Cost)	Mechanical Evaporation + IWLF	Mechanical Evaporation + HWLF
Deep-Well Injection (Low Cost): 9 mgd	$7,789,000	$315,000		1										
Deep-Well Injection (Low Cost): 30 mgd (30%)	$21,098,000	$881,000										1		
Mechanical Evaporation: 9 mgd - IWLF	$21,127,000	$3,089,000			1									
Mechanical Evaporation: 30 mgd (100%) - IWLF	$63,783,000	$9,681,000											1	
Mechanical Evaporation: 9 mgd - HWLF	$21,127,000	$4,197,000				1								
Mechanical Evaporation: 30 mgd (100%) - HWLF	$63,783,000	$13,163,000												1
Deep-Well Injection (Low Cost): 30 mgd (100%)	$21,098,000	$434,000						1						
Mechanical Evaporation: 30 mgd (30%) - IWLF	$63,783,000	$5,295,000							1					
Mechanical Evaporation: 30 mgd (30%) - HWLF	$63,783,000	$6,340,000								1				
Deep-Well Injection (High Cost): 9 mgd	$10,111,000	$507,000	1											
Deep-Well Injection (High Cost): 30 mgd (100%)	$21,318,000	$1,468,000									1			
Deep-Well Injection (High Cost): 30 mgd (30%)	$21,318,000	$721,000					1							
Chemical Feed (HCl): 9 mgd	$667,000	$12,000		1										
Chemical Feed (HCl): 30 mgd (30%)	$1,406,000	$25,000						1						
Chemical Feed (HCl): 30 mgd (100%)	$1,406,000	$26,000										1		
Brine Minization: 9 mgd	$963,000	$541,000		1										
Brine Minization: 30 mgd (30%)	$1,673,000	$429,000						1						
Brine Minization: 30 mgd (100%)	$1,673,000	$873,000										1		
Subtotal Cost			**$10,111,000**	**$9,419,000**	**$21,127,000**	**$21,127,000**	**$21,318,000**	**$24,177,000**	**$63,783,000**	**$63,783,000**	**$21,318,000**	**$24,177,000**	**$63,783,000**	**$63,783,000**
ADDITIONAL PROJECT COSTS:														
Overall Sitework:	6%		$607,000	$566,000	$1,268,000	$1,268,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000
Plant Computer System:	6%		$607,000	$566,000	$1,268,000	$1,268,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000	$1,280,000	$1,451,000	$3,827,000	$3,827,000
Yard Electrical:	9%		$910,000	$848,000	$1,902,000	$1,902,000	$1,919,000	$2,176,000	$5,741,000	$5,741,000	$1,919,000	$2,176,000	$5,741,000	$5,741,000
Yard Piping:	8%		$809,000	$754,000	$1,691,000	$1,691,000	$1,706,000	$1,935,000	$5,103,000	$5,103,000	$1,706,000	$1,935,000	$5,103,000	$5,103,000
SUBTOTAL OF ADDITIONAL PROJECT COSTS:			$13,044,000	$12,153,000	$27,256,000	$27,256,000	$27,503,000	$31,190,000	$82,281,000	$82,281,000	$27,503,000	$31,190,000	$82,281,000	$82,281,000
COST DATA ESCALATION (JAN '18 TO JAN '19)	1.0125		$13,208,000	$12,306,000	$27,598,000	$27,598,000	$27,848,000	$31,582,000	$83,313,000	$83,313,000	$27,848,000	$31,582,000	$83,313,000	$83,313,000
CONTRACTOR MARKUPS:														
Overhead	12%		$1,585,000	$1,477,000	$3,312,000	$3,312,000	$3,342,000	$3,790,000	$9,998,000	$9,998,000	$3,342,000	$3,790,000	$9,998,000	$9,998,000
Subtotal:			$14,793,000	$13,783,000	$30,910,000	$30,910,000	$31,190,000	$35,372,000	$93,311,000	$93,311,000	$31,190,000	$35,372,000	$93,311,000	$93,311,000
Profit	10%		$1,480,000	$1,379,000	$3,091,000	$3,091,000	$3,119,000	$3,538,000	$9,332,000	$9,332,000	$3,119,000	$3,538,000	$9,332,000	$9,332,000
Subtotal:			$16,273,000	$15,162,000	$34,001,000	$34,001,000	$34,309,000	$38,910,000	$102,643,000	$102,643,000	$34,309,000	$38,910,000	$102,643,000	$102,643,000
Mob/Bonds/Insurance	3%		$489,000	$455,000	$1,021,000	$1,021,000	$1,030,000	$1,168,000	$3,080,000	$3,080,000	$1,030,000	$1,168,000	$3,080,000	$3,080,000
Subtotal:			$16,762,000	$15,617,000	$35,022,000	$35,022,000	$35,339,000	$40,078,000	$105,723,000	$105,723,000	$35,339,000	$40,078,000	$105,723,000	$105,723,000
Contingency	30%		$5,029,000	$4,686,000	$10,507,000	$10,507,000	$10,602,000	$12,024,000	$31,717,000	$31,717,000	$10,602,000	$12,024,000	$31,717,000	$31,717,000
Subtotal:			$21,791,000	$20,303,000	$45,529,000	$45,529,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000
SUBTOTAL OF CONTRACTOR MARKUPS:			$21,791,000	$20,303,000	$45,529,000	$45,529,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000	$45,941,000	$52,102,000	$137,440,000	$137,440,000
NON-CONSTRUCTION COSTS:														
Permitting:	2%		$436,000	$407,000	$911,000	$911,000	$919,000	$1,043,000	$2,749,000	$2,749,000	$919,000	$1,043,000	$2,749,000	$2,749,000
Engineering:	10%		$2,180,000	$2,031,000	$4,553,000	$4,553,000	$4,595,000	$5,211,000	$13,744,000	$13,744,000	$4,595,000	$5,211,000	$13,744,000	$13,744,000
Services During Construction:	8%		$1,744,000	$1,625,000	$3,643,000	$3,643,000	$3,676,000	$4,169,000	$10,996,000	$10,996,000	$3,676,000	$4,169,000	$10,996,000	$10,996,000
Commissioning & Startup:	2%		$436,000	$407,000	$911,000	$911,000	$919,000	$1,043,000	$2,749,000	$2,749,000	$919,000	$1,043,000	$2,749,000	$2,749,000
Land / ROW:	1%		$218,000	$204,000	$456,000	$456,000	$460,000	$522,000	$1,375,000	$1,375,000	$460,000	$522,000	$1,375,000	$1,375,000
Legal / Admin:	2%		$436,000	$407,000	$911,000	$911,000	$919,000	$1,043,000	$2,749,000	$2,749,000	$919,000	$1,043,000	$2,749,000	$2,749,000
SUBTOTAL OF NON-CONSTRUCTION COSTS:			$27,241,000	$25,384,000	$56,914,000	$56,914,000	$57,429,000	$65,133,000	$171,802,000	$171,802,000	$57,429,000	$65,133,000	$171,802,000	$171,802,000
Total Capital Cost			**$27,241,000**	**$25,384,000**	**$56,914,000**	**$56,914,000**	**$57,429,000**	**$65,133,000**	**$171,802,000**	**$171,802,000**	**$57,429,000**	**$65,133,000**	**$171,802,000**	**$171,802,000**
Unit Capital Cost ($/gal of desalination facility capacity)			*$3.00*	*$2.80*	*$6.30*	*$6.30*	*$1.90*	*$2.20*	*$5.70*	*$5.70*	*$1.90*	*$2.20*	*$5.70*	*$5.70*
25-Year Bond Payment ($/yr)			$1,932,816	$1,801,057	$4,038,188	$4,038,188	$4,074,729	$4,621,346	$12,189,774	$12,189,774	$4,074,729	$4,621,346	$12,189,774	$12,189,774
Annual O&M Cost ($/yr)			$513,357	$878,883	$3,127,729	$4,249,620	$730,040	$899,133	$5,361,386	$6,419,488	$1,486,405	$1,802,317	$9,802,376	$13,328,032
25-Year Annual Cost ($/yr)			**$2,446,172**	**$2,679,940**	**$7,165,917**	**$8,287,808**	**$4,804,768**	**$5,520,480**	**$17,551,160**	**$18,609,262**	**$5,561,134**	**$6,423,663**	**$21,992,150**	**$25,517,806**
25-Year WISE Water Rate Increase ($/kgal)			**$0.75**	**$0.82**	**$2.20**	**$2.54**	**$1.47**	**$1.69**	**$5.39**	**$5.71**	**$1.71**	**$1.97**	**$6.75**	**$7.83**
Annual O&M Cost ($/yr)			$513,357	$878,883	$3,127,729	$4,249,620	$730,040	$899,133	$5,361,386	$6,419,488	$1,486,405	$1,802,317	$9,802,376	$13,328,032
Long-Term Annual Cost ($/yr)			**$513,357**	**$878,883**	**$3,127,729**	**$4,249,620**	**$730,040**	**$899,133**	**$5,361,386**	**$6,419,488**	**$1,486,405**	**$1,802,317**	**$9,802,376**	**$13,328,032**
Long-Term WISE Water Rate Increase ($/kgal)			**$0.16**	**$0.27**	**$0.96**	**$1.30**	**$0.22**	**$0.28**	**$1.65**	**$1.97**	**$0.46**	**$0.55**	**$3.01**	**$4.09**

Salinity Management Plan

South Metro WISE Authority

TM 3 - Water Blending

February 2020

Salinity Management Plan

Document Title:	TM 3 – Water Blending
Client Name:	South Metro WISE Authority
Project Manager:	Klint Reedy
Author:	Jack Greene reviewed by Klint Reedy

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Aurora Water

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Acronyms and Abbreviations

Ac	Acre
af	Acre Feet
afy	Acre Feet per Year
BWPF	Binney Water Purification Facility
Castle Rock TCR	Town of Castle Rock
CCPWA	Cherry Creek Project Water Authority
Centennial CWSD	Centennial Water and Sanitation District
CWCB	Colorado Water Conservation Board
Cottonwood	Cottonwood Water and Sanitation District
Dominion	Dominion Water and Sanitation District
Hp	Horsepower
Inverness	Inverness Water and Sanitation District
kgal	Kilogallon (thousands of gallons)
LF	Linear Feet
Meridian MMD	Meridian Metropolitan District
mgd	Million Gallons per Day
O&M	Operations and Maintenance
Pinery	Pinery Water and Sanitation District
Parker Water PWSD	Parker Water and Sanitation District
PS	Pump Station
PWP	Prairie Waters Project
Rangeview	Rangeview Metropolitan District
RHR	Rueter-Hess Reservoir
SMWA	South Metro WISE Authority
Stonegate	Stonegate Village Metropolitan District
TDS	Total Dissolved Solids
TM	Technical Memorandum
WDA	Water Delivery Agreement
WISE	Water Infrastructure and Supply Efficiency
WPF	Water Purification Facility

1. Introduction

The purpose of this study is to explore options to mitigate elevated total dissolved solids (TDS) concentrations present in return flows from the South Platte River that will be delivered to the South Metro WISE Authority (SMWA) by Aurora Water and Denver Water as part of the Water Infrastructure and Supply Efficiency (WISE) project. When practical, options are configured to allow others in the region to also participate in and benefit from the salinity management solutions.

Key overall goals of this study include the following:

1. Investigate how desalination options can be configured to reduce salinity in South Platte River return flows.

2. Study options for brine disposal beyond deep-well injection.

3. Develop water blending concepts incorporating the extension of existing blending concepts and the identification of new blending concepts.

4. Gain increased insight into long-standing questions on inland salinity management and brine disposal principals.

The Salinity Management Plan ("Plan") required numerous interrelated evaluations to be performed. To effectively manage the work effort, the Plan has been broken into the following documents:

- Project Summary

- TM 1 – Salinity Removal

- TM 2 – Brine Disposal

- **TM 3 – Water Blending (this memorandum)**

1.1 Objectives of the Water Blending Evaluation

One option for managing salinity in WISE water from the South Platte River is to blend WISE water with other waters that have lower TDS concentrations. Objectives of this portion of the project were to:

- Identify potential low salinity water that could be available for blending

- Identify potential blend locations

- Develop example layout facilities of select blend strategies

- Identify lowest cost range associated with limited cost risks occurring

- Identify specific and plausible risks that could increase the water blending cost

- Determine the incremental increase in cost associated with each risk

- Provide a summary of cost ranges

1.2 Relevant WISE Background

The WISE Project is an agreement between SMWA members, Denver Water and Aurora Water. Denver Water and Aurora Water deliver their reusable return flows diverted from the South Platte River to SMWA as “WISE water,” allowing SMWA members to reduce their dependence on non-renewable groundwater. WISE water is diverted from the South Platte via the Aurora Water Prairie Waters Project (PWP) Riverbank Filtration Wells (RBF Wells) at the Aurora Water North Campus in Brighton, CO and then treated at the Aurora Water Binney Water Purification Facility (BWPF).

Through May 31, 2030, Denver Water and Aurora Water are required, per the WISE Water Delivery Agreement (WDA), to deliver water with a TDS concentration at or below 500 mg/L. Currently, Denver Water and Aurora Water meet this water quality goal by blending some their low TDS mountain water supplies to reduce TDS concentrations in WISE water diverted from South Platte River return flows. Following May 31, 2030, the WDA allows Denver Water and Aurora Water to deliver unblended WISE water to SMWA. Salinity in water diverted by Aurora Water’s RBF Wells can vary from below 500 mg/L of TDS during spring runoff periods to above 700 mg/L of TDS during periods with lower flow, generally in the early fall and winter. Although the water quality agreement of the WDA expires in 2030, Denver Water and Aurora Water are still required per the WDA to deliver SMWA 100,000 acre-feet (af) of WISE water over defined 10-year periods. The WDA allows deliveries of WISE water from Denver Water and Aurora Water to SMWA to range from a daily flowrate of 0 million gallons per day (mgd) to 30 mgd. As described in more detail throughout this study, there are also limitations on the minimum and maximum annual volumes of water that can be delivered to SMWA throughout the 10-year period.

2. Water Blending Concept Overview

The section provides an overview of key water blending considerations utilized in this study.

2.1 Blend Methods Considered

The following blend methods were originally considered for this study.

2.1.1 Extend Current Blend Agreement

Through May 2030, Aurora Water and Denver Water have agreed to provide SMWA with access to water with low TDS concentrations, allowing the WISE water to be blended to TDS concentrations below 500 mg/L. After May 2030, the requirement to provide blend water to SMWA expires.

Early in this study, it was determined that assessing the feasibility of extending the current blend agreement would require extensive modeling of post 2030 conditions. These modeling conditions would vary both future hydrology and future infrastructure assumptions. This analysis would inform discussions and potentially negotiations of opportunities to extend the current blend agreement. Therefore, this study focused on the feasibility of other salinity management options for SMWA to provide an understanding of options that can be implemented if the current agreement cannot be extended.

It is recommended to begin evaluating the ability to extend the current blend agreement in 2020 and make a final decision before 2023. If needed, this will allow SMWA adequate time to begin final permitting and detailed design of an alternate option in 2024 with the goal of finalizing construction before the current agreement expires in 2030.

2.1.2 Develop New Blend Concepts with Blending Occurring in a Water Tank

Blending in a relatively small tank (between 1 and 5 million gallons) has the benefit of not using storage in existing reservoirs or require the construction of a new reservoir. However, it would require SMWA to manage two types of water in real time to meet water quality goals. In a simple analysis, it was determined that during a peak WISE delivery condition of 30 mgd and assuming a 1:1 blend of 150 mg/L low TDS water and 750 mg/L WISE water, the resulting blend would produce 60 mgd of water at 450 mg/L of TDS. Peak WISE deliveries can occur during non-summer conditions and all SMWA members collectively do not have 60 mgd of water demands during that condition. For these reasons, blending without a reservoir was not evaluated further.

2.1.3 Develop New Blend Concepts with Blending Occurring in a Reservoir

Blending in a reservoir has several benefits. First, it allows SMWA to blend two different water types over an extended period of time, which reduces the required peak flowrate of low TDS water to match peak flowrates of WISE water deliveries. Second, WISE water deliveries can vary between zero and 30 mgd and between zero and 24,914 acre-feet per year (afy). A reservoir would allow SMWA to receive variable WISE water deliveries and subsequently deliver water to SMWA members at a time and amount that better aligns with SMWA needs and water quality goals.

After reviewing logical blend locations, two locations were selected for evaluation:

- **East Reservoir** is a potential future reservoir site located one drainage basin east of Aurora Reservoir. This site was selected for evaluation because there are existing and previously planned future pipelines designed to convey WISE water and low salinity water to this general area.

- **Rueter-Hess Reservoir (RHR)** is an existing reservoir owned by Parker Water and Sanitation District (Parker Water). This site was selected for evaluation because it is located central to WISE members and there are already future proposed pipelines that would deliver water to Rueter-Hess Reservoir that could perform multiple purposes including facilitating blending of WISE water.

More details on both sites are provided in subsequent sections.

2.2 Required Blend Water Volume and Operational Storage Volume

The WISE WDA requires a total of 100,000 af of water be delivered to SMWA over a 10-year period. The WDA also defines a series of minimum and maximum delivery requirements within that 10-year period. However, the exact timing and amounts of water delivered in any given day, month, or year is highly variable.

The allowable minimum and maximum delivery terms throughout a 10-year period were informed by a series of hydrologic and infrastructure modeling scenarios that evaluated how much water Aurora Water and Denver Water could deliver if past hydrology repeated itself while expected future infrastructure configurations were in place. The modeling showed there was a governing 10-year period where just over 100,000 acre-feet of water would be available for SMWA. The modeled hydrologic variability within those 10-years was used as guidance for developing the delivery terms in the Water Delivery Agreement.

The same modeling was used to inform this study by defining the assumed WISE water delivery amounts into a reservoir over a governing future 20-year period. **Figure 1** provides an example of the time series modeling performed to determine the required reservoir volume that may be needed to meet SMWA water quality goals.

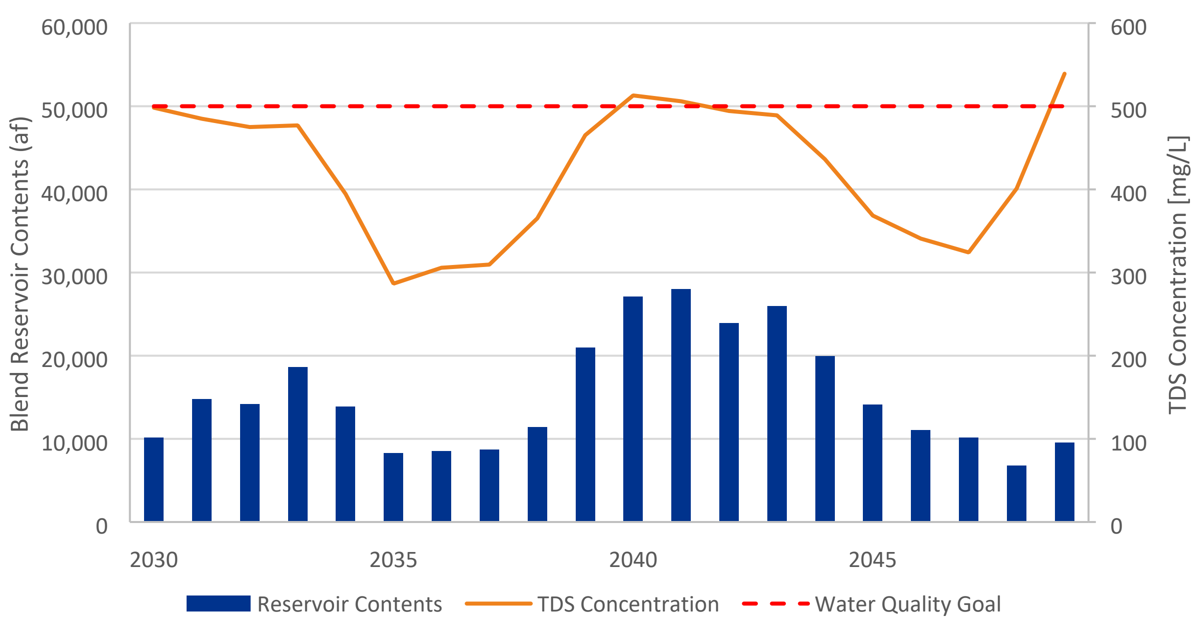


Figure 1. Example Time Series of Reservoir Operations Limiting TDS Concentrations to 500 mg/L

The sensitivity of the required reservoir size and amount of required low salinity blend water to varying assumptions was evaluated. **Table 1** shows the amount of blend water required and the amount of storage used for different final water quality goals and for different assumed long-term WISE water salinity concentrations.

Table 1. Blend Water and Storage Requirements.

Average TDS in WISE Water (mg/L of TDS)	Water Quality Goal in Reservoir (mg/L of TDS)	Blend Water (150 mg/L of TDS) to Meet Water Quality Goal (afy)	Required Reservoir Volume to Meet Water Quality Goal (af)
720	Below 500	13,500	32,000
653	Below 500	10,000	30,000
653	Below 400	20,000	34,000

Table 1 shows that the amount of low salinity water needed is highly sensitive to the desired maximum reservoir water quality goals for TDS concentrations. For example, twice the low salinity water (20,000 afy compared to 10,000 afy) is required to maintain concentrations below 400 mg/L as compared to 500 mg/L. **Figure 1** shows that targeting TDS concentrations below 500 mg/L, the TDS concentrations in the reservoir are still below 400 mg/L for almost half of the investigated time series.

Table 1 also shows that the required amount of blend water is somewhat sensitive to the assumed long-term average concentrations of TDS in WISE water. If long-term average TDS concentrations in WISE water were 10 percent higher (720 mg/L compared to 653 mg/L), an additional 3,500 afy of blend water is needed to maintain TDS concentrations below 500 mg/L. Lastly, it is worth noting that the reservoir volume required does not vary significantly under the above evaluated conditions because the primary factor driving the required size of the reservoir is the assumed variable WISE water delivery rates as described above.

2.3 Blend Options Considered

A workshop was held where a wide range of different low salinity blend waters were considered. Low salinity water from the West Slope or the Colorado-Big Thompson project were briefly considered. However, these supplies would have significant political, permitting and infrastructure requirements that were assumed to make these potential low salinity supplies less desirable than the other low salinity supply options. However, if none of the other alternatives are deemed desirable, these options could be reconsidered while considering the WDA has significant limits on SMWA pursuing Colorado River Basin water.

2.3.1 Blend with Denver Water Low Salinity Supplies

A blend concept was developed where Denver Water and SMWA could share new or existing storage, where some of the water stored in the reservoir would be WISE water. Due to differences in water quality put into the reservoir by SMWA and Denver Water, the concept would require Denver Water to regularly route water with low salinity through the shared reservoir to manage the overall water quality within the reservoir for both parties. This concept could provide cost effective storage for Denver Water and provide a water quality benefit for SMWA. However, this concept does not currently align with Denver Water's operational and water quality strategies, therefore Denver Water has indicated that this option is not available for further consideration for this study.

2.3.2 Blend with Aurora Water Low Salinity Supplies

A blend concept was developed where low salinity water owned by Aurora Water destined for their Wemlinger Water Purification Facility (WPF) would first be routed through East Reservoir, treated by the BWPF South Platte Treatment Train and returned to the Wemlinger WPF using the planned Wemlinger Blend Pipeline. This concept is described in detail in the following sections.

2.3.3 Blend with SMWA Low Salinity Supplies

A blend concept was developed where a mix of low salinity water owned by SMWA members would be routed away from their systems to Rueter-Hess Reservoir to blend with WISE water. Blended water would be treated at the Parker Water Rueter-Hess WPF and delivered to the WISE pipeline at a new entry point to the WISE system via reverse operation of the RidgeGate pipeline for subsequent delivery to all SMWA members. This concept is described in detail in the following sections.

2.3.4 Blend with Desalinated Parker Water Lower South Platte Supplies

A blend concept was developed where Parker Water would change the finished water quality goal of their future desalination plant on the Lower South Platte to reduce the salinity in this supply from a current TDS concentration target of 400 mg/L to 150 mg/L. The future Parker Water desalination facility would produce water of similar quality to Aurora Water and Denver Water low salinity supplies. Although this concept is feasible and this water could be used in-lieu of the other low salinity water supplies mentioned above, this concept requires extensive use of desalination. This concept was not fully evaluated in this study because this option relies on salinity removal instead of water blending with an existing low salinity water supply.

3. Blend in East Reservoir Concept

East Reservoir is a potential future reservoir site located one drainage basin to the east of Aurora Reservoir. This site is located on land owned by the Colorado State Land Board. The Rangeview Metropolitan District (Rangeview) has decreed rights to locate a reservoir in a portion of the proposed footprint of East Reservoir and therefore advancement of a reservoir at this site requires coordination with Rangeview.

Aurora Water previously evaluated locating a reservoir at this location of between 61,100 and 153,000 af. The previous studies completed by Aurora Water have shown that geotechnical conditions are suitable for a large reservoir and environmental conditions are such that impacts could be sufficiently mitigated.

WISE water is currently blended at the BWPF located northwest of the proposed location of East Reservoir. Compared to other options, the extent of new pipelines required to blend in East Reservoir is limited. Another potential benefit of this site is that East Reservoir could be constructed to provide adequate blend volume for SMWA and meet operational storage needs of Rangeview and potentially Aurora Water. Lastly, from a cost perspective, the natural geometry of the drainage basin is such that economies of scale are realized if a reservoir between 60,000 and 120,000 af is constructed for multiple parties as compared to a 30,000 af reservoir used only by SMWA.

3.1 Infrastructure and Operations Assumptions

This concept assumes raw WISE water with TDS concentrations between 500 and 775 mg/L is blended with a steady flow of approximately 9 mgd of low salinity water (near 150 mg/L of TDS) to produce a blended water with a TDS concentration below 500 mg/L. It is assumed that the low salinity water is continuously routed through East Reservoir while WISE water is delivered to the reservoir at variable rates and withdrawn from the reservoir at rates that manage the salinity in the reservoir and the ultimate required size of the reservoir.

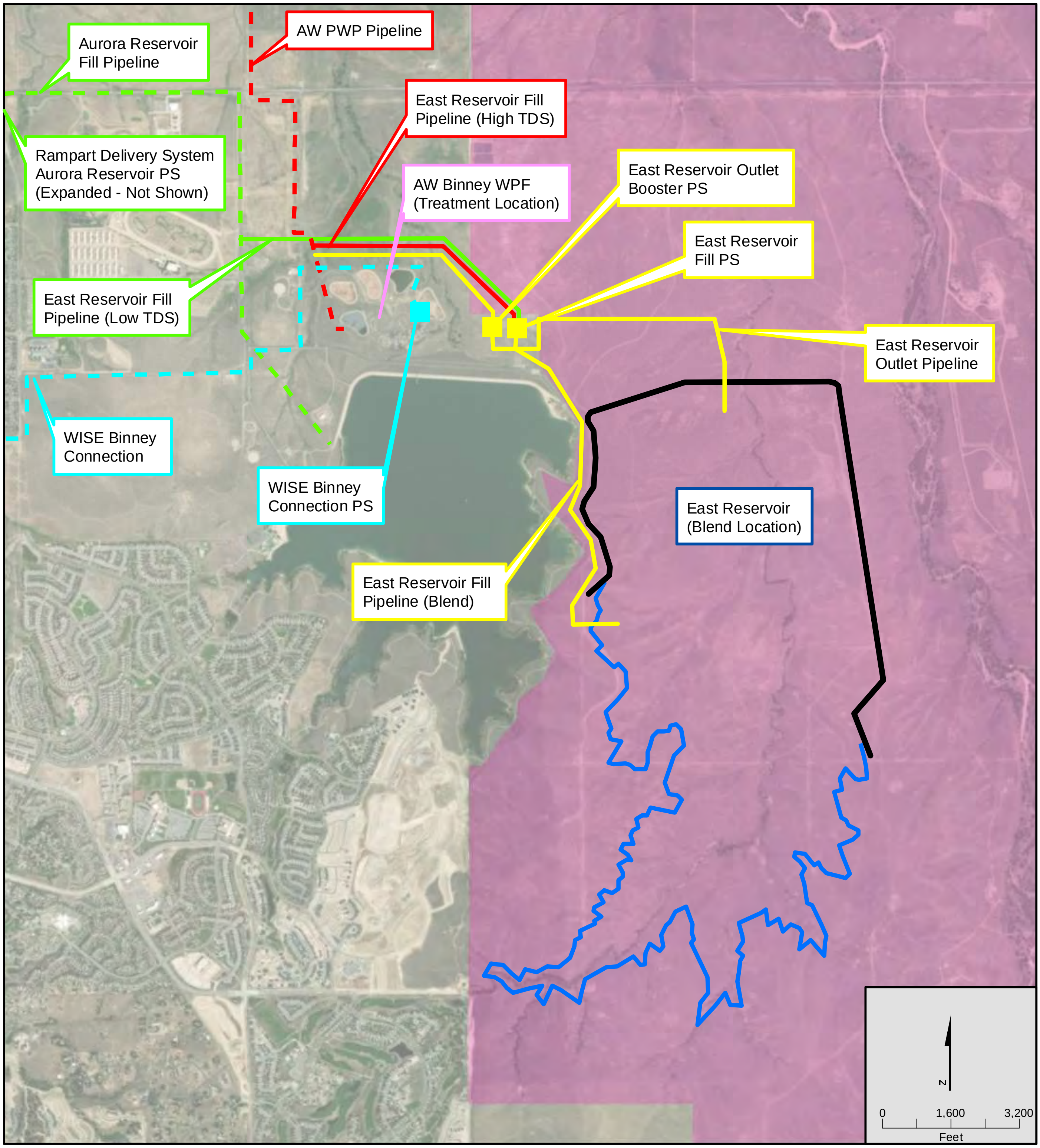
As described in detail below, this concept assumes low salinity water is provided by Aurora Water. However, the concept would also work with only minor adjustments if low salinity water was diverted to East Reservoir from the future pipeline that will convey Parker Water Lower South Platte water to Rueter-Hess Reservoir.

3.1.1 Infrastructure Assumptions

Figure 2 shows infrastructure needed for this concept. Each of the pipelines shown on **Figure 2** represents a different water quality as summarized below:

- **Dashed Green Pipeline** is an existing pipeline owned by Aurora Water called the Aurora Reservoir Fill Pipeline. Water with TDS concentrations near 150 mg/L is diverted from Strontia Springs Reservoir by Aurora Water into parallel pipelines (called the Rampart Pipelines) that flow by gravity to the Griswold WPF, Wemlinger WPF and the Aurora Reservoir Pump Station (ARPS) near Quincy Reservoir. Any water not directly diverted to Wemlinger WPF or Griswold WPF can be pumped by the ARPS through the Aurora Reservoir Fill Pipeline to Aurora Reservoir.

- **Solid Green Pipeline** would be a new pipeline constructed by SMWA that would connect to the Aurora Reservoir Fill Pipeline. A flow control valve on the Aurora Reservoir Fill Pipeline would control the flow sent from this pipeline to East Reservoir.



LEGEND

Pump Station
Existing Raw Water Pipeline (Low TDS)
New Raw Water Pipeline (Low TDS)
Existing Raw Water Pipeline (High TDS)
New Raw Water Pipeline (High TDS)
New Raw Water Pipeline (Blend)
Existing Treated Water Pipeline (Blend)
New Treated Water Pipeline (Blend)
Top of Embankment
Maximum Inundation Limits
State Land Board

FIGURE 2
Blend in East Reservoir Concept
TM 3 - Water Blending
WISE Salinity Management Plan

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- **Dashed Red Pipeline** is the existing Aurora Water PWP Pipeline. Water with TDS concentrations between 500 mg/L and 775 mg/L is diverted from the South Platte River via shallow alluvial wells near Brighton, CO and pumped to the BWPF for advanced treatment. WISE water is delivered to SMWA through this system.

- **Solid Red Pipeline** would be a new pipeline constructed by SMWA that would connect to the PWP Pipeline. The flow control valve on this pipeline would be controlled by Aurora Water and would be set to the delivery rate of WISE water to SMWA. As shown on **Figure 2**, water in this pipeline would be directed to East Reservoir.

- **Solid Yellow Pipelines** would be new pipelines constructed by SMWA where the low salinity water (solid green pipeline) and elevated salinity water (solid red pipeline) converge at a future East Reservoir Fill Pump Station. Water from both the red and green lines would be pumped in a single yellow pipeline conveying blended water into East Reservoir. A solid yellow pipeline is also shown leaving East Reservoir carrying blended water back to the PWP pipeline for subsequent treatment by the BWPF South Platte Treatment Train. Note that there is an East Reservoir Outlet Booster Pump Station located on the East Reservoir Outlet Pipeline, which would only be required when water levels in East Reservoir are low.

- **Dashed Teal Pipeline** is an SMWA owned pipeline that is partially existing and partially under design. Water delivered to Aurora Water from SMWA via the East Reservoir Outlet Pipeline will vary in TDS concentrations of between 300 mg/L and 500 mg/L. This water might be blended with other water being conveyed in the PWP Pipeline. However, Aurora Water should have operational flexibility to provide SMWA with a treated blend of water matching TDS concentrations of the raw water blend delivered to the PWP Pipeline from East Reservoir. Once treated in the BWPF South Platte Treatment Train, the WISE Binney Connection Pump Station would pump treated and blended water into the WISE Binney Connection Pipeline (dashed teal pipeline) for subsequent distribution to WISE members via the WISE Pipeline.

- **Wemlinger Blend Pipeline** is a planned Aurora Water pipeline that is not shown on **Figure 2** for clarity. However, a pump station located at the end of the BWPF South Platte Treatment Train before disinfection would convey treated but not disinfected water from the PWP Pipeline to the headworks of the Wemlinger WPF that would allow Aurora Water to blend this water with low salinity water delivered directly to the Wemlinger WPF from Strontia Springs Reservoir. It is important to note that the Wemlinger Blend Pump Station and Pipeline is a project that Aurora Water plans to build with or without the SMWA coordinated operations outlined in this section.

3.1.2 Operations Assumptions and Operations Cost Allocation Assumptions

This concept assumes that Aurora Water would route 9 mgd or 18 mgd (depending on SMWA's water quality goal) of low salinity water (near 150 mg/L of TDS), typically delivered from Strontia Springs Reservoir to the Wemlinger WPF, through East Reservoir for the benefit of SMWA. A like amount of blended water (between 300 and 500 mg/L of TDS) from East Reservoir would be simultaneously returned to Aurora Water at the Wemlinger WPF via the Wemlinger Blend Pipeline. The infrastructure described above is configured to facilitate this water blending concept.

The costs presented in the following section allocate energy costs to pump low salinity water through the Aurora Reservoir Pump Station, East Reservoir Fill Pump Station, East Reservoir Outlet Pump Station, and the Wemlinger Blend Pump Station to SMWA. This is the pumping required to send water destined for the Wemlinger WPF through East Reservoir and back to the Wemlinger WPF. In addition, the cost to treat this water at the BWPF South Platte Treatment Train before it is pumped back to the Wemlinger WPF is also allocated to SMWA because these and other mentioned costs would not have been realized by Aurora Water if the water were sent directly to the Wemlinger WPF.

3.1.3 Estimated Water Loss

The calculated long-term average loss of WISE water for blending in a reservoir is about 7% as compared to 4 – 8% for desalination, followed by deep-well injection and less than 1% for desalination followed by mechanical evaporation.

3.2 Estimated Costs

Table 2 presents a summary of the capital and annual operations and maintenance (O&M) costs allocated to SMWA for the facilities described in this section. As shown, the costs allocated to SMWA vary based on if Rangeview and Aurora Water decide to partner in the construction of East Reservoir or SMWA constructs East Reservoir alone. If SMWA partners with Rangeview and Aurora Water, the reservoir size would increase to provide operational storage for these partners in addition to operating as a blend reservoir for SMWA. Complete cost estimates can be found in **Appendix A – Cost Appendix**.

It is unknown if future phosphorus concentrations in South Platte water would be sufficiently high enough to cause harmful algal blooms in East Reservoir. If this were the case, mechanical removal of phosphorus from South Platte water would need to occur prior to entering East Reservoir. **Table 2** shows costs for blending in East Reservoir with a water quality goal of 500 mg/L of TDS both with and without a phosphorus removal treatment plant. It is assumed the treatment plant would be located on the same site as the East Reservoir Fill Pump Station.

Table 2. Estimated Costs for East Reservoir Blend Concept with a Water Quality Goal of 500 mg/L of TDS.

Major Component of East Reservoir Blend Concept	SMWA Costs without Partners		SMWA Costs with Partners	
	Capital Cost	**Annual O&M Cost**	**Capital Cost**	**Annual O&M Cost**
East Reservoir Embankment and Appurtenant Items	$120.1 M	$0.3 M	$88.7 M	$0.2 M
East Reservoir Fill Pump Station	$15.4 M	$0.5 M	$11.0 M	$0.4 M
Land Acquisition for East Reservoir	$13.9 M	$ -	$8.3 M	$ -
East Reservoir Outlet Booster Pump Station	$6.6 M	$0.2 M	$4.3 M	$0.2 M
Other Pipelines and Use of Existing AW Facilities*	$8.2 M	$3.1 M	$5.7 M	$3.1 M
Total	**$164.9 M**	**$4.1 M**	**$118.0 M**	**$3.9 M**
Phosphorus Removal Facility	$97.4 M	$4.3 M	$86.8 M	$3.7 M
Total with Phosphorus Removal	**$262.3 M**	**$8.4 M**	**$204.8 M**	**$7.6 M**

* Assumes SMWA uses the Aurora Reservoir Pump Station, the BWPF South Platte Treatment Train and Wemlinger Blend Pump Station and Pipeline to divert and return low salinity water to Aurora Water at the Wemlinger WPF.

Costs for the East Reservoir blending concept are presented in two different formats on **Figure 3**:

- **Capital and Annual O&M Costs** that are allocated to SMWA are shown on the outside of each bar on the graphic.
- **Unit Cost Impact to the WISE Water Rate** are shown within each bar. It is important to note that these unit ($/kgal) costs would be ***in addition*** to the future WISE water rate and includes capital cost bond repayment and annual O&M costs per kgal of WISE water delivered. Aurora Water may charge an additional "blend fee" above the costs shown to SMWA for using their low salinity water to blend with WISE water in East Reservoir. The blend fee charged by Aurora Water is unknown but is listed as a possible additional cost for each concept.

Figure 3 shows the above costs for different East Reservoir concepts that include:

- TDS goals of 400 or 500 mg/L
- With and without phosphorus pretreatment
- Partnering with Rangeview and Aurora Water or SMWA constructing East Reservoir alone

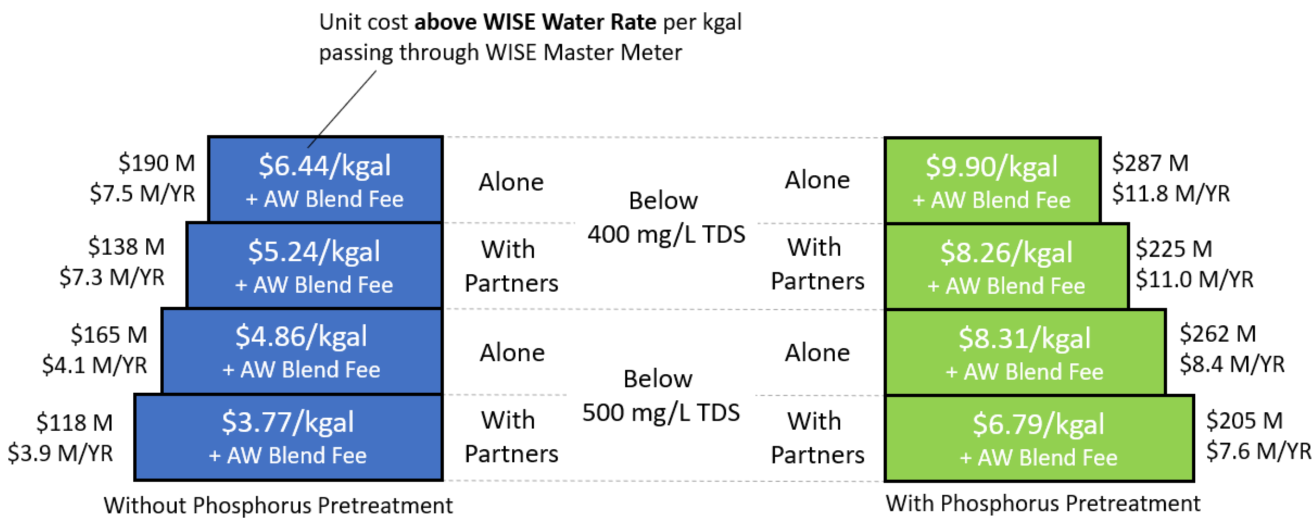


Figure 3. East Reservoir Blend Concept Costs and Impacts to the WISE Water Rate.

4. Blend in Rueter-Hess Reservoir Concept

Rueter-Hess Reservoir is an existing 75,000 af reservoir owned by Parker Water. The Town of Castle Rock (Castle Rock), Castle Pines North Metropolitan District, and Stonegate Village Metropolitan District also own 8,000 af, 1,500 af, and 1,200 af of storage in the reservoir, respectively. Parker Water may not need all of the remaining storage; however, the exact volume of storage potentially available for non-Parker Water needs cannot be precisely determined without further studies. As described in Section 2.2, up to 34,000 af of storage volume may be required to accomplish WISE water blending objectives. The analysis described below assumes adequate storage capacity in Rueter-Hess Reservoir would be available. However, if this concept is selected for more detailed investigations, the amount of storage potentially available for blending operations and the amount of storage required should be more closely evaluated.

Although Rueter-Hess Reservoir has already been constructed, the permit to construct limited the types of water that can be stored in the reservoir without further permit review. The process for getting approval to store new waters in Rueter-Hess Reservoir can take up to three years and it is unlikely, but possible, that some waters might not gain permit approval.

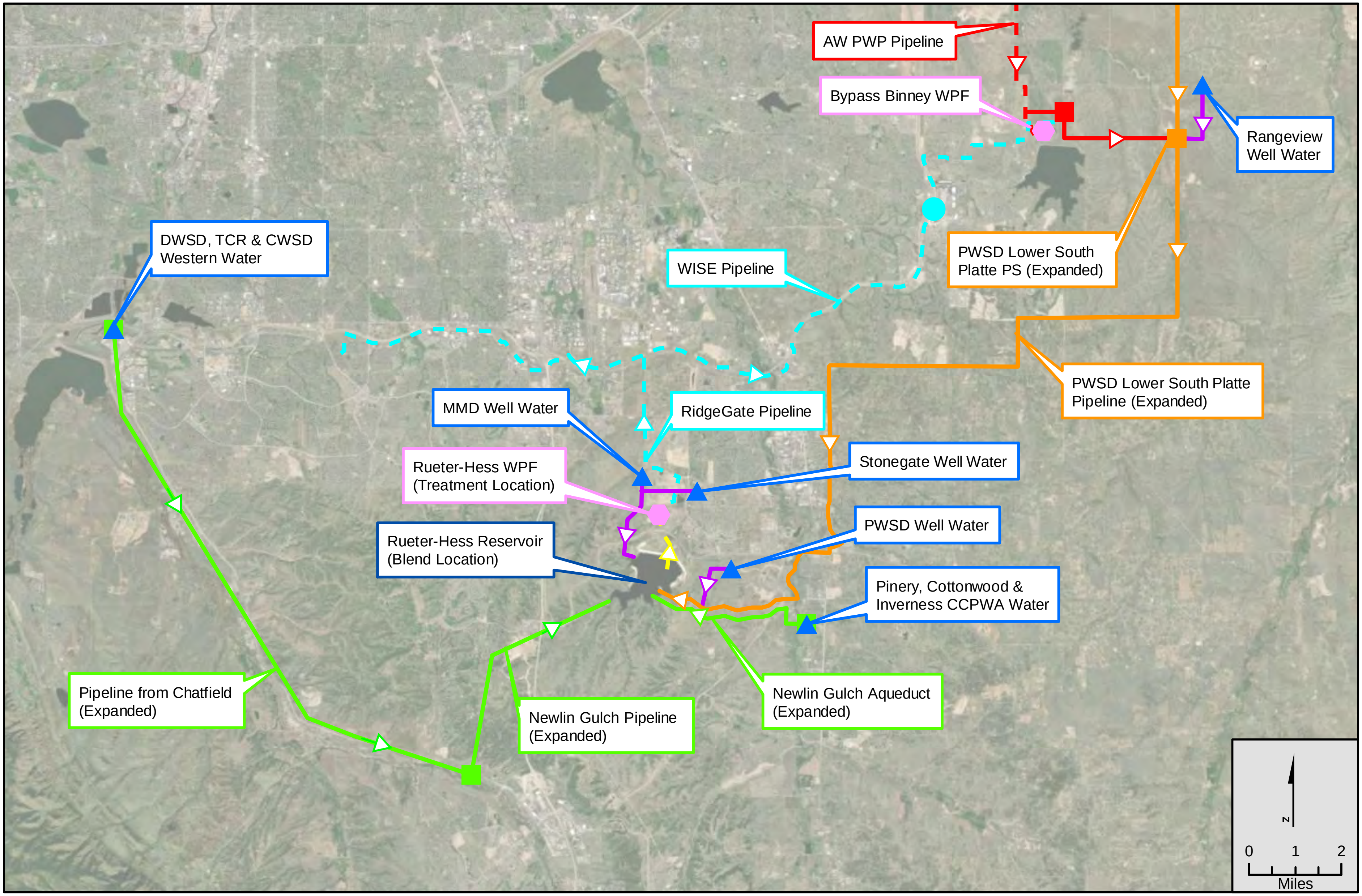
4.1.1 Infrastructure Assumptions

Figure 4 shows the infrastructure needed for this concept. Each of the pipelines shown on **Figure 4** represents a different water quality as summarized below:

- **Dashed Red Pipeline** is the existing Aurora Water PWP Pipeline also shown on **Figure 2**.

- **Solid Red Pipeline** would be a new pipeline constructed by SMWA that would connect to the PWP Pipeline. The flow control valve on this pipeline would be controlled by Aurora Water and would be set to the delivery rate of WISE water to SMWA. As shown on **Figure 4**, water in this pipeline would be directed to a pump station along the future Parker Water Lower South Platte Pipeline designed to convey a portion of their Lower South Platte water to Rueter-Hess Reservoir.

Solid Orange Pipeline is the future Parker Water Lower South Platte Pipeline designed to convey a portion of their Lower South Platte water to Rueter-Hess Reservoir. This pipeline would be oversized to convey Parker Water's Lower South Platte water, WISE water and the low salinity water contribution from Rangeview. The Future Parker Water pump station from this location to Rueter-Hess Reservoir would also be expanded to convey this additional flow.



LEGEND

- Blend Water Source
- Pump Station
- Storage Tank
- Water Purification Facility
- New Raw Water Pipeline (Low TDS)
- Existing Treated Water Pipeline (Low TDS)
- New Treated Water Pipeline (Low TDS)
- New Raw Water Pipeline (Partial Blend)
- Existing Raw Water Pipeline (High TDS)
- New Raw Water Pipeline (High TDS)
- Existing Raw Water Pipeline (Blend)
- Existing Treated Water Pipeline (Blend)

FIGURE 4
Blend in Rueter-Hess Reservoir Concept
TM 3 - Water Blending
WISE Salinity Management Plan

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- **Solid Purple Pipelines** would convey treated, low salinity water from the Rangeview, Stonegate Village Metropolitan District (Stonegate), Meridian Metropolitan District (Meridian) and Parker Water either directly or other proposed infrastructure that would convey water to Rueter-Hess Reservoir.
  - Contribution from Rangeview: Rangeview would convey low salinity finished water from a new or existing groundwater well to the future Parker Water Lower South Platte Pump Station for subsequent delivery to Rueter-Hess Reservoir to meet their blend water contribution. Conveying water through the Parker Water Lower South Platte Pipeline avoids the need to backflow the WISE Pipeline and RigeGate Pipeline for a portion of the year to convey water from Rangeview to Rueter-Hess Reservoir.
  - Contributions from Stonegate and Meridian: Stonegate and Meridian would convey low salinity water from their respective groundwater supplies via a new pipeline directly to Rueter-Hess Reservoir to meet their collective blend water contribution. Constructing a dedicated fill system avoids the need to backflow the RidgeGate Pipeline for a portion of the year or wheel water through the Parker Water distribution system and ensures the low salinity water is delivered to the reservoir.
  - Contribution from Parker Water: Parker water would redirect low salinity water from their groundwater wells to the Newlin Gulch Aqueduct for subsequent delivery to Rueter-Hess Reservoir to meet their blend contribution.
- **Solid Green Pipelines** would convey raw, low salinity water from Dominion Water and Sanitation District (Dominion), Castle Rock, Centennial Water and Sanitation District (Centennial), Pinery Water and Wastewater District (Pinery), Cottonwood Water and Sanitation District (Cottonwood) and Inverness Water and Sanitation District (Inverness) to Rueter-Hess Reservoir.
  - Contributions from Pinery, Cottonwood and Inverness: Pinery, Cottonwood and Inverness are partners in the Cherry Creek Project Water Authority (CCPWA). Low salinity water from this project would be diverted by expanding the existing Parker Water system that diverts and conveys water from Cherry Creek to Rueter-Hess Reservoir. It is assumed that the existing Parker Water pump station would be expanded, and a new parallel pipeline would be constructed convey CCPWA water to Rueter-Hess Reservoir to meet blend water contributions of CCPWA partners.
  - Contributions from Dominion, Castle Rock and Centennial: Castle Rock is currently studying a pipeline that would convey water from Chatfield Reservoir to Rueter-Hess Reservoir. This pipeline would be oversized to convey low salinity water supplies from Castle Rock, Dominion and Centennial to Rueter-Hess Reservoir to meet their collective blend water contribution.
- **Dashed Teal Pipelines** are the existing WISE Pipeline and RidgeGate Pipeline. Water blended in Rueter-Hess Reservoir would be treated at the Parker Water Rueter-Hess WPF and delivered to the WISE Pipeline or Parker Water distribution system. All WISE members would receive treated, blended water at the same connection point they receive WISE water prior to May 2030.

4.1.2 Operations Assumptions and Operations Cost Allocation Assumptions

This concept assumes that each SMWA member makes their own low salinity water available for conveyance to Rueter-Hess Reservoir in an approximately 1:1 or 2:1 ratio to their WISE subscription (depending on SMWA's water quality goal). The concept also assumes that the future Parker Water Lower South Platte Pipeline is oversized to convey WISE water and the low salinity water contribution from Rangeview to Rueter-Hess Reservoir. Low and elevated salinity water in Rueter-Hess Reservoir would be blended and subsequently treated by the Parker Water Rueter-Hess WPF and delivered to the WISE Pipeline via the RidgeGate Pipeline. Withdrawal rates of blended water would be optimized to minimize TDS concentrations in the reservoir, minimize reservoir storage and peak withdrawal flowrates to minimize the needed expansion of the Rueter-Hess WPF.

4.1.3 **Estimated Water Loss**

The calculated long-term average WISE water loss for this concept is about 7% as compared to 4 – 8% for desalination with deep-well injection and less than 1% for desalination followed by mechanical evaporation.

4.2 Estimated Costs

Table 3 presents a summary of the capital and annual O&M costs for the infrastructure and operations described in this section. At this early feasibility stage, cost allocation among SMWA members was not completed. Complete cost estimates can be found in **Appendix A – Cost Appendix**.

The largest cost for this option is the assumed cost to buy capacity in Rueter-Hess Reservoir from Parker Water. It is worth noting that Castle Rock already owns capacity in Rueter-Hess Reservoir and their existing storage may (or may not) meet their operational needs and storage needs for blending operations. Similarly, Parker Water is estimated to own more capacity in Rueter-Hess Reservoir than required for their operations. However, if Parker Water increases their needed capacity in Rueter-Hess Reservoir to accomplish blending objectives, it would reduce future opportunities to lease or sell storage capacity to others. For these reasons, this study assumes that the entire estimated volume required for blend operations would have a unit cost of $7,234/af.

Like the East Reservoir option, future phosphorus concentrations in raw WISE water may be sufficiently high enough that mechanical removal of phosphorus may be required before the water enters the reservoir. **Table 3** shows the costs for blending in Rueter-Hess Reservoir with a water quality goal of 500 mg/L of TDS both with and without a phosphorus removal treatment plant. It is assumed that the phosphorus removal treatment plant would be located on an open parcel of land directly east of the BWPF and treated prior to entering the Parker Water Lower South Platte Pipeline.

Table 3. Estimated Costs for Rueter-Hess Reservoir Concept with a Water Quality Goal of 500 mg/L of TDS.

Major Component of Rueter-Hess Reservoir Blend Concept	SMWA Costs	
	Capital Cost	**Annual O&M Cost**
Purchase Storage in Rueter-Hess Reservoir	$217.0 M	$ -
Expand Parker Water Rueter-Hess Water Purification Facility	$129.1 M	$10.1 M
Required Infrastructure to Convey SMWA Supplies to RHR	$49.8 M	$1.2 M
Expand Parker Water Lower South Platte Pipeline	$24.4 M	$0.1 M
Expand Parker Water Lower South Platte Pump Station	$15.2 M	$0.8 M
Miscellaneous Pipelines, Pump Stations and Other Items	$10.2 M	$0.1 M
Total	**$445.7 M**	**$12.2 M**
Phosphorus Removal Facility	$97.4 M	$4.3 M
Total with Phosphorus Removal	**$543.1 M**	**$16.5 M**

Costs for the Rueter-Hess Reservoir blending concept are presented in two different formats on **Figure 5**:

- **Capital and Annual O&M Costs** that are allocated to SMWA are shown on the outside of each bar on the graphic.
- **Unit Cost Impacts to the WISE Water Rate** are shown within each bar. It is important to note that these unit ($/kgal) costs would be ***in addition*** to the future WISE water rate and includes capital cost bond repayment and annual O&M costs per kgal of WISE water delivered. Under this blending concept, SMWA would bypass treatment at the BWPF, which would lower the future WISE water rate by $3.55/kgal (per SMWA Financial Consultant Jason Mumm). Therefore, unit cost impacts to the WISE water rate shown on **Figure 5** and **Figure 6** (in the following section) are the net impact of capital and annual O&M costs and the rate credit for bypassing treatment at the BWPF.

Figure 5 shows the costs for different Rueter-Hess Reservoir blend concepts that include:

- TDS goals of 400 or 500 mg/L
- With or without phosphorus pretreatment

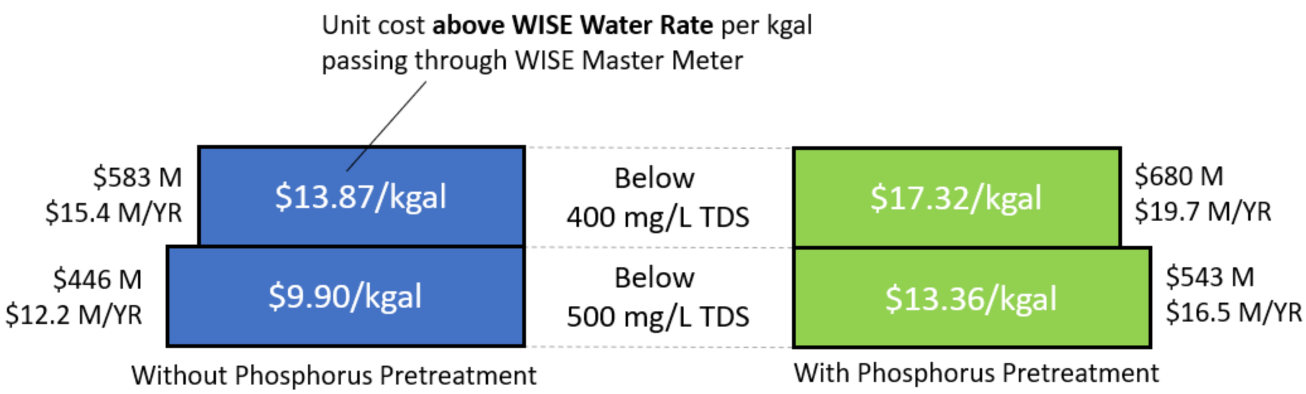
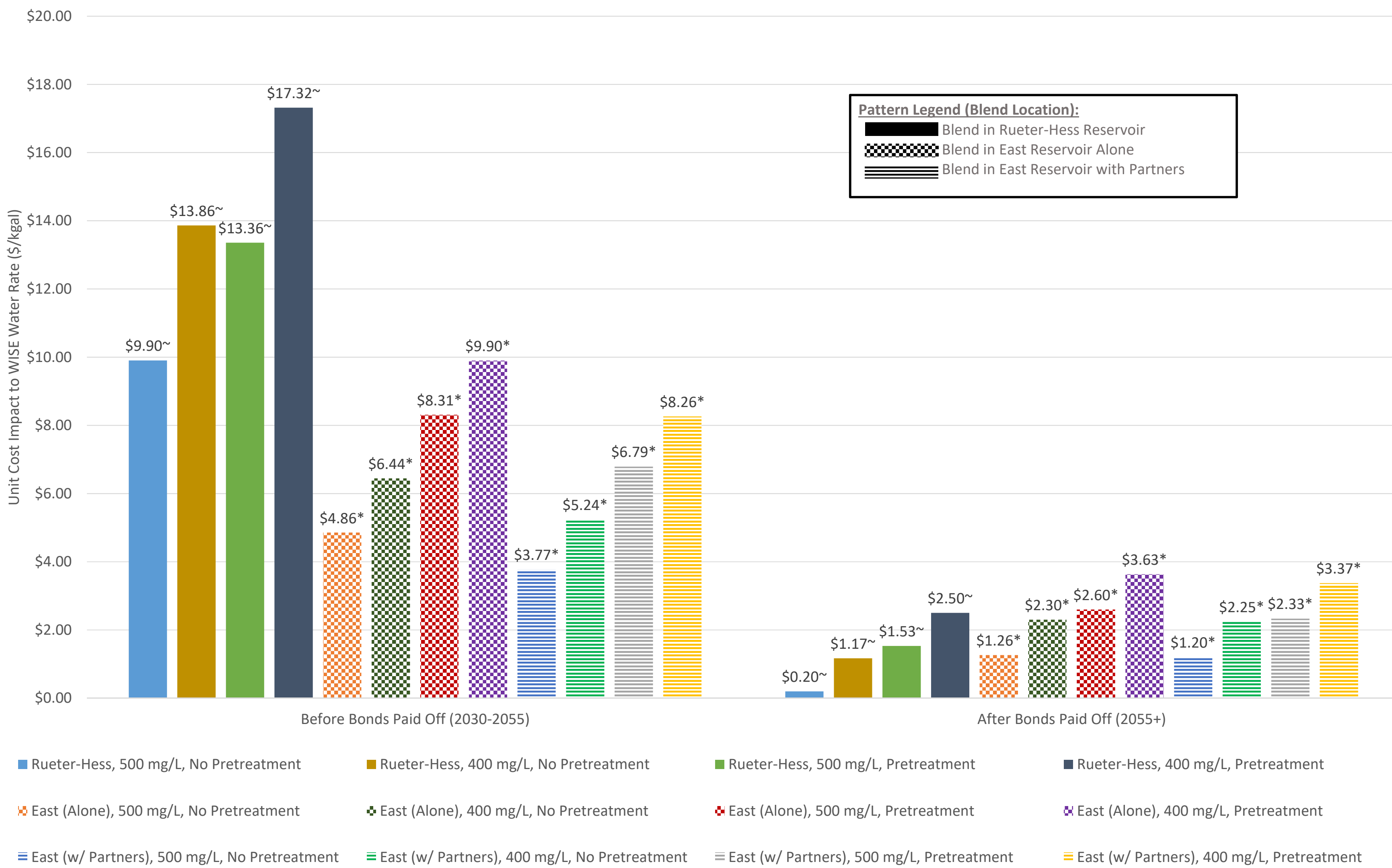


Figure 5. Reuter-Hess Reservoir Blend Concept Costs and Impacts to the WISE Water Rate.

5. Summary of Findings

Blending concepts in either East or Rueter-Hess Reservoir could be implemented to meet SMWA's water quality objectives. However, there are significant cost and implementation uncertainties based on the wide range of costs presented and reliance on other water providers to use their low salinity water supplies and/or infrastructure.

Figure 6 presents unit cost impacts on the WISE water rate before and after the bond repayment period for investigated blending concepts in East and Reuter-Hess Reservoir. **Figure 6** shows generally that blending in Rueter-Hess Reservoir is more expensive than blending in East Reservoir while capital costs are being repaid. However, after capital costs have been repaid, unit costs for Rueter-Hess Reservoir concepts are lower or comparable to East Reservoir concepts due to the rate credit for bypassing water treatment at the BWPF.



Note:
~ Costs include WISE water rate credit of $3.55/kgal for bypassing water treatment at the BWPF per SMWA Financial Consultant Jason Mumm
* Costs do not include unknown blend fee for routing Aurora Water mountain water through East Reservoir for the benefit of SMWA

Appendix A. Cost Appendix

	Capital Cost											Annual O&M		
Infrastructure Item	Unit	Unit Cost	Capital Cost	Item Capacity	SMWA Use by Capacity	AW Use by Capacity	Capacity Use by Others	SMWA Pro-Rata Use	Assumed SMWA Capital Responsibility		Annual O&M Cost	Assumed SMWA Annual O&M Responsbility	
Blend In East Reservoir (Alone) Concept													
Target 500 mg/L of TDS without Phosphorus Pretreatment													
1 Conveyance of Low Salinity Water from Aurora Reservoir Fill Pipeline to East Reservoir Fill PS													
a Use Existing Aurora Reservoir Pump Station	- -	- -	-	- -	- -	- -	- -	-	-	-	$275,357	100.0%	$275,357
b Pipeline from Tee near Robertsdale Tank to East Reservoir Fill PS (24")	7,500 lf	$252 /lf	$1,889,884	9 mgd	9 mgd	0 mgd	0 mgd	100.0%	100.0%	$1,889,884	$9,449	100.0%	$9,449
Subtotal			**$1,889,884**							**$1,889,884**	**$284,806**		**$284,806**
2 Conveyance of WISE Water to East Reservoir Fill PS													
a Pipeline from AW PWP Tee to East Reservoir Fill PS (42")	5,500 lf	$363 /lf	$1,994,790	30 mgd	30 mgd	0 mgd	0 mgd	100.0%	100.0%	$1,994,790	$9,974	100.0%	$9,974
Subtotal			**$1,994,790**							**$1,994,790**	**$9,974**		**$9,974**
3 East Reservoir Fill PS & Pipeline, East Reservoir and Outlet Pipeline to Booster PS													
a East Reservoir Fill PS	1,000 hp	$15,447 /hp	$15,447,178	39 mgd	39 mgd	0 mgd	0 mgd	100.0%	100.0%	$15,447,178	$515,965	100.0%	$515,965
b Pipeline from East Reservoir Fill PS to East Reservoir (48")	1,700 lf	$426 /lf	$724,113	39 mgd	39 mgd	0 mgd	0 mgd	100.0%	100.0%	$724,113	$3,621	100.0%	$3,621
c East Reservoir Embankment and Dam Appurtenant Items (30,000 af)	7,834,364 cy	$15.42 /cy	$120,777,839	30,000 af	30,000 af	0 af	0 af	100.0%	100.0%	$120,777,839	$301,945	100.0%	$301,945
d Land Costs	925 ac	$15,000 /ac	$13,875,000	30,000 af	30,000 af	0 af	0 af	100.0%	100.0%	$13,875,000	$0	0.0%	$0
e Pipeline from East Reservoir to East Reservoir Outlet Booster PS (36")	6,000 lf	$316 /lf	$1,897,791.43	18 mgd	18 mgd	0 mgd	0 mgd	100.0%	100.0%	$1,897,791	$9,489	100.0%	$9,489
Subtotal			**$152,721,921**							**$152,721,921**	**$831,019**		**$831,019**
4 Conveyance of Blended Water to BWPF and Aurora Water Mountain Water to Wemlinger WPF													
a East Reservoir Outlet Booster PS to AW PWP Pipeline	200 hp	$32,902 /hp	$6,580,482	18 mgd	18 mgd	0 mgd	0 mgd	100.0%	100.0%	$6,580,482	$227,915	100.0%	$227,915
b Pipeline from East Reservoir Oulet Booster PS to AW PWP Pipeline (36")	5,500 lf	$316 /lf	$1,739,642	18 mgd	18 mgd	0 mgd	0 mgd	100.0%	100.0%	$1,739,642	$8,698	100.0%	$8,698
c Treat Blended Water Through GAC Filters without Disinfection at BWPF	- -	- -	-	- -	- -	- -	- -	-	-	-	$2,480,680	100.0%	$2,480,680
d Use Planned Wemlinger Blend Pump Station and Pipeline	- -	- -	-	- -	- -	- -	- -	-	-	-	$275,357	100.0%	$275,357
Subtotal			**$8,320,124**							**$8,320,124**	**$2,992,650**		**$2,992,650**
Grand Total			**$164,926,719**							**$164,926,719**	**$4,118,450**		**$4,118,450**

25-Year Bond Payment ($/yr)	**$11,701,956**
Annual O&M Cost ($/yr)	**$4,118,450**
25-Year Total Annual Cost ($/yr)	**$15,820,406**
25-Year WISE Rate Increase ($/kgal)	**$4.86**
Annual O&M Cost ($/yr)	**$4,118,450**
Long-Term Term Annual Cost ($/yr)	**$4,118,450**
Long-Term WISE Rate Increase ($/kgal)	**$1.26**

Blend In East Reservoir (Alone) Concept

Target 400 mg/L of TDS without Phosphorus Pretreatment

	Capital Cost										Annual O&M		
Infrastructure Item	**Unit**	**Unit Cost**	**Capital Cost**	**Item Capacity**	**SMWA Use by Capacity**	**AW Use by Capacity**	**Capacity Use by Others**	**SMWA Pro-Rata Use**	**Assumed SMWA Capital Responsibility**		**Annual O&M Cost**	**Assumed SMWA Annual O&M Responsbility**	
1 Conveyance of Low Salinity Water from Aurora Reservoir Fill Pipeline to East Reservoir Fill PS													
a Use Existing Aurora Reservoir Pump Station	- -	- -	-	- -	- -	- -	- -	-	-	-	$585,456	100.0%	$585,456
b Pipeline from Tee near Robertsdale Tank to East Reservoir Fill PS (36")	7,500 lf	$316 /lf	$2,372,239	18 mgd	18 mgd	0 mgd	0 mgd	100.0%	100.0%	$2,372,239	$11,861	100.0%	$11,861
Subtotal			**$2,372,239**							**$2,372,239**	**$597,317**		**$597,317**
2 Conveyance of WISE Water to East Reservoir Fill PS													
a Pipeline from AW PWP Tee to East Reservoir Fill PS (42")	5,500 lf	$363 /lf	$1,994,790	30 mgd	30 mgd	0 mgd	0 mgd	100.0%	100.0%	$1,994,790	$9,974	100.0%	$9,974
Subtotal			**$1,994,790**							**$1,994,790**	**$9,974**		**$9,974**
3 East Reservoir Fill PS & Pipeline, East Reservoir and Outlet Pipeline to Booster PS													
a East Reservoir Fill PS	1,200 hp	$14,179 /hp	$17,014,953	48 mgd	48 mgd	0 mgd	0 mgd	100.0%	100.0%	$17,014,953	$681,611	100.0%	$681,611
b Pipeline from East Reservoir Fill PS to East Reservoir (54")	1,700 lf	$472 /lf	$802,977	48 mgd	48 mgd	0 mgd	0 mgd	100.0%	100.0%	$802,977	$4,015	100.0%	$4,015
c East Reservoir Embankment and Dam Appurtenant Items (34,000 af)	9,235,249 cy	$15.25 /cy	$140,822,183	34,000 af	34,000 af	0 af	0 af	100.0%	100.0%	$140,822,183	$352,055	100.0%	$352,055
d Land Costs	1,000 ac	$15,000 /ac	$15,000,000	34,000 af	34,000 af	0 af	0 af	100.0%	100.0%	$15,000,000	$0	0.0%	$0
e Pipeline from East Reservoir to East Reservoir Outlet Booster PS (42")	6,000 lf	$363 /lf	$2,176,134	27 mgd	27 mgd	0 mgd	0 mgd	100.0%	100.0%	$2,176,134	$10,881	100.0%	$10,881
Subtotal			**$175,816,247**							**$175,816,247**	**$1,048,562**		**$1,048,562**
4 Conveyance of Blended Water to BWPF and Aurora Water Mountain Water to Wemlinger WPF													
a East Reservoir Outlet Booster PS to AW PWP Pipeline	300 hp	$27,196 /hp	$8,158,695	27 mgd	27 mgd	0 mgd	0 mgd	100.0%	100.0%	$8,158,695	$277,430	100.0%	$277,430
b Pipeline from East Reservoir Oulet Booster PS to AW PWP Pipeline (42")	5,500 lf	$363 /lf	$1,994,790	27 mgd	27 mgd	0 mgd	0 mgd	100.0%	100.0%	$1,994,790	$9,974	100.0%	$9,974
c Treat Blend Water Through GAC Filters without Disinfection at BWPF	- -	- -	-	- -	- -	- -	- -	-	-	-	$4,961,360	100.0%	$4,961,360
d Use Planned Wemlinger Blend Pump Station and Pipeline	- -	- -	-	- -	- -	- -	- -	-	-	-	$585,456	100.0%	$585,456
Subtotal			**$10,153,484**							**$10,153,484**	**$5,834,220**		**$5,834,220**
Grand Total			**$190,336,761**							**$190,336,761**	**$7,490,073**		**$7,490,073**

25-Year Bond Payment ($/yr)	**$13,504,861**
Annual O&M Cost ($/yr)	**$7,490,073**
25-Year Total Annual Cost ($/yr)	**$20,994,934**
25-Year WISE Rate Increase ($/kgal)	**$6.44**

Annual O&M Cost ($/yr)	**$7,490,073**
Long-Term Term Annual Cost ($/yr)	**$7,490,073**
Long-Term WISE Rate Increase ($/kgal)	**$2.30**

Blend In East Reservoir (Alone) Concept

Additional Cost of Phosphorus Removal Ahead of Reservoir

	Capital Cost										Annual O&M		
Infrastructure Item	**Unit**	**Unit Cost**	**Capital Cost**	**Item Capacity**	**SMWA Use by Capacity**	**AW Use by Capacity**	**Capacity Use by Others**	**SMWA Pro-Rata Use**	**Assumed SMWA Capital Responsibility**		**Annual O&M Cost**	**Assumed SMWA Annual O&M Responsbility**	
1 Pretreatment of WISE Water to Remove Phosphorus													
a East Reservoir Pretreatment (Phosphorus Precipitation)	30 mgd	$3,245,395 /mgd	$97,361,844	30 mgd	30 mgd	0 mgd	0 mgd	100.0%	100.0%	$97,361,844	$4,345,533	100.0%	$4,345,533
Subtotal			**$97,361,844**							**$97,361,844**	**$4,345,533**		**$4,345,533**
Grand Total			**$97,361,844**							**$97,361,844**	**$4,345,533**		**$4,345,533**

25-Year Bond Payment ($/yr)	**$6,908,062**
Annual O&M Cost ($/yr)	**$4,345,533**
25-Year Total Annual Cost ($/yr)	**$11,253,595**
25-Year WISE Rate Increase ($/kgal)	**$3.45**

Annual O&M Cost ($/yr)	**$4,345,533**
Long-Term Term Annual Cost ($/yr)	**$4,345,533**
Long-Term WISE Rate Increase ($/kgal)	**$1.33**

Blend In East Reservoir (With Partners) Concept

Target 500 mg/L of TDS without Phosphorus Pretreatment

	Capital Cost										Annual O&M		
Infrastructure Item	**Unit**	**Unit Cost**	**Capital Cost**	**Item Capacity**	**SMWA Use by Capacity**	**AW Use by Capacity**	**RNG Use by Capacity**	**SMWA Pro-Rata Use**	**Assumed SMWA Capital Responsibility**		**Annual O&M Cost**	**Assumed SMWA Annual O&M Responsbility**	
1 Conveyance of Low Salinity Water from Aurora Reservoir Fill Pipeline to East Reservoir Fill PS													
a Use Existing Aurora Reservoir Pump Station	- -	- -	-	- -	- -	- -	- -	-	-	-	$275,357	100.0%	$275,357
b Pipeline from Tee near Robertsdale Tank to East Reservoir Fill PS (36")	7,500 lf	$316 /lf	$2,372,239	18 mgd	9 mgd	4 mgd	5 mgd	50.0%	50.0%	$1,186,120	$11,861	50.0%	$5,931
Subtotal			**$2,372,239**							**$1,186,120**	**$287,218**		**$281,287**
2 Conveyance of WISE Water to East Reservoir Fill PS													
a Pipeline from AW PWP Tee to East Reservoir Fill PS (54")	5,500 lf	$472 /lf	$2,597,866	46 mgd	30 mgd	16 mgd	0 mgd	65.2%	65.2%	$1,694,260	$12,989	65.2%	$8,471
Subtotal			**$2,597,866**							**$1,694,260**	**$12,989**		**$8,471**
3 East Reservoir Fill PS & Pipeline, East Reservoir and Outlet Pipeline to Booster PS													
a East Reservoir Fill PS	2,000 hp	$11,154 /hp	$22,307,669	79 mgd	39 mgd	35 mgd	5 mgd	49.4%	49.4%	$11,012,647	$997,883	43.4%	$433,177
b Pipeline from East Reservoir Fill PS to East Reservoir (72")	1,700 lf	$725 /lf	$1,233,143	79 mgd	39 mgd	35 mgd	5 mgd	49.4%	49.4%	$608,767	$6,166	49.4%	$3,044
c East Reservoir Embankment and Dam Appurtenant Items (69,000 af)	14,776,077 cy	$14.58 /cy	$215,487,254	69,000 af	28,394 af	27,855 af	12,751 af	41.2%	41.2%	$88,674,540	$538,718	41.2%	$221,686
d Land Acquisition	1,350 ac	$15,000 /ac	$20,250,000	69,000 af	28,394 af	27,855 af	12,751 af	41.2%	41.2%	$8,333,019	$0	0.0%	$0
e Pipeline from East Reservoir to East Reservoir Outlet Booster PS (54")	6,000 lf	$472 /lf	$2,834,035	45 mgd	18 mgd	24 mgd	3 mgd	40.0%	40.0%	$1,133,614	$14,170	40.0%	$5,668
Subtotal			**$262,112,100**							**$109,762,587**	**$1,556,937**		**$663,575**
4 Conveyance of Blended Water to BWPF and Aurora Water Mountain Water to Wemlinger WPF													
a East Reservoir Outlet Booster PS to AW PWP Pipeline	500 hp	$21,393 /hp	$10,696,559	45 mgd	18 mgd	24 mgd	3 mgd	40.0%	40.0%	$4,278,624	$483,468	42.6%	$206,166
b Pipeline from East Reservoir Oulet Booster PS to AW PWP Pipeline (54")	5,500 lf	$472 /lf	$2,597,866	45 mgd	18 mgd	24 mgd	3 mgd	40.0%	40.0%	$1,039,146	$12,989	40.0%	$5,196
c Treat Blend Water Through GAC Filters without Disinfection at BWPF	- -	- -	-	- -	- -	- -	- -	-	-	-	$3,348,918	74.1%	$2,480,680
d Use Planned Wemlinger Blend Pump Station and Pipeline	- -	- -	-	- -	- -	- -	- -	-	-	-	$275,357	100.0%	$275,357
Subtotal			**$13,294,425**							**$5,317,770**	**$4,120,733**		**$2,967,399**
Grand Total			**$280,376,630**							**$117,960,736**	**$5,977,877**		**$3,920,732**

25-Year Bond Payment ($/yr)	**$8,369,604**
Annual O&M Cost ($/yr)	**$3,920,732**
25-Year Total Annual Cost ($/yr)	**$12,290,336**
25-Year WISE Rate Increase ($/kgal)	**$3.77**
Annual O&M Cost ($/yr)	**$3,920,732**
Long-Term Term Annual Cost ($/yr)	**$3,920,732**
Long-Term WISE Rate Increase ($/kgal)	**$1.20**

Blend In East Reservoir (With Partners) Concept

Target 400 mg/L of TDS without Phosphorus Pretreatment

Infrastructure Item	Unit	Unit Cost	Capital Cost	Item Capacity	SMWA Use by Capacity	AW Use by Capacity	RNG Use by Capacity	SMWA Pro-Rata Use	Assumed SMWA Capital Responsibility		Annual O&M Cost	Assumed SMWA Annual O&M Responsbility	
	Capital Cost										Annual O&M		
1 Conveyance of Low Salinity Water from Aurora Reservoir Fill Pipeline to East Reservoir Fill PS													
a Use Existing Aurora Reservoir Pump Station	- -	- -	-	- -	- -	- -	- -	-	-	-	$585,456	100.0%	$585,456
b Pipeline from Tee near Robertsdale Tank to East Reservoir Fill PS (42")	7,500 lf	$363 /lf	$2,720,168	28 mgd	18 mgd	5 mgd	5 mgd	64.3%	64.3%	$1,748,679	$13,601	64.3%	$8,743
Subtotal			**$3,953,310**							**$1,748,679**	**$605,222**		**$594,199**
2 Conveyance of WISE Water to East Reservoir Fill PS													
a Pipeline from AW PWP Tee to East Reservoir Fill PS (54")	5,500 lf	$472 /lf	$2,597,866	46 mgd	30 mgd	16 mgd	0 mgd	65.2%	65.2%	$1,694,260	$12,989	65.2%	$8,471
Subtotal			**$2,597,866**							**$1,694,260**	**$12,989**		**$8,471**
3 East Reservoir Fill PS & Pipeline, East Reservoir and Outlet Pipeline to Booster PS													
a East Reservoir Fill PS	2,200 hp	$10,665 /hp	$23,463,913.26	89 mgd	48 mgd	36 mgd	5 mgd	53.9%	53.9%	$12,654,695	$1,173,147	50.6%	$593,684
b Pipeline from East Reservoir Fill PS to East Reservoir (72")	1,700 lf	$725 /lf	$1,233,143	89 mgd	48 mgd	36 mgd	5 mgd	53.9%	53.9%	$665,066	$6,166	53.9%	$3,325
c East Reservoir Embankment and Dam Appurtenant Items (74,000 af)	15,976,188 cy	$14.44 /cy	$230,688,615	74,000 af	32,743 af	28,292 af	12,964 af	44.2%	44.2%	$102,074,850	$576,722	44.2%	$255,187
d Land Acquisition	1,413 ac	$15,000 /ac	$21,187,500	74,000 af	32,743 af	28,292 af	12,964 af	44.2%	44.2%	$9,375,022	$0	0.0%	$0
e Pipeline from East Reservoir to East Reservoir Outlet Booster PS (60")	6,000 lf	$552 /lf	$3,314,809	55 mgd	27 mgd	25 mgd	3 mgd	49.1%	49.1%	$1,627,270	$16,574	49.1%	$8,136
Subtotal			**$279,887,980**							**$126,396,902**	**$1,772,609**		**$860,333**
4 Conveyance of Blended Water to BWPF and Aurora Water Mountain Water to Wemlinger WPF													
a East Reservoir Outlet Booster PS to AW PWP Pipeline	700 hp	$18,265 /hp	$12,785,587	55 mgd	27 mgd	25 mgd	3 mgd	49.1%	49.1%	$6,276,561	$586,586	51.5%	$301,939
b Pipeline from East Reservoir Oulet Booster PS to AW PWP Pipeline (60")	5,500 lf	$552 /lf	$3,038,575	55 mgd	27 mgd	25 mgd	3 mgd	49.1%	49.1%	$1,491,664	$15,193	49.1%	$7,458
c Treat Blend Water Through GAC Filters without Disinfection at BWPF	- -	- -	-	- -	- -	- -	- -	-	-	-	$6,201,700	80.0%	$4,961,360
d Use Planned Wemlinger Blend Pump Station and Pipeline	- -	- -	-	- -	- -	- -	- -	-	-	-	$585,456	100.0%	$585,456
Subtotal			**$15,824,162**							**$7,768,225**	**$7,388,935**		**$5,856,213**
Grand Total			**$302,263,318**							**$137,608,067**	**$9,779,756**		**$7,319,217**

25-Year Bond Payment ($/yr)	**$9,763,630**
Annual O&M Cost ($/yr)	**$7,319,217**
25-Year Total Annual Cost ($/yr)	**$17,082,847**
25-Year WISE Rate Increase ($/kgal)	**$5.24**
Annual O&M Cost ($/yr)	**$7,319,217**
Long-Term Term Annual Cost ($/yr)	**$7,319,217**
Long-Term WISE Rate Increase ($/kgal)	**$2.25**

Blend In East Reservoir (With Partners) Concept

Additional Cost of Phosphorus Removal Ahead of Reservoir

	Capital Cost										Annual O&M		
Infrastructure Item	**Unit**	**Unit Cost**	**Capital Cost**	**Item Capacity**	**SMWA Use by Capacity**	**AW Use by Capacity**	**RNG Use by Capacity**	**SMWA Pro-Rata Use**	**Assumed SMWA Capital Responsibility**		**Annual O&M Cost**	**Assumed SMWA Annual O&M Responsbility**	
1 Pretreatment of South Platte Water to Remove Phosphorus													
a East Reservoir Pretreatment (Phosphorus Precipitation)	46 mgd	$2,892,598 /mgd	$133,059,523	46 mgd	30 mgd	16 mgd	0 mgd	65.2%	65.2%	$86,777,950	$7,474,085	49.2%	$3,675,675
Subtotal			**$133,059,523**							**$86,777,950**	**$7,474,085**		**$3,675,675**
Grand Total			**$133,059,523**							**$86,777,950**	**$7,474,085**		**$3,675,675**

25-Year Bond Payment ($/yr)	**$6,157,109**
Annual O&M Cost ($/yr)	**$3,675,675**
25-Year Total Annual Cost ($/yr)	**$9,832,784**
25-Year WISE Rate Increase ($/kgal)	**$3.02**

Annual O&M Cost ($/yr)	**$3,675,675**
Long-Term Term Annual Cost ($/yr)	**$3,675,675**
Long-Term WISE Rate Increase ($/kgal)	**$1.13**

Blend In Rueter-Hess Reservoir Concept

Target 500 mg/L of TDS without Phosphorus Pretreatment

Infrastructure Item	Unit	Unit Cost	Capital Cost	Capital Cost: Item Capacity	SMWA Use by Capacity	Capacity Use by Others	SMWA Pro-Rata Use	Assumed SMWA Capital Responsibility		Annual O&M: Annual O&M Cost	Assumed SMWA Annual O&M Responsbility	
1 Conveyance of Low Salinity Water from SMWA Members to Rueter-Hess Reservoir												
a Blend Water Contribution from Meridian and Stonegate (800 and 1000 afy, respectively)												
i Pipeline from Stonegate to MMD Zone 2 Tank/Pump Station (8")	7,000 lf	$145 /lf	$1,018,481	0.9 mgd	0.9 mgd	0.0 mgd	100.0%	100.0%	$1,018,481	$5,092	100.0%	$5,092
ii Chemicals for Existing Groundwater Disinfection Systems	1.6 mgd	$0 /mgd	$0	1.6 mgd	1.6 mgd	0.0 mgd	100.0%	100.0%	$0	$88,384	100.0%	$88,384
iii Use Existing MMD Zone 2 Pump Station to Pump to Rueter-Hess Reservoir	1.6 mgd	$0 /mgd	$0	1.6 mgd	1.6 mgd	0.0 mgd	100.0%	100.0%	$0	$57,693	100.0%	$57,693
iv Pipeline from MMD Zone 2 Tank/Pump Station to Rueter-Hess Reservoir (12")	12,000 lf	$158 /lf	$1,897,791	1.6 mgd	1.6 mgd	0.0 mgd	100.0%	100.0%	$1,897,791	$9,489	100.0%	$9,489
b Blend Water Contribution from Cottonwood, Inverness and Pinery (400, 500 and 500 afy, respectively)												
i Development of Additional CCPWA Water above SMWA Member Shares	225 af	$31,091 /af	$6,995,372	225 af	225 af	0.0 af	100.0%	100.0%	$6,995,372	$34,977	100.0%	$34,977
ii Expanded Pump Station from Cherry Creek to Rueter-Hess Reservoir	1,317 hp	$13,572 /hp	$17,876,807	18.2 mgd	5.2 mgd	13.0 af	28.5%	28.5%	$5,100,406	$362,270	28.5%	$103,357
iii Expanded Pipeline from Cherry Creek to Rueter-Hess Reservoir (36")	20,500 lf	$316 /lf	$6,484,121	18.2 mgd	5.2 mgd	13.0 af	28.5%	28.5%	$1,849,975	$32,421	28.5%	$9,250
c Blend Water Contribution from Parker Water (1937.5 afy)												
i Flow Control Vault to Redirect Well Water to Rueter-Hess Reservoir	1.7 mgd	$79,277 /mgd	$137,142	1.7 mgd	1.7 mgd	0.0 mgd	100.0%	100.0%	$137,142	$686	100.0%	$686
ii Pipeline from Well Water from Zone 2 to Rueter-Hess Reservoir (12")	7,000 lf	$158 /lf	$1,107,045	1.7 mgd	1.7 mgd	0.0 mgd	100.0%	100.0%	$1,107,045	$5,535	100.0%	$5,535
d Blend Water Contribution from Castle Rock, Dominion and Centennial (1737.5, 1325 and 1000 afy, respectively)												
i Expanded Pump Station from Chatfield Reservoir to Plum Creek WRF	2,700 hp	$9,687 /hp	$26,155,119	17.4 mgd	7.3 mgd	10.2 mgd	41.7%	41.7%	$10,900,425	$1,669,004	31.1%	$518,937
ii Expanded Pipeline from Chatfield Reservoir to Plum Creek WRF (36")	70,224 lf	$316 /lf	$22,211,751	17.4 mgd	7.3 mgd	10.2 mgd	41.7%	41.7%	$9,256,984	$111,059	41.7%	$46,285
iii Expanded Pump Station from Plum Creek WRF to Rueter-Hess Reservoir	1,000 hp	$15,447 /hp	$15,447,178	17.4 mgd	7.3 mgd	10.2 mgd	41.7%	41.7%	$6,437,776	$694,272	32.5%	$225,346
iv Expanded Pipeline from Plum Creek WRF to Rueter-Hess Reservoir (36")	28,565 lf	$316 /lf	$9,035,005	17.4 mgd	7.3 mgd	10.2 mgd	41.7%	41.7%	$3,765,435	$45,175	41.7%	$18,827
e Blend Water Contribution from Rangeview (800 afy)												
i Chemicals for Existing Groundwater Disinfection Systems	0.7 mgd	$0 /mgd	$0	0.7 mgd	0.7 mgd	0.0 mgd	100.0%	100.0%	$0	$39,282	100.0%	$39,282
ii Pipeline from Rangeview to PWSD Lower South Platte Pump Station (8")	9,100 lf	$145 /lf	$1,324,026	0.7 mgd	0.7 mgd	0.0 mgd	100.0%	100.0%	$1,324,026	$6,620	100.0%	$6,620
Subtotal			**$109,689,838**						**$49,790,860**	**$3,161,958**		**$1,169,760**
2 Conveyance of WISE Water to Rueter-Hess Reservoir												
a Use Existing WISE Binney Connect PS to PWSD Lower South Platte Pump Station	- -	- -	-	- -	- -	- -	-	-	-	-	-	-
b Pipline from WISE Binney Connect PS to PWSD Lower South Platte Pipeline (42")	15,400 lf	$363 /lf	$5,585,411	30.0 mgd	30.0 mgd	0.0 mgd	100.0%	100.0%	$5,585,411	$27,927	100.0%	$27,927
c Expanded PWSD Lower South Platte Pump Station	3,600 hp	$8,462 /hp	$30,464,831	40.0 mgd	20.0 mgd	20.0 mgd	50.0%	50.0%	$15,232,415	$2,033,618	37.1%	$754,035
d Expanded PWSD Lower South Platte Pipeline (48")	114,480 lf	$426 /lf	$48,762,612	40.0 mgd	20.0 mgd	20.0 mgd	50.0%	50.0%	$24,381,306	$243,813	50.0%	$121,907
Subtotal			**$84,812,854**						**$45,199,133**	**$2,305,358**		**$903,868**
3 Storage of Water in Rueter-Hess Reservoir and Treatment at RHWPF												
a Storage in Reuter-Hess Reservoir	30,000 af	$7,234 /af	$217,026,395	30,000 af	30,000 af	0 af	100.0%	100.0%	$217,026,395	$0	0.0%	$0
b Water Treatment at PWSD Rueter-Hess Water Purification Facility	18 mgd	$7,174,787 /mgd	$129,146,167	18.0 mgd	18.0 mgd	0.0 mgd	100.0%	100.0%	$129,146,167	$10,127,572	100.0%	$10,127,572
Subtotal			**$346,172,561**						**$346,172,561**	**$10,127,572**		**$10,127,572**
4 Conveyance of Water Back to WISE Pipeline and SMWA Members												
a Conveyance in the RidgeGate Pipeline to WISE Pipeline (42")	22,400 lf	$363 /lf	$8,124,234	32.0 mgd	18.0 mgd	14.0 mgd	56.3%	56.3%	$4,569,882	$40,621	56.3%	$22,849
Subtotal			**$8,124,234**						**$4,569,882**	**$40,621**		**$22,849**
Grand Total			**$548,799,488.08**						**$445,732,435**	**$15,635,510**		**$12,224,050**

25-Year Bond Payment ($/yr)	**$31,625,812**
Annual O&M Cost ($/yr)	**$12,224,050**
25-Year Total Annual Cost ($/yr)	**$43,849,862**
25-Year WISE Rate Increase ($/kgal)	**$13.46**

Annual O&M Cost ($/yr)	**$12,224,050**
Long-Term Term Annual Cost ($/yr)	**$12,224,050**
Long-Term WISE Rate Increase ($/kgal)	**$3.75**

Blend In Rueter-Hess Reservoir Concept

Target 400 mg/L of TDS without Phosphorus Pretreatment

Infrastructure Item	Capital Cost									Annual O&M		
	Unit	Unit Cost	Capital Cost	Item Capacity	SMWA Use by Capacity	Capacity Use by Others	SMWA Pro-Rata Use	Assumed SMWA Capital Responsibility		Annual O&M Cost	Assumed SMWA Annual O&M Responsbility	
1 Conveyance of Low Salinity Water from SMWA Members to Rueter-Hess Reservoir												
a Blend Water Contribution from Meridian and Stonegate (1600 and 2000 afy, respectively)												
i Pipeline from Stonegate to MMD Zone 2 Tank/Pump Station (12")	7,000 lf	$158 /lf	$1,107,045	1.8 mgd	1.8 mgd	0.0 mgd	100.0%	100.0%	$1,107,045	$5,535	100.0%	$5,535
ii Chemicals for Existing Groundwater Disinfection Systems	3.2 mgd	$0 /mgd	$0	3.2 mgd	3.2 mgd	0.0 mgd	100.0%	100.0%	$0	$176,767	100.0%	$176,767
iii Use Existing MMD Zone 2 Pump Station to Pump to Rueter-Hess Reservoir	3.2 mgd	$0 /mgd	$0	3.2 mgd	3.2 mgd	0.0 mgd	100.0%	100.0%	$0	$110,771	100.0%	$110,771
iv Pipeline from MMD Zone 2 Tank/Pump Station to Rueter-Hess Reservoir (16")	12,000 lf	$190 /lf	$2,277,350	3.2 mgd	3.2 mgd	0.0 mgd	100.0%	100.0%	$2,277,350	$11,387	100.0%	$11,387
b Blend Water Contribution from Cottonwood, Inverness and Pinery (800, 1000 and 1000 afy, respectively)												
i Development of Additional CCPWA Water above SMWA Member Shares	1,625 af	$31,091 /af	$50,522,131	1,625 af	1,625 af	0 af	100.0%	100.0%	$50,522,131	$252,611	100.0%	$252,611
ii Expanded Pump Station from Cherry Creek to Rueter-Hess Reservoir	2,146 hp	$10,791 /hp	$23,157,110	29.6 mgd	16.6 mgd	13.0 af	56.1%	56.1%	$12,998,913	$500,695	56.1%	$281,055
iii Expanded Pipeline from Cherry Creek to Rueter-Hess Reservoir (42")	20,500 lf	$363 /lf	$7,435,125	29.6 mgd	16.6 mgd	13.0 af	56.1%	56.1%	$4,173,601	$37,176	56.1%	$20,868
c Blend Water Contribution from Parker Water (3875 afy)												
i Flow Control Vault to Redirect Well Water to Rueter-Hess Reservoir	3.5 mgd	$79,277 /mgd	$274,284	3.5 mgd	3.5 mgd	0.0 mgd	100.0%	100.0%	$274,284	$1,371	100.0%	$1,371
ii Pipeline from Well System to Reuter-Hess Reservoir (16")	7,100 lf	$190 /lf	$1,347,432	3.5 mgd	3.5 mgd	0.0 mgd	100.0%	100.0%	$1,347,432	$6,737	100.0%	$6,737
e Blend Water Contribution from Castle Rock, Dominion and Centennial (3475, 2650 and 2000 afy, respectively)												
i Expanded Pump Station from Chatfield Reservoir to Plum Creek WRF	3,700 hp	$8,354 /hp	$30,910,619	24.7 mgd	14.5 mgd	10.2 mgd	58.8%	58.8%	$18,185,613	$1,988,774	45.7%	$908,345
ii Expanded Pipeline from Chatfield Reservoir to Plum Creek WRF (42")	70,300 lf	$363 /lf	$25,497,039	24.7 mgd	14.5 mgd	10.2 mgd	58.8%	58.8%	$15,000,647	$127,485	58.8%	$75,003
iii Expanded Pump Station from Plum Creek WRF to Rueter-Hess Reservoir	1,300 hp	$13,656 /hp	$17,752,581	24.7 mgd	14.5 mgd	10.2 mgd	58.8%	58.8%	$10,444,358	$804,565	47.4%	$380,981
iv Expanded Pipeline from Plum Creek WRF to Rueter-Hess Reservoir (42")	28,600 lf	$363 /lf	$10,372,906	24.7 mgd	14.5 mgd	10.2 mgd	58.8%	58.8%	$6,102,681	$51,865	58.8%	$30,513
f Blend Water Contribution from Rangeview (1600 afy)												
i Chemicals for Existing Groundwater Disinfection Systems	1.4 mgd	$0 /mgd	$0	1.4 mgd	1.4 mgd	0.0 mgd	100.0%	100.0%	$0	$78,563	100.0%	$78,563
ii Pipeline from Rangeview to PWSD Lower South Platte Pump Station (12")	9,100 lf	$158 /lf	$1,439,159	1.4 mgd	1.4 mgd	0.0 mgd	100.0%	100.0%	$1,439,159	$7,196	100.0%	$7,196
Subtotal			**$172,092,781**						**$123,873,214**	**$4,161,498**		**$2,347,705**
2 Conveyance of WISE Water to Rueter-Hess Reservoir												
a Use Existing WISE Binney Connect PS to PWSD Lower South Platte Pump Station	- -	- -	-	- -	- -	- -	-	-	-	-	-	-
b Pipline from WISE Binney Connect PS to PWSD Lower South Platte Pipeline (42")	15,400 lf	$363 /lf	$5,585,411	30.0 mgd	30.0 mgd	0.0 mgd	100.0%	100.0%	$5,585,411	$27,927	100.0%	$27,927
c Expanded PWSD Lower South Platte Pump Station	3,600 hp	$8,462 /hp	$30,464,831	40.0 mgd	20.0 mgd	20.0 mgd	50.0%	50.0%	$15,232,415	$2,033,618	37.1%	$754,035
d Expanded PWSD Lower South Platte Pipeline (48")	114,500 lf	$426 /lf	$48,771,131	40.0 mgd	20.0 mgd	20.0 mgd	50.0%	50.0%	$24,385,566	$243,856	50.0%	$121,928
Subtotal			**$84,821,373**						**$45,203,392**	**$2,305,401**		**$903,890**
3 Storage of Water in Rueter-Hess Reservoir and Treatment at RHWTP												
a Storage in Reuter-Hess Reservoir	34,000 af	$7,234 /af	$245,963,247	34,000 af	34,000 af	0 af	100.0%	100.0%	$245,963,247	$0	0.0%	$0
b Water Treatment at PWSD Rueter-Hess Water Purification Facility	27.0 mgd	$5,969,810 /mgd	$161,184,861	27.0 mgd	27.0 mgd	0.0 mgd	100.0%	100.0%	$161,184,861	$12,095,457	100.0%	$12,095,457
Subtotal			**$407,148,109**						**$407,148,109**	**$12,095,457**		**$12,095,457**
4 Conveyance of Water Back to WISE Pipeline and SMWA Members												
a Conveyance in the RidgeGate Pipeline to WISE Pipeline (42")	22,400 lf	$363 /lf	$8,124,234	32.0 mgd	27.0 mgd	5.0 mgd	84.4%	84.4%	$6,854,823	$40,621	84.4%	$34,274
Subtotal			**$8,124,234**						**$6,854,823**	**$40,621**		**$34,274**
Grand Total			**$672,186,497**						**$583,079,538**	**$18,602,977**		**$15,381,325**

25-Year Bond Payment ($/yr)	**$41,370,926**
Annual O&M Cost ($/yr)	**$15,381,325**
25-Year Total Annual Cost ($/yr)	**$56,752,251**
25-Year WISE Rate Increase ($/kgal)	**$17.42**

Annual O&M Cost ($/yr)	**$15,381,325**
Long-Term Term Annual Cost ($/yr)	**$15,381,325**
Long-Term WISE Rate Increase ($/kgal)	**$4.72**

Blend In Rueter-Hess Reservoir Concept
Estimated Change to the WISE Water Rate

Infrastructure Item	Capital Cost								Annual O&M	
	Unit	Unit Cost	Capital Cost	Item Capacity	SMWA Use by Capacity	Capacity Use by Others	SMWA Pro-Rata Use	Assumed SMWA Capital Responsibility	Annual O&M Cost	Assumed SMWA Annual O&M Responsbility
1 Estimated Change to the WISE Rate										
a Estimated Decrease in WISE Water Rate for bypassing BWPF	10,000 /af	($836) /af	($8,359,386.67)	10,000 /af	10,000 /af	0 /af	100%	100.0% ($8,359,387)	($3,219,753)	100.0% ($3,219,753)
Subtotal			**($8,359,387)**					**($8,359,387)**	**($3,219,753)**	**($3,219,753)**
Grand Total			**($8,359,387)**					**($8,359,387)**	**($3,219,753)**	**($3,219,753)**

Capital Cost Savings ($/yr)	**($8,359,387)**
Annual O&M Cost Savings ($/yr)	**($3,219,753)**
Total Annual Cost Savings ($/yr)	**($11,579,140)**
WISE Rate Savings ($/kgal)	**($3.55)**

Unit costs were developed for use PWP Treatment Train at BWPF based on costs in 2018 per Jason Mumm.

Blend In Rueter-Hess Reservoir Concept
Additional Cost of Phosphorus Removal Ahead of Reservoir

Infrastructure Item	Capital Cost								Annual O&M	
	Unit	Unit Cost	Capital Cost	Item Capacity	SMWA Use by Capacity	Capacity Use by Others	SMWA Pro-Rata Use	Assumed SMWA Capital Responsibility	Annual O&M Cost	Assumed SMWA Annual O&M Responsbility
1 Pretreatment of WISE Water to Remove Phosphorus										
a Reuter-Hess Reservoir Pretreatment (Phoshprus Precipitation)	30 mgd	$3,245,395 /mgd	$97,361,844	30.0 mgd	30.0 mgd	0.0 mgd	100.0%	100.0% $97,361,844	$4,345,533	100.0% $4,345,533
Subtotal			**$97,361,844**					**$97,361,844**	**$4,345,533**	**$4,345,533**
Grand Total			**$97,361,844**					**$97,361,844**	**$4,345,533**	**$4,345,533**

25-Year Bond Payment ($/yr)	**$6,908,062**
Annual O&M Cost ($/yr)	**$4,345,533**
25-Year Total Annual Cost ($/yr)	**$11,253,595**
25-Year WISE Rate Increase ($/kgal)	**$3.45**

Annual O&M Cost ($/yr)	**$4,345,533**
Long-Term Term Annual Cost ($/yr)	**$4,345,533**
Long-Term WISE Rate Increase ($/kgal)	**$1.33**