Alto Lakes Water and Sanitation District

Concentrate Management Study

July 2012

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Executive Summary

Alto Lakes Water and Sanitation District (ALW&SD or the "District") engaged GHD to prepare a Concentrate Management Plan for their planned Phase 2 for the Water System Improvement Project.

The entire water supply for the ALW&SD service area is derived from groundwater sources that contain several constituents that exceed the State of New Mexico's secondary standards. These constituents are iron, manganese and Total Dissolved Solids (TDS). An earlier study determined that no single treatment technology could reliably address all water quality issues, therefore a two-step treatment plan was recommended.

Disposing of the brine generated by a TDS reduction technology, such as a membrane process, requires a disposal strategy. The District has limited land area for brine disposal and has concluded that additional land purchase is not an option. Phase 1 consists of the first stage of treatment: oxidation followed by an iron and manganese removal system. This system has been implemented and is currently in operation.

Prior to implementing Phase 2, ALW&SD initiated a Concentrate Management Study to:

1. Evaluate process alternatives for maximizing recovery and minimizing brine volumes from a recommended membrane process;
2. Develop design criteria for desalination equipment;
3. Evaluate blending plans, and
4. Determine the capacity of on-site storage and brine volume reduction using an enhanced evaporation method on existing land property currently owned by the District.

Three desalination processes were evaluated. The recommended process alternative consists of a first stage nanofiltration system, followed by chemical conditioning, and a seawater membrane system as a brine concentrator.

Three blending plans were evaluated. The recommended plan consists of a 1:1 blending of raw water with desalinated water, which will maintain a TDS level of 960 mg/L year round.

On-site brine storage will be located north and south of the treatment plant. Each storage area is approximately 5,000 square feet. Evaporation of brine cannot be achieved by natural evaporation. Therefore, the use of enhanced evaporation equipment will be needed.

The total project cost is estimated at $1.8 million. The cost of water is estimated at $2.51/1,000 gallons.

2. Introduction

2.1 Background

The Alto Lakes Water & Sanitation District (ALW&SD or the "District") is a quasi-municipal governmental subdivision in the State of New Mexico. It was created to provide water and wastewater-related services to the subdivisions of Alto Lakes. The District acquired the assets of the Alto Lakes Water Corporation (ALWC) on April 1, 2008 and now operates the community water and wastewater system.

The District derives its potable water supply from groundwater wells. The water quality produced from these wells exceeds the New Mexico Environmental Department's secondary standards for iron, manganese and Total Dissolved Solids (TDS). Earlier studies have recommended the use of an iron and manganese removal system and a desalination process. The iron and manganese removal system is currently installed and in operation.

While there are technical publications and on-going research on brine reduction and disposal methods, the applicability of these technologies at each locality is unique. The purpose of this study is to:

- recommend a desalination process that fits with the objectives of the Concentrate Management Plan;
- utilize only the land area currently owned by ALW&SD that is adjacent to the treatment plant for brine storage, and
- identify an appropriate enhanced evaporation method for brine reduction.

The ability to manage brine concentrate produced as a by-product of a desalination process is a significant factor in determining project feasibility. A Concentrate Management Plan consists of strategies to optimize the production of water, water conservation, brine minimization, and implementation of a brine disposal methodology. In most inland desalination facilities, concentrate management can constitute a significant portion of the overall project cost. Additionally, complex regulatory environments, permitting costs and increasing operational costs can make planning-level decisions uncertain. In an earlier study, a number of brine disposal options were evaluated. All of the options required more land acquisition by ALW&SD. Since then, the District has concluded that additional land acquisition is no longer an option, and a Concentrate Management Plan will rely on brine volume minimization, enhanced evaporation, and storage on property currently owned by ALW&SD.

2.2 Water Quality

All potable water supplied to the residents of Alto Lakes is derived from existing groundwater wells. Due to the subsurface aquifer geology, the groundwater contains high levels of inorganic dissolved solids. The raw water supply is high in salinity, hardness, iron, manganese and sulfate. These inorganic salts present treatment challenges and reduce the recovery efficiencies of a membrane process. Currently, the raw water is treated using a manganese dioxide system to reduce the concentrations of iron and manganese. Therefore, recommendations made in this report will assume that the iron and manganese concentrations are lowered to acceptable levels prior to further treatment with a membrane process.

2.2.1 Raw Water Quality

The raw water quality parameters used for this study are shown in **Table 2-1**.

Table 2-1 - Raw Water Quality - Alto Lakes Water & Sanitation District

Parameter	Units	Date: 07/20/11
pH	unit	7.3
TDS (calculated)	mg/l	1,775
Alkalinity (HCO3)	mg/l	170
Calcium	mg/l	295
Magnesium	mg/l	110
Sodium	mg/l	110
Potassium	mg/l	3.0
Bromide	mg/l	<.20
Strontium	mg/l	8.6
Hardness (as CaCO3)	mg/l	1190
Sulfate	mg/l	985
Chloride	mg/l	155
Fluoride	mg/l	0.46
Boron	mg/l	0.096
Silica as SiO_2	mg/l	22
Nitrite (NO_2)	mg/l	<0.20
Barium	mg/l	0.018
Copper	mg/l	0.0055
Lead	mg/l	<0.0025
Iron	mg/l	0.83

The raw water analysis indicates a notable concentration of sulfate. The aquifers in the vicinity of Alto Lakes are known to be rich in calcium sulfate, commonly known as gypsum. The alkalinity level is considered moderate and will not require large doses of acid to lower its pH. Silica concentration is moderately high.

The TDS is calculated to be 1,775 mg/L and is classified as brackish water.

2.2.2 Finished Water Quality Goals

The finished water quality criteria as developed in the Preliminary Engineering Report for the Water System Improvements, November 21, 2008 is summarized in **Table 2-2**.

Table 2-2 - Key Finished Water Design Criteria

Constituent	Units	Secondary Standard	Alto Lakes Well Water Concentration	ALW&SD Goal
Iron	mg/l	0.3	0.9	<0.3
Manganese	mg/l	0.05	0.08	<0.05

TDS	mg/l	500	1320	<500
Hardness	mg/l	N/A	850	<100

The production of treated water (permeate) from the membrane process can meet the stipulated goals. However, blending of permeate with raw water bypass will be necessary as part of the Concentrate Management Plan, and the blended TDS and Hardness will exceed the stated goals.

2.3 Brine Disposal

A membrane process is operated such that only a portion of the feedwater is driven through the membrane. The balance of the feedwater, which does not permeate through the membrane, will form the brine stream. The brine stream exiting a membrane system carries the rejected dissolved solids. Minimizing the brine volume and effectively managing its storage and disposal are critical to the success of this project. The Preliminary Engineering Report (PER) for the Water System Improvement, dated November 2008, identified enhanced evaporation as the preferred alternative for brine disposal.

Evaporation is a well-established method for reducing the volume of brine solution and requires relatively low maintenance compared to heat-induced mechanical evaporators or crystallizers. Natural evaporation ponds are most appropriate for smaller brine volumes and in regions having a high evaporation rate, level terrain and low land costs. According to the PER, Alto Lakes receives an annual average of over 22 inches of precipitation and evaporates 65 inches per year. The land area is limited and as such, enhanced evaporation methods are justified for use at the Alto Lakes Treatment Plant. During the winter period when there is no appreciable evaporation, the enhanced evaporation equipment will not be in operation and storage capacity will be provided.

2.3.1 Site Constraints

ALW&SD has two parcels of land totaling approximately 5 acres. The southern parcel is subdivided into 3 lots. The existing treatment plant sits on Lot 3 and portions of Lots 1 and 2. The northern parcel is approximately 2.5 acres. Approximately 5,000 square feet of land area south of the existing treatment plant can be used for brine storage and installation of enhanced evaporation equipment. The lot north of the treatment plant can be cleared for construction of another 5,000-sq ft brine storage area. Combined, these two areas are not large enough to function as a natural evaporation pond.

The northern parcel has about 50 feet by 150 feet of relatively flat terrain. Further to the north, the topography of the land consists of steep downward slopes; development of terraces for brine storage is not feasible and could interfere with the natural drainage for storm water flows.

Based on these constraints, the desalination process must be designed for maximum water recovery and produce the lowest amount of brine. This study will evaluate a secondary process to reduce the brine volume and incorporate the use of enhanced evaporation equipment as part of the Concentrate Management Plan.

3. Treatment Considerations and Treatment Process Development

The most widely used processes for desalination are Reverse Osmosis (RO), Nanofiltration (NF) and Electrodialysis Reversal (EDR). This section of the report evaluates these three basic membrane processes as primary treatment to reduce the TDS level. A secondary process consisting of RO and EDR will be evaluated to further reduce the brine volume. A water-softening process will also be evaluated to determine its effectiveness in improving recovery rates in the secondary membrane process by removing carbonate and non-carbonate hardness and lowering the risks of membrane scaling.

- Process Alternative A: Use of NF membranes in the first stage operating at about 80% recovery, followed by a softening process to allow higher recovery in a secondary brackish water RO (BWRO) membrane brine concentrator system to further reduce the brine volume;
- Process Alternative B: Use of NF membranes in the first stage operating at about 80% recovery, followed by the use of anti-scalant and pH adjustment prior to a seawater RO (SWRO) membrane brine concentrator system to further reduce its volume, and
- Process Alternative C: Use of NF membranes in the first stage operating at about 80% recovery, followed by an EDR system to reduce the brine volume.

It should also be noted that an additional accrued benefit of a brine concentrator process is that its product water is blended directly into the finished water stream. Each of these unit processes is briefly described below in the following subsections.

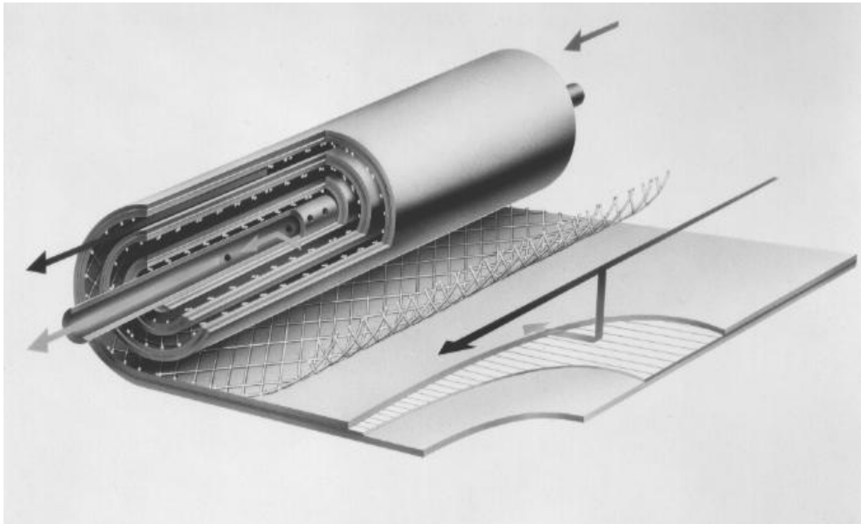
3.1 Pressurized Membrane Systems (Reverse Osmosis and Nanofiltration)

RO and NF are pressurized membrane processes in which water is forced through a semi-permeable membrane. Water permeates through the membranes, leaving the salts in the brine stream as illustrated in **Figure 3-1**. An RO system treating brackish water typically operates at about 160 psi. NF systems operate at about 110 psi.

RO systems produce higher quality permeate with a low TDS concentration. The NF membranes allow a slightly higher permeability of mono-valent ions such as sodium and chloride and the permeate has a higher TDS concentration. NF is effective in rejecting di-valent ions, such as calcium, sulfate and carbonates. Therefore, NF is sometimes referred to as a “softening” process.

The most common operational limitation to achieving high recovery of water is the potential of scale formation or precipitation of salt crystals on the membrane surface. The concentrations of dissolved salts increase as water permeates through the membranes. When these elevated salt concentrations exceed respective solubility limits, the risk of precipitation on the membrane surface occurs.

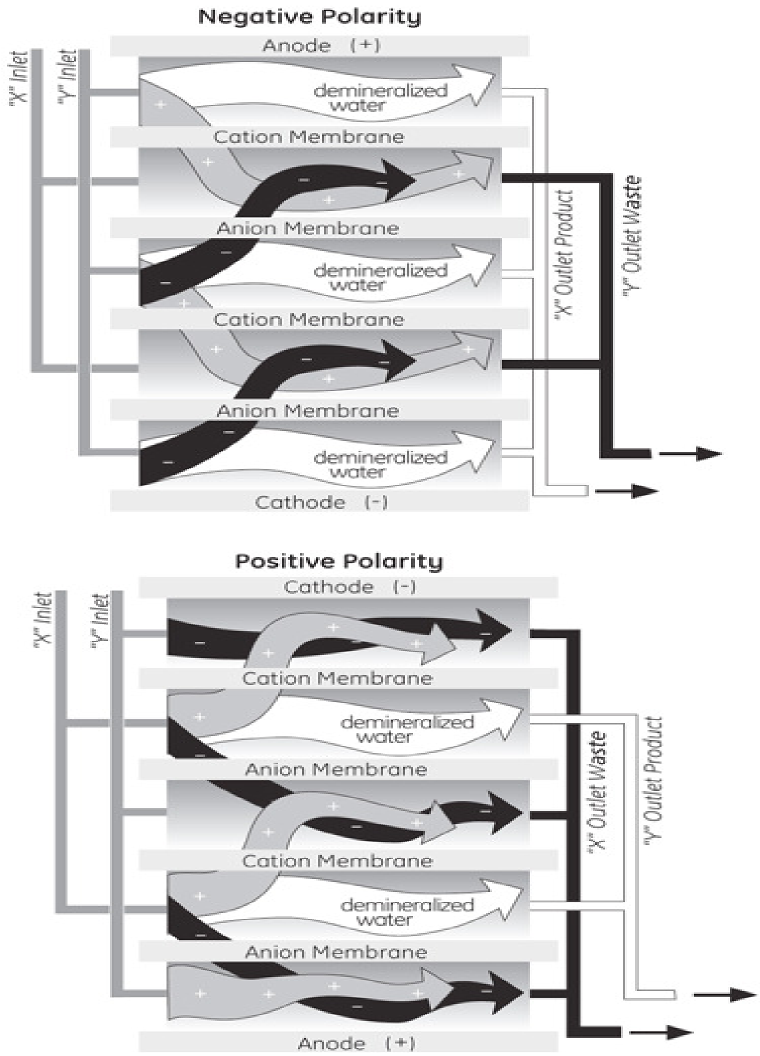
Figure 3-1 - Spiral-wound RO membrane



3.2 Electrodialysis Reversal (EDR)

EDR is a process by which an electrical current is used in association with ion-selective membranes. Membranes are installed in pairs and arranged in a stack. Each pair contains one positively charged ion selective membrane (cation) and one negatively charged ion membrane (anion) as illustrated in Figure 3.2. A DC current is passed through the water within the membrane stack. The dissociated ions migrate to an opposite-charged electrode. Cations (such as sodium, calcium) are drawn to the negative electrode, while anions (such as chloride, sulfate) migrate towards the positive electrode. This arrangement results in anions and cations being drawn (in opposite directions) into concentrated channels yielding two separate streams; a diluate stream with lower TDS concentrations, and a higher ionic concentration stream (brine).

Figure 3-2 - EDR operation in negative and positive polarities



The most common limitation of the EDR process is the high energy needed to attract high concentrations of ions through its membrane.

3.3 Pretreatment Processes

Pretreatment is a critical component of a membrane process. Surface scaling occurs on the membranes when crystallization of sparingly soluble salts occurs as its concentrations begin to exceed its solubility limits.

Pretreatment chemicals can be used to manage scale-forming compounds on RO, NF and EDR membranes. In most cases, the addition of anti-scalants and acid is sufficient to improve the performance of the membrane system. These chemicals interfere with the nucleation process and inhibit the formation of crystals.

Another common element in the pretreatment process is the use of cartridge filters. Polypropylene-wound filters are commonly used. Depending on the sizes of particulate matter in the feedwater, filter pore sizes can range from 5 to 20 microns.

3.3.1 pH adjustment

The primary purpose for reducing the feed pH is to reduce the potential of calcium carbonate scaling on the membrane surfaces. Typically, hydrochloric acid (HCl) or sulfuric acid (H_2SO_4) can be used to lower the pH in the feed water. Sulfuric acid is preferred over hydrochloric acid due to its lower cost and low fuming potential. Hydrochloric acid is preferred when sulfate scaling is a concern such as the precipitation of calcium sulfate, barium sulfate or strontium sulfate. Sulfuric acid increases the sulfate ion concentration in the feedwater, which directly increases the potential for sulfate-based scaling.

Sulfate appears to be the limiting factor in water recovery in this case. The chemical analysis dated 7/20/2011 indicated a sulfate (SO_4) concentration of 985 mg/l. Sulfuric acid is recommended for use in this case. Admit tingly, the use of sulfuric acid will add to the concentration of sulfate in the feedwater. However, in considering the already high level of sulfates in the feedwater, the addition of 9 to 10 mg/l of sulfuric acid will have little to no impact on the saturation levels of these sparingly soluble sulfate-based salts.

The reduction in pH is an effective method to control calcium carbonate (hardness) scaling and is recommended for this system.

3.3.2 Anti-Scalant

The addition of anti-scaling chemical(s) to a membrane process inhibits the precipitation of salts in the brine stream and is recommended for use in this project. The use of anti-scalants will improve recovery rates by lowering the scaling potential of sparingly soluble salts beyond their solubility limits or saturation levels.

3.4 RO Recovery Maximizing Processes

To achieve a higher overall recovery, a water softening process was evaluated. Water softeners work to remove or reduce the concentrations of calcium and magnesium salts. These salts are not very soluble and as their concentrations increase, the potential for scaling or precipitation in the membrane modules increases considerably. Water softening can be achieved using lime, ion exchange (IX) or pelletized adsorption media.

3.4.1 Lime Softening

Lime softening is a common process used to remove calcium and magnesium hardness. The addition of calcium hydroxide (lime) raises the pH and drives the equilibrium of dissolved carbon dioxide to its bicarbonate and carbonate states. The shift in the equilibrium will initiate the precipitation of calcium carbonate and magnesium hydroxide from the brine stream into an external tank or reactor. As the softened brine is recirculated back into the secondary membrane process, it reduces the risk associated with the formation of “scales” on the membrane.

3.4.2 Ion Exchange

Ion exchange (IX) uses a cation exchange resin to replace calcium ions with sodium ions. Most ion exchange systems use a fixed-bed column. Feed water is continually passed through a bed of ion exchange resin beads in a down-flow or up-flow mode until the resin is exhausted. Exhaustion occurs when all the sites on the resin beads have been filled by predominantly calcium and magnesium ions. The bed is then regenerated by rinsing it with concentrated sodium chloride solution. IX is commonly used for small applications. Use in large-scale facilities is rare due to its high operation and maintenance costs. The waste stream from the resin regeneration process will need to be discharged into a storage pond.

An important consideration in the applicability of an IX process includes water quality parameters such as pH, competing ions, resin type and alkalinity.

3.4.3 Pellet Softening

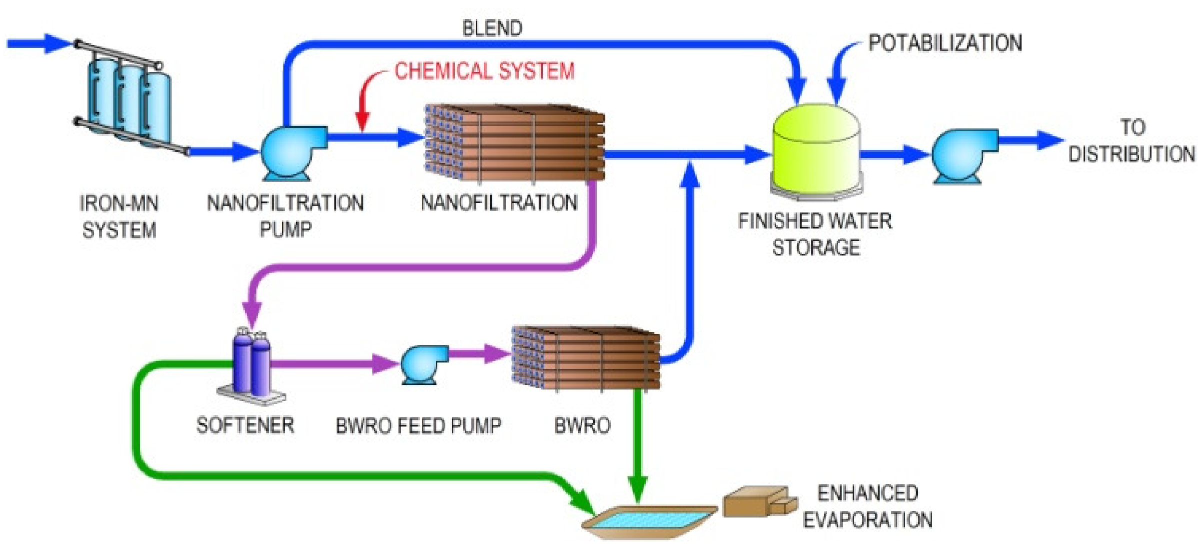
An alternative to traditional softening processes is Pellet Softening. Pellet softeners utilize the same chemical principles as lime-soda softening, but have the advantage of not creating an undesirable sludge. Depending on the hydraulics, a pelletized softening process can be gravity-fed or designed in a pressurized tank. Compounds of magnesium and calcium are precipitated in a reactor by increasing its pH. The calcium and magnesium compounds precipitate on sand particles in a fluidized bed. The sand pellets are then removed and disposed of as solid waste.

Pellet reactor softener systems originated and are commonly utilized in Europe. To date, they are not widely used in the United States.

3.5 Description of Process Alternatives

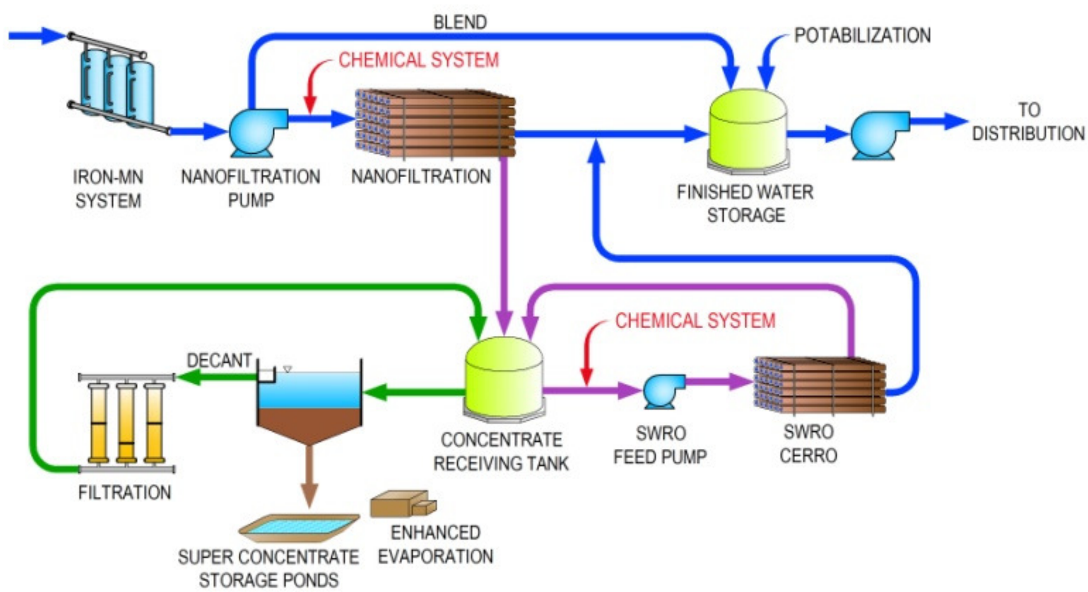
Three process alternatives were evaluated based on the criteria of (1) ease of operation, (2) recovery, and (3) cost.

Figure 3-3 - Process Alternative A: Nanofiltration / Softening / brackish water RO (BWRO) brine concentrator



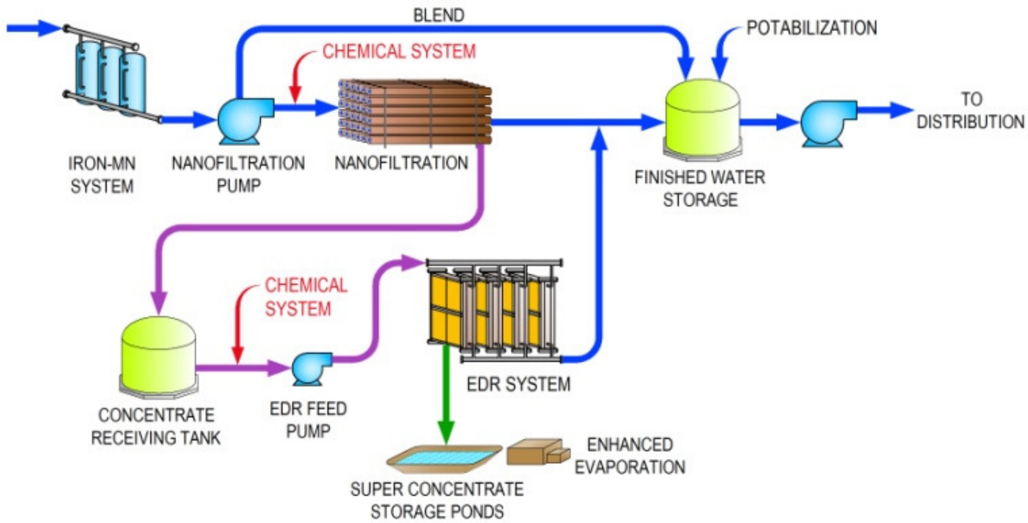
This process will be designed to treat raw feedwater using NF membranes in the primary system, operating at about 80% recovery. The concentrated brine from the NF system would be treated by an ion exchange system and further treated in a secondary brine-concentrating BWRO system.

Figure 3-4 - Process Alternative B: Nanofiltration / chemical addition / seawater RO (SWRO) brine concentrator



This process will be designed to treat raw feedwater using NF membranes in the primary system operating at about 80-85% recovery. The concentrated brine from the NF system would be dosed with additional anti-scalant. The pH will be lowered to 4.0 with sulfuric acid, in preparation for further treatment in a secondary brine concentrating SWRO system. The brine concentrator system operates in a batch-treatment mode, so two concentrate receiving tanks will be required in order to allow for continuous operation.

Figure 3-5 - Process Alternative C: Nanofiltration / Electrodialysis Reversal (EDR)



This process will treat raw feedwater using NF membranes in the primary system, operating at about 80% recovery. The concentrate brine from the NF system would then be dosed with anti-scalant prior to further treatment in an EDR brine concentrator.

3.6 Recovery Rate(s)

The design recovery for a membrane system is typically estimated using membrane performance modeling software. These models use empirical formulas to calculate the maximum recovery that can be achieved across membrane elements in a pressure vessel. The recovery rates are based on salt saturation indices derived from concentrating a specified feedwater quality. If recovery is pushed significantly beyond appropriate design parameters, the concentrate will become saturated with salts and scaling potential increases.

Using the raw water quality analysis provided by ALW&SD, evaluations of recovery and saturation limits were conducted for both the primary NF and secondary RO, and EDR brine concentrators (**Table 3-1**).

Table 3-1 - Comparison of Recovery

Scenario / Process Train Description	Primary NF	Secondary Brine Concentrator	Overall System Recovery
A : NF > Softening > BWRO	80%	80%	95%
B: NF > Chemical Addition > SWRO	85%	67%	95%
C: NF > EDR	80%	50%	90%

3.7 Evaluation of Process Alternatives

Process Alternative A, using NF-Softening-BWRO processes, will require an intermediate softening process. The entire brine stream from the primary NF process will require softening prior to introduction into a secondary BWRO system. Section 3.4 discusses three process options available for softening. The cost associated with an IX system is high. It will require a salt-based regenerant and adds to the on-site waste storage volume. A lime softening process will require additional space at the treatment facility. In the US, pellet softening has only been tested in a pilot study by Western Municipal Water District. Without softening, the secondary BWRO system will not work. This process is not recommended.

Process Alternative B, using NF-Chemical Addition-SWRO processes, has been tested with groundwater from the Tularosa Basin aquifer which has known high concentration of calcium sulfate. Batch tests had been performed on samples collected at the Alto Water Treatment Plant and a 95% recovery was achieved. It is recommended that ALW&SD perform a small-scale pilot test at the treatment plant. The cost of equipment is approximately $7,000 and the test can be conducted by plant staff. This process is recommended for further consideration.

Process Alternative C, using NF-EDR processes, will require high energy consumption due to the high ionic strength of the brine concentrate. This alternative is appropriate for high recoveries but is cost-prohibitive, and not recommended.

3.8 Enhanced Evaporation (EE)

Based on the land area available for the construction of ponds, natural evaporation alone is insufficient to dry up the brine within an annual cycle. Therefore, an enhanced evaporation system will be needed. EE serves as an alternative to conventional evaporation ponds, with the advantage of a reduced footprint. Several types of EE methods were evaluated in an earlier study performed by the District. EE systems could consist of a pond system equipped with mechanical equipment such sprayers and misters. Mechanical evaporators and heat-induced crystallizers are not recommended due to their high capital and operating costs. These types of evaporators are better suited for industrial applications.

EE systems using high pressure misters are also not recommended. These systems will generate dry salt dust particles which will settle on nearby homes.

Wind Aided Intensified eVaporation (WAIV) was considered for use. WAIV uses wind energy to evaporate wetted surfaces. Pumps are used to draw brine from a storage pond and discharge it onto vertically spaced fabric. Water that is not evaporated is collected and drained back into the storage pond. The pumps operate continuously at low pressures to wet the surfaces of the fabric.

The baseline for cost comparison of an EE system is the cost of trucking the brine to a landfill. The closest landfill is approximately 100 miles (200 miles round trip). Hauling cost is approximately $3 per mile. Therefore, one round trip will cost the District $600. Each tanker has a capacity of 4,000 gallons. Therefore, the cost of disposal is $150 per 1,000 gallons. On a peak production day, over 6,000 gallons of brine is generated. The cost of disposal by will be about $900 for hauling, plus the disposal fee charged by the landfill operator. Annual cost of hauling of brine can equate to over $200,000.

4. Concentrate Management Plan

A Concentrate Management Plan is developed by evaluating each element of a desalination program and evaluating the impact it has on the overall strategy. The evaluation is based on the following factors:

- Selection of a desalination technology;
- Brine stream minimization by maximizing water recovery;
- Brine stream minimization by reducing the production of permeate and increasing the by-pass flow to produce blended water with a higher level of TDS;
- Cost considerations;
- Ease of operation;
- Effective land use, and
- Storage and final disposal of super-concentrate.

4.1 Desalination Technology

The selected technology for desalination will consist of a primary NF system, followed by a secondary SWRO system. The NF membrane technology is selected as it offers the best recovery at the lowest energy cost. The NF system will be designed with the following criteria:

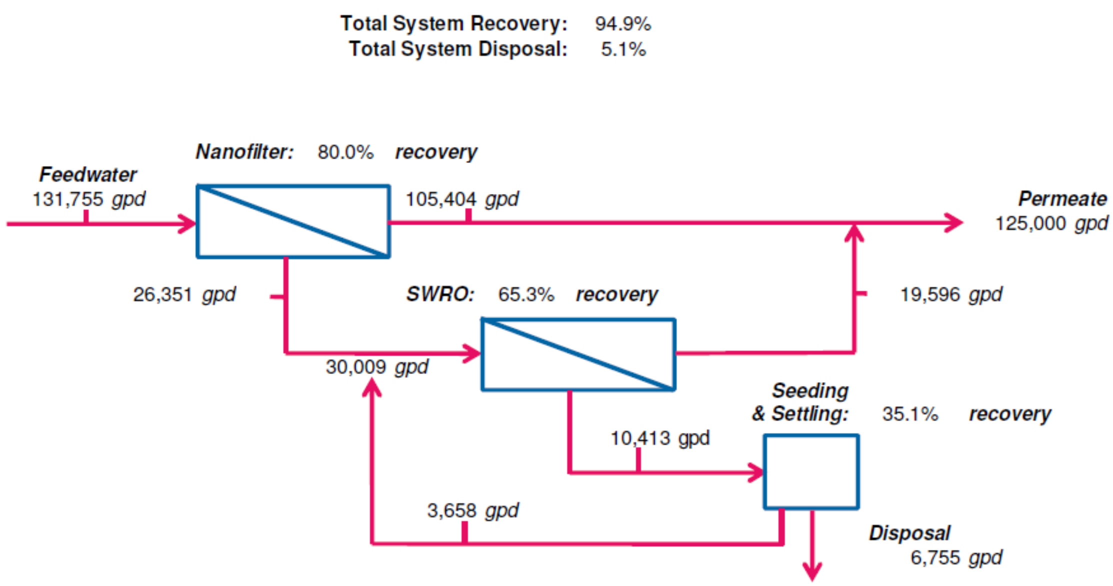
- 2 x 1 array: 2 pressure vessels in the first stage, followed by 1 pressure vessel in the second stage;
- 7 elements: Each pressure vessel will house seven 8” x 40” NF membranes. Preliminary projections were done using DOW NF90-400 membranes, or equivalent;
- 80-85% recovery, and
- Pretreatment consisting of sulfuric acid addition, anti-scalant and a 10-micron cartridge filtration system.

At full production, approximately 26,000 gpd (18 gpm) of concentrate will be produced by the primary NF process. The concentrate will be further processed in a secondary brine concentrator with the following design criteria:

- 4 single element pressure vessels with all vessels arranged in parallel configuration;
- Four 8” x 40” SWRO membranes;
- 67-75% recovery in batch mode, and
- Chemical conditioning using additional sulfuric acid and anti-scalants.

A schematic of this process is depicted in **Figure 4-1**, shown below.

Figure 4-1 - Process Schematic



4.2 Water Recovery

By using a 2-step desalination process, the overall water recovery is approximately 95%. For every 100 gallons of feedwater, approximately 5 gallons will be discharged as super-concentrate.

4.3 Blended Water TDS

In order to minimize the brine stream, several blending plans were evaluated. In developing these blending plans, several assumptions were made. The maximum (peak) water demand is 250,000 gpd, occurring in July; low water demand of 150,000 gpd occurs during the winter months. A maximum permeate production rate of 125,000 gpd was used in the evaluation. Three blending scenarios were evaluated.

- Blend Plan 1 – This plan maximizes the production of permeate, year round. During low water demand periods, the production of permeate remains at 125,000 gpd; it is blended with 25,000 gpd of raw water. Blending Plan 1 produces higher water quality during the low demand periods. It also generates the largest total annual volume of brine. When a 250,000 gpd water demand is needed, 125,000 gpd of permeate will be blended with 125,000 gpd of raw water to produce 250,000 gpd with a TDS level of about 960 mg/L.
- Blend Plan 2 – This plan sets a maximum TDS of 960 mg/L during the summer months. During the winter months when demand is lower, the TDS of the blend will be approximately 800 mg/L.
- Blend Plan 3 – This plan sets the TDS of the blended water at 960 mg/L, year round. This plan will generate the lowest total annual volume of brine. Production of permeate will match the demand and blend ratio will be maintained at 1:1.

Table 4-1 - Production Projections

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	31	28	31	30	31	30	31	31	30	31	30	31	
Target Production (gpd):	150,000	170,000	190,000	210,000	230,000	250,000	250,000	230,000	210,000	190,000	170,000	150,000	
Blend Plan 1					**Maximum Permeate Production**					*Annual Concentrate Production (gal):*		*2,339,136*	
Permeate (gpd)	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	
% of Total:	0.83	0.74	0.66	0.60	0.54	0.50	0.50	0.54	0.60	0.66	0.74	0.83	
Permeate TDS (mg/l):	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	
Bypass (gpd):	25,000	45,000	65,000	85,000	105,000	125,000	125,000	105,000	85,000	65,000	45,000	25,000	
% of Total:	0.17	0.26	0.34	0.40	0.46	0.50	0.50	0.46	0.40	0.34	0.26	0.17	
BypassTDS (mg/l):	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	
Total (gpd):	150,000	170,000	190,000	210,000	230,000	250,000	250,000	230,000	210,000	190,000	170,000	150,000	
Permeate + Blend TDS (mg/l):	*373*	*545*	*682*	*792*	*883*	*960*	*960*	*883*	*792*	*682*	*545*	*373*	706 :avg
Blend Plan 2					**800 - 960 TDS Blend Water**					*Annual Concentrate Production (gal):*		*2,106,520*	
Permeate (gpd)	88,600	100,400	112,200	124,000	125,000	125,000	125,000	125,000	124,000	112,200	100,400	88,600	
% of Total:	0.59	0.59	0.59	0.59	0.54	0.50	0.50	0.54	0.59	0.59	0.59	0.59	
Permeate TDS (mg/l):	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	
Bypass (gpd):	61,400	69,600	77,800	86,000	105,000	125,000	125,000	105,000	86,000	77,800	69,600	61,400	
% of Total:	0.41	0.41	0.41	0.41	0.46	0.50	0.50	0.46	0.41	0.41	0.41	0.41	
BypassTDS (mg/l):	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	
Total Blend (gpd):	150,000	170,000	190,000	210,000	230,000	250,000	250,000	230,000	210,000	190,000	170,000	150,000	
Permeate + Blend TDS (mg/l):	*800*	*800*	*800*	*800*	*883*	*960*	*960*	*883*	*800*	*800*	*800*	*800*	841 :avg
Blend Plan 3					**Constant 960 TDS Blend Water**					*Annual Concentrate Production (gal):*		*1,872,442*	
Permeate (gpd)	75,000	84,950	95,000	105,000	115,000	125,000	125,000	115,000	105,000	95,000	84,950	75,000	
% of Total:	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Permeate TDS (mg/l):	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	79.33	
Bypass (gpd):	75,000	85,050	95,000	105,000	115,000	125,000	125,000	115,000	105,000	95,000	85,050	75,000	
% of Total:	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
BypassTDS (mg/l):	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	1,839.84	
Total Blend (gpd):	150,000	170,000	190,000	210,000	230,000	250,000	250,000	230,000	210,000	190,000	170,000	150,000	
Permeate + Blend TDS (mg/l):	*960*	*960*	*960*	*960*	*960*	*960*	*960*	*960*	*960*	*960*	*960*	*960*	960 :avg

Table 4-2 - Target Production Projection Graph

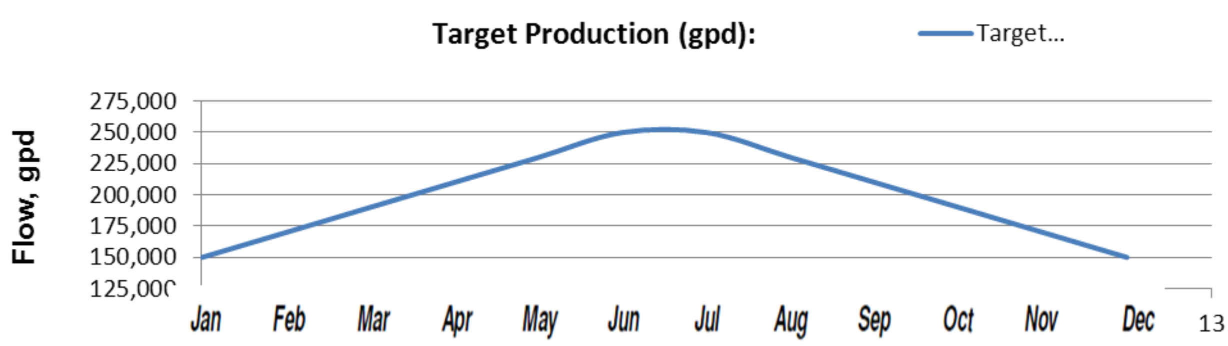
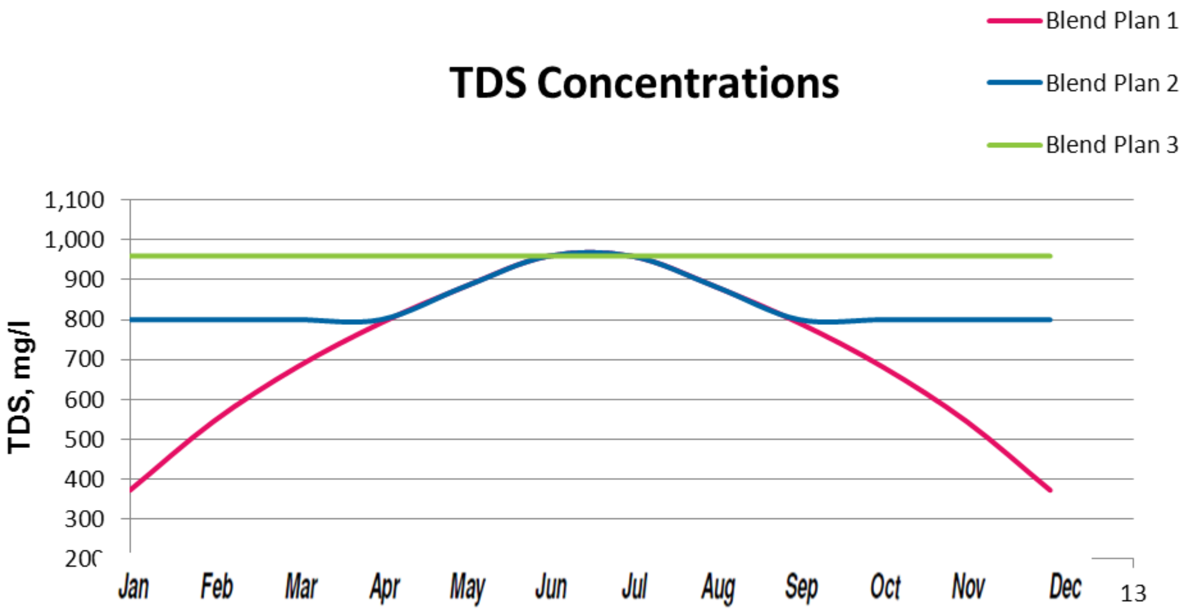


Figure 4-2 - Production TDS Concentration Graph



The storage requirements associated with these Blend Plans are presented in Section 4.5. Due to land area limitations, and capital and operating costs, Blend Plan 3 is recommended. It maintains a level of consistency in the water quality and generates the least amount of brine.

4.4 Brine Storage

The study evaluates two options for storage of concentrate during the winter months. Evaporation data indicates no significant evaporation occurs November through March. During this period, water demand is also the lowest.

Brine can be stored in above-ground tanks and/or lined ponds. As the stored brine is evaporated using enhanced evaporation techniques, the salinity increases. Coated steel tanks will corrode and will be difficult to maintain.

Large HDPE tanks are not cost effective. Therefore, a double-lined HDPE storage pond will be used to store concentrate during the winter months. HDPE or plastic tanks could be used to supplement the capacity of lined ponds.

4.5 Storage Volume

For volumetric analysis, two ponds were used in the calculations. Above ground tanks can be installed adjacent to the ponds to reduce the depth of each pond. Due to land area limitations, two ponds, each with a surface area of 5,000 sq. ft., will be used. The pond will be constructed with 2 (vertical) : 1 (horizontal) side slopes.

The annual precipitation and pan evaporation rates are 22 inches and 60 inches, respectively, with a total net water loss of 38 inches. This rate of evaporation is insufficient to reduce the volume of brine stored in the ponds, and the use of enhanced evaporation equipment will be needed. The inclusion of enhanced evaporation equipment will be in addition to the 5,000 sq. ft. of open pond surface.

Blend Plan 1 will require approximately 550,000 gallons of storage. Total pond depth including freeboard is approximately 22 feet. Blend Plan 1 is not recommended.

Figure 4-3 - Blend Plan 1 Storage Depth Graph

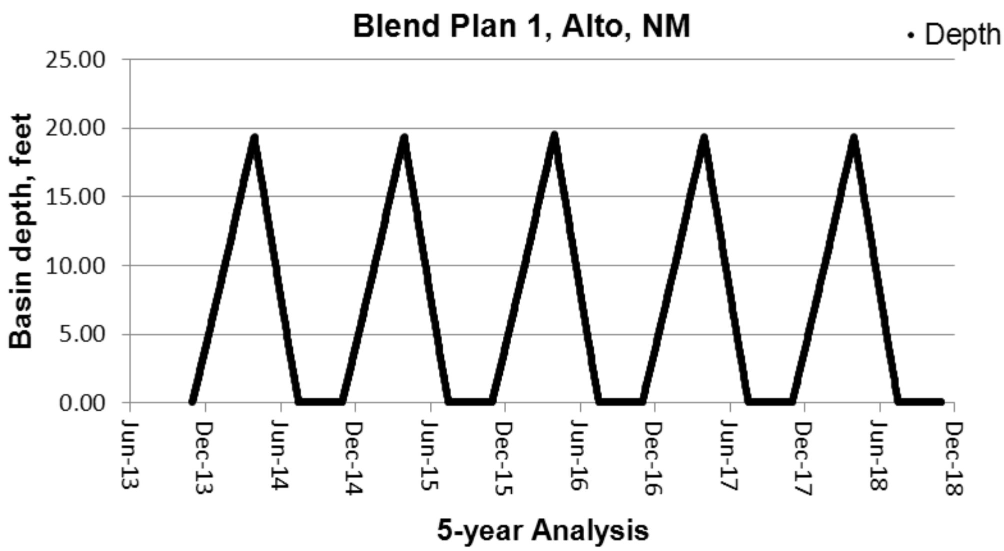
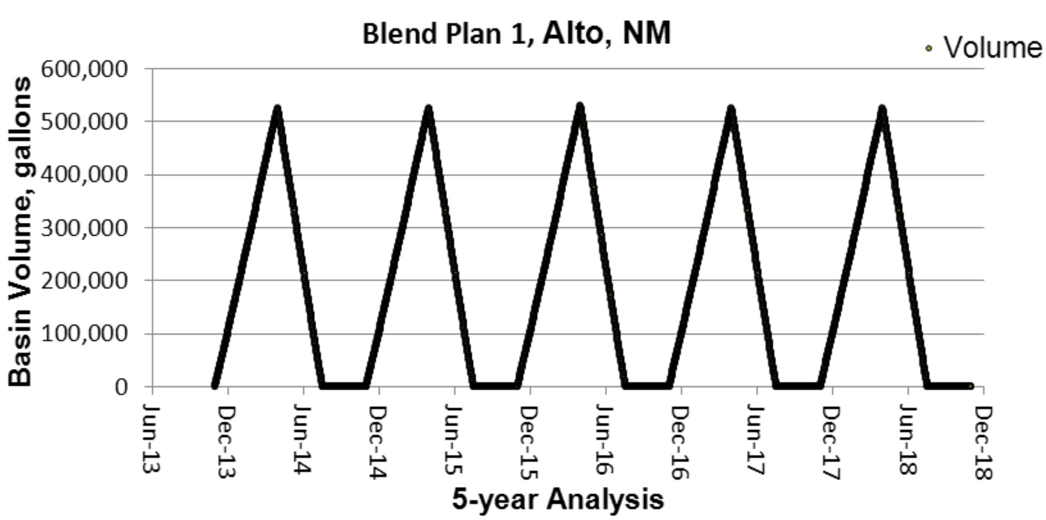


Figure 4-4 - Blend Plan 1 Storage Volume Graph



Blend Plan 2 will require approximately 450,000 gallons of storage. Total pond depth is approximately 17 feet. Blend Plan 2 is not recommended.

Figure 4-5 - Blend Plan 2 Storage Depth Graph

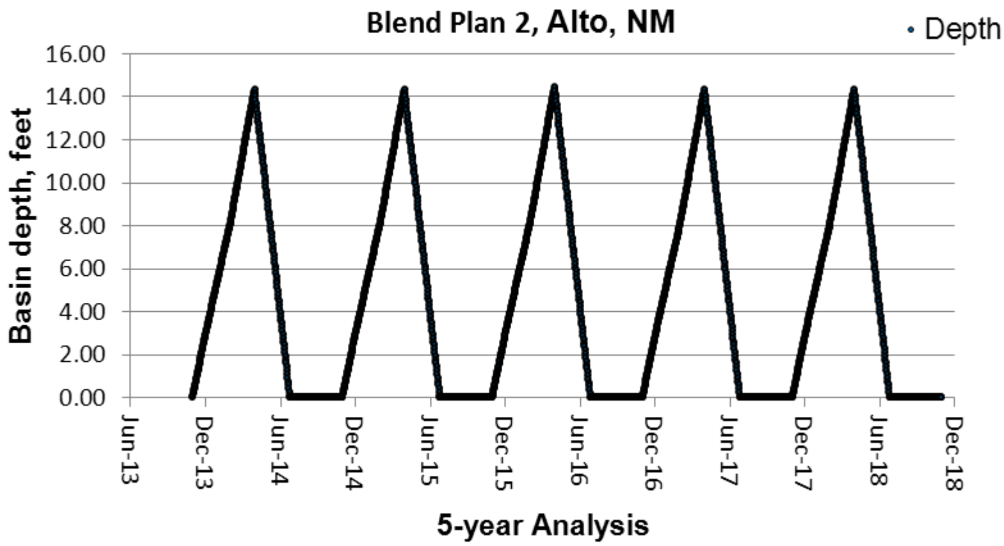
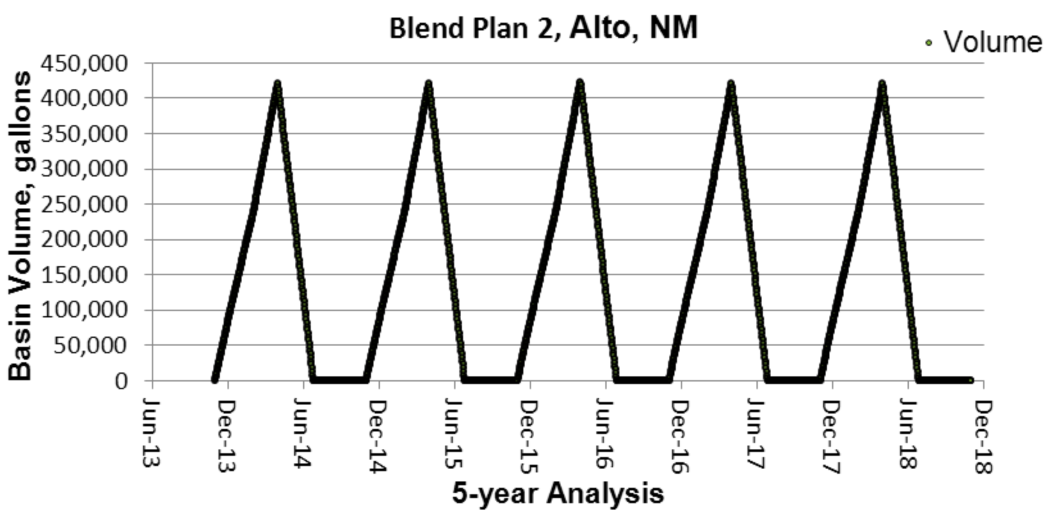


Figure 4-6 - Blend Plan 2 Storage Volume Graph



Using Blend Plan 3, permeate is blended with raw water in a 1:1 ratio. In this case, approximately 400,000 gallons of storage is required. Total pond depth is approximately 14 feet. The depth of the ponds can be reduced using above-ground tanks. Blend Plan 3 is recommended.

Figure 4-7 - Blend Plan 3 Storage Depth Graph

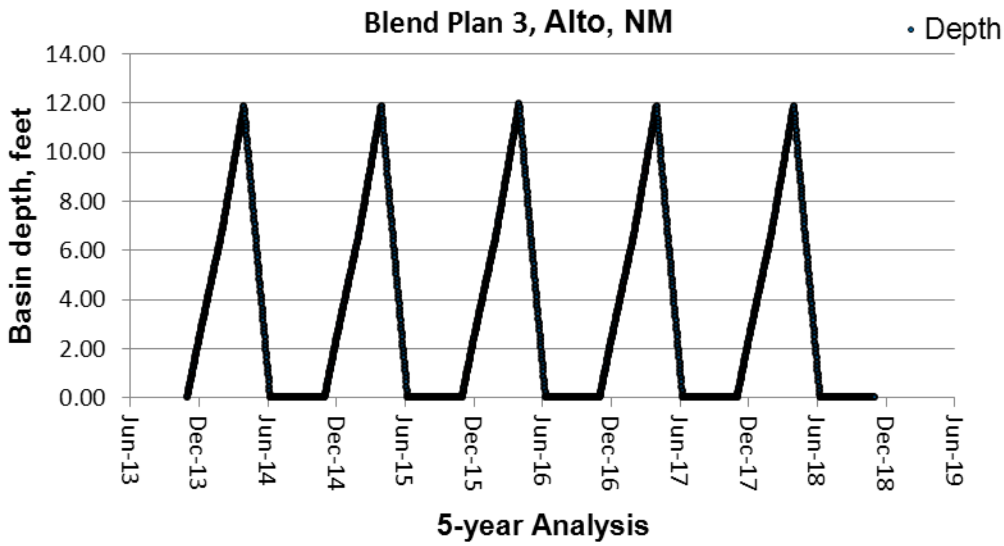
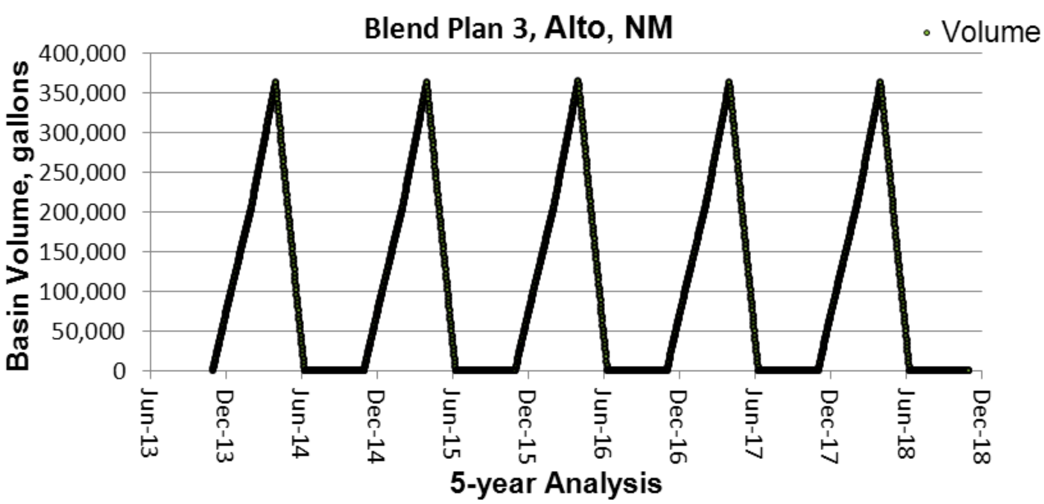


Figure 4-8 - Blend Plan 3 Storage Volume Graph



4.6 Enhanced Evaporation (EE)

Section 4.5 shows that the small area available for brine disposal is insufficient. The use of Enhanced Evaporation will be required to completely dry up the winter storage volumes during the summer months. EE systems such as the WAIV system can be used effectively. Alternatively, a similar lower cost system can be designed and built to provide the necessary surface area. However, the drawback is that the system will not be as modularized and efficient as the WAIV system.

The WAIV system considered for this project will consist of modularized units measuring approximately 25 feet x 70 feet. To maximize evaporation, the units will be approximately 18 feet in height. Each unit will be operated using a 5 HP pump.

4.7 Opinion of Probable Costs

The NF-SWRO system will consist of the following:

- Sulfuric Acid System, with metering pump and storage tank
- Anti-Scalant Dosing System, with metering pump, and storage tank
- Nanofiltration Unit, with built-in cartridge filtrations system, high pressure pump
- Seawater Brine Concentrator Unit, with high pressure pump
- Clean-in Place System, with tanks, pump

Control system, valves and piping, installation	$600,000
Storage Ponds, excavation, liners	$150,000
Enhanced Evaporation (WAIV), including pumping equipment	$400,000
Miscellaneous Contractor Costs	$100,000
Site Piping & Site Work	$100,000
Total	$1,350,000
Engineering Design and Construction Administration Costs	$150,000
Contingencies (20%)	$300,000
TOTAL PROJECT COSTS	**$1,800,000**

Nanofiltration System (10 HP, approx. 92 gpm)	$20/day
SWRO System (12 HP, 23 gpm)	$22/day
WAIV Pumping System (5 HP)	$10/day
Chemical Costs	$30/day
Maintenance Cost	$60/day
Labor Cost (3 hrs/day)	$90/day
Total Daily O&M Cost	$232/day

Cost of Blended Water (125,000 gpd permeate + 125,000 gpd raw)		$0.93/1,000 gallons
Amortized Capital Cost ($1.8 million @ 8%)		$144,000
	or	$395/day
TOTAL COST OF BLENDED WATER		**$2.51/1,000 gallons****

** Does not include cost of iron/manganese system and other existing treatment costs.

5. Permitting Requirements

The construction of this facility will require permits from the New Mexico Environmental Department, Drinking Water Bureau. An Application for Construction or Modification of a Public Water Supply System will be needed. Review timeframe is expected to be 60 days.

3

Preliminary Design Calculations

Nanofiltration Projections

Reverse Osmosis System Analysis for FILMTEC™ Membranes ROSA 7.2.7 ConfigDB u392554_148
Project: ALWSD Case: 1
Peter Chan, GHD 3/19/2012

Project Information: March 19, 2012 Peter Chan

Case-specific: Nanofiltration at 80% Recovery

System Details

Feed Flow to Stage 1	91.49 gpm	Pass 1 Permeate Flow	73.19 gpm	Osmotic Pressure:	
Raw Water Flow to System	91.49 gpm	Pass 1 Recovery	80.00 %	Feed	9.85 psig
Feed Pressure	89.45 psig	Feed Temperature	70.0 F	Concentrate	40.38 psig
Flow Factor	0.85	Feed TDS	1838.25 mg/l	Average	25.12 psig
Chem. Dose (100% H2SO4)	9.26 mg/l	Number of Elements	21	Average NDP	44.06 psig
Total Active Area	8400.00 ft²	Average Pass 1 Flux	12.55 gfd	Power	4.45 kW
Water Classification: Well Water SDI < 3				Specific Energy	1.01 kWh/kgal

Stage	Element	#PV	#Ele	Feed Flow (gpm)	Feed Press (psig)	Recirc Flow (gpm)	Conc Flow (gpm)	Conc Press (psig)	Perm Flow (gpm)	Avg Flux (gfd)	Perm Press (psig)	Boost Press (psig)	Perm TDS (mg/l)
1	NF90-400	2	7	91.49	84.45	0.00	28.87	63.91	62.62	16.10	0.00	0.00	57.21
2	NF90-400	1	7	28.87	58.91	0.00	18.30	44.36	10.57	5.44	0.00	0.00	298.74

Pass Streams (mg/l as Ion)							
Name	Feed	Adjusted Feed	Concentrate		Permeate		
			Stage 1	Stage 2	Stage 1	Stage 2	Total
NH4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	2.89	2.89	8.38	12.28	0.35	1.64	0.54
Na	105.85	105.85	312.44	462.16	10.61	53.29	16.78
Mg	105.85	105.85	331.39	516.98	1.88	10.15	3.07
Ca	283.86	283.86	889.02	1387.04	4.91	26.98	8.09
Sr	8.27	8.27	25.92	40.43	0.14	0.79	0.24
Ba	0.02	0.02	0.05	0.08	0.00	0.00	0.00
CO3	0.44	0.21	2.72	7.20	0.00	0.01	0.00
HCO3	170.00	158.94	482.90	732.92	7.75	39.90	12.38
NO3	0.20	0.20	0.34	0.35	0.14	0.31	0.16
Cl	155.00	155.63	459.62	679.86	15.51	78.40	24.59
F	0.46	0.46	1.34	1.96	0.06	0.27	0.09
SO4	985.00	994.07	3118.77	4874.08	14.65	80.43	24.15
SiO2	22.00	22.00	67.11	102.07	1.21	6.59	1.98
Boron	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	9.40	17.53	18.67	20.55	17.65	19.10	17.87
TDS	1839.84	1838.25	5699.99	8817.42	57.21	298.74	92.07
pH	7.30	7.00	7.35	7.44	5.84	6.47	6.03

Reverse Osmosis System Analysis for FILMTEC™ Membranes | ROSA 7.2.7 ConfigDB u392554_148
Project: ALWSD | Case: 1
Peter Chan, GHD | 3/19/2012

Design Warnings

-None-

Solubility Warnings

Langelier Saturation Index > 0
Stiff & Davis Stability Index > 0
CaSO4 (% Saturation) > 100%
BaSO4 (% Saturation) > 100%
SrSO4 (% Saturation) > 100%
CaF2 (% Saturation) > 100%
Antiscalants may be required. Consult your antiscalant manufacturer for dosing and maximum allowable system recovery.

Stage Details

Stage 1 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.13	5.95	27.08	45.74	1838.25	84.45
2	0.14	5.40	33.86	39.79	2109.00	79.32
3	0.14	4.90	42.69	34.40	2434.69	75.12
4	0.15	4.44	54.40	29.50	2831.90	71.72
5	0.16	3.99	70.37	25.06	3323.36	69.00
6	0.17	3.55	92.80	21.07	3939.10	66.85
7	0.18	3.09	125.40	17.52	4717.17	65.19
Stage 2 Element	Recovery	Perm Flow (gpm)	Perm TDS (mg/l)	Feed Flow (gpm)	Feed TDS (mg/l)	Feed Press (psig)
1	0.09	2.47	163.37	28.87	5699.99	58.91
2	0.08	2.08	204.85	26.40	6217.20	56.14
3	0.07	1.73	257.21	24.32	6730.37	53.68
4	0.06	1.42	322.86	22.59	7225.46	51.48
5	0.05	1.16	404.58	21.17	7689.73	49.49
6	0.05	0.94	504.69	20.00	8113.02	47.66
7	0.04	0.76	624.84	19.06	8489.43	45.96

Scaling Calculations

	Raw Water	Adjusted Feed	Concentrate
pH	7.30	7.00	7.44
Langelier Saturation Index	0.26	-0.07	1.70
Stiff & Davis Stability Index	0.30	-0.03	1.13
Ionic Strength (Molal)	0.05	0.05	0.24
TDS (mg/l)	1839.84	1838.25	8817.42
HCO3	170.00	158.94	732.92
CO2	9.40	17.53	20.54
CO3	0.44	0.21	7.20
CaSO4 (% Saturation)	38.62	38.93	298.27
BaSO4 (% Saturation)	280.52	282.51	1376.59
SrSO4 (% Saturation)	61.86	62.31	342.83
CaF2 (% Saturation)	7.98	7.98	706.31
SiO2 (% Saturation)	18.77	18.77	87.07
Mg(OH)2 (% Saturation)	0.00	0.00	0.01

To balance: 0.63 mg/l Cl added to feed.

Appendix B

Preliminary Design Calculations

Storage Cycle - Data

Date	Pond Volume in Gallons	Discharge Added in Gallons	Evaporation in Gallons	Precipitation in Gallons	Water Depth in Feet	Depth Specific Surface Area, ft^2	WAIV Evaporation in Gallons	Total Storage Required in Gallons	WAIV Enhanc. (x greater than conventional evap)
1-Nov	0	2,178	0	140	0.00	3216	0	2,318	0.0
2-Nov	2,318	2,178	0	140	0.08	3225	0	4,636	0.0
3-Nov	4,636	2,178	0	140	0.15	3233	0	6,954	0.0
4-Nov	6,954	2,178	0	140	0.23	3242	0	9,272	0.0
5-Nov	9,272	2,178	0	140	0.30	3251	0	11,589	0.0
6-Nov	11,589	2,178	0	140	0.38	3259	0	13,907	0.0
7-Nov	13,907	2,178	0	140	0.46	3268	0	16,225	0.0
8-Nov	16,225	2,178	0	140	0.53	3277	0	18,543	0.0
9-Nov	18,543	2,178	0	140	0.61	3285	0	20,861	0.0
10-Nov	20,861	2,178	0	140	0.68	3294	0	23,179	0.0
11-Nov	23,179	2,178	0	140	0.76	3303	0	25,497	0.0
12-Nov	25,497	2,178	0	140	0.84	3312	0	27,815	0.0
13-Nov	27,815	2,178	0	140	0.91	3320	0	30,133	0.0
14-Nov	30,133	2,178	0	140	0.99	3329	0	32,450	0.0
15-Nov	32,450	2,178	0	140	1.06	3338	0	34,768	0.0
16-Nov	34,768	2,178	0	140	1.14	3347	0	37,086	0.0
17-Nov	37,086	2,178	0	140	1.22	3356	0	39,404	0.0
18-Nov	39,404	2,178	0	140	1.29	3364	0	41,722	0.0
19-Nov	41,722	2,178	0	140	1.37	3373	0	44,040	0.0
20-Nov	44,040	2,178	0	140	1.44	3382	0	46,358	0.0
21-Nov	46,358	2,178	0	140	1.52	3391	0	48,676	0.0
22-Nov	48,676	2,178	0	140	1.60	3400	0	50,994	0.0
23-Nov	50,994	2,178	0	140	1.67	3409	0	53,311	0.0
24-Nov	53,311	2,178	0	140	1.75	3418	0	55,629	0.0
25-Nov	55,629	2,178	0	140	1.82	3426	0	57,947	0.0
26-Nov	57,947	2,178	0	140	1.90	3435	0	60,265	0.0
27-Nov	60,265	2,178	0	140	1.98	3444	0	62,583	0.0
28-Nov	62,583	2,178	0	140	2.05	3453	0	64,901	0.0
29-Nov	64,901	2,178	0	140	2.13	3462	0	67,219	0.0
30-Nov	67,219	2,178	0	140	2.21	3471	0	69,537	0.0
1-Dec	69,537	1,923	0	257	2.28	3480	0	71,717	0.0
2-Dec	71,717	1,923	0	257	2.35	3488	0	73,897	0.0
3-Dec	73,897	1,923	0	257	2.42	3497	0	76,077	0.0
4-Dec	76,077	1,923	0	257	2.50	3505	0	78,257	0.0
5-Dec	78,257	1,923	0	257	2.57	3514	0	80,436	0.0
6-Dec	80,436	1,923	0	257	2.64	3522	0	82,616	0.0
7-Dec	82,616	1,923	0	257	2.71	3531	0	84,796	0.0
8-Dec	84,796	1,923	0	257	2.78	3539	0	86,976	0.0
9-Dec	86,976	1,923	0	257	2.85	3548	0	89,156	0.0
10-Dec	89,156	1,923	0	257	2.92	3556	0	91,336	0.0
11-Dec	91,336	1,923	0	257	3.00	3565	0	93,516	0.0
12-Dec	93,516	1,923	0	257	3.07	3573	0	95,696	0.0
13-Dec	95,696	1,923	0	257	3.14	3582	0	97,876	0.0
14-Dec	97,876	1,923	0	257	3.21	3591	0	100,056	0.0
15-Dec	100,056	1,923	0	257	3.28	3599	0	102,236	0.0
16-Dec	102,236	1,923	0	257	3.35	3608	0	104,416	0.0
17-Dec	104,416	1,923	0	257	3.43	3616	0	106,596	0.0
18-Dec	106,596	1,923	0	257	3.50	3625	0	108,776	0.0
19-Dec	108,776	1,923	0	257	3.57	3634	0	110,956	0.0
20-Dec	110,956	1,923	0	257	3.64	3642	0	113,136	0.0
21-Dec	113,136	1,923	0	257	3.71	3651	0	115,316	0.0
22-Dec	115,316	1,923	0	257	3.78	3659	0	117,496	0.0
23-Dec	117,496	1,923	0	257	3.85	3668	0	119,676	0.0
24-Dec	119,676	1,923	0	257	3.93	3677	0	121,856	0.0
25-Dec	121,856	1,923	0	257	4.00	3685	0	124,036	0.0
26-Dec	124,036	1,923	0	257	4.07	3694	0	126,216	0.0
27-Dec	126,216	1,923	0	257	4.14	3703	0	128,395	0.0
28-Dec	128,395	1,923	0	257	4.21	3712	0	130,575	0.0
29-Dec	130,575	1,923	0	257	4.28	3720	0	132,755	0.0
30-Dec	132,755	1,923	0	257	4.35	3729	0	134,935	0.0
31-Dec	134,935	1,923	0	257	4.43	3738	0	137,115	0.0
1-Jan	137,115	1,923	0	230	4.50	3746	0	139,268	0.0
2-Jan	139,268	1,923	0	230	4.57	3755	0	141,421	0.0
3-Jan	141,421	1,923	0	230	4.64	3764	0	143,574	0.0
4-Jan	143,574	1,923	0	230	4.71	3772	0	145,727	0.0
5-Jan	145,727	1,923	0	230	4.78	3781	0	147,879	0.0
6-Jan	147,879	1,923	0	230	4.85	3790	0	150,032	0.0
7-Jan	150,032	1,923	0	230	4.92	3799	0	152,185	0.0
8-Jan	152,185	1,923	0	230	4.99	3807	0	154,338	0.0
9-Jan	154,338	1,923	0	230	5.06	3816	0	156,491	0.0
10-Jan	156,491	1,923	0	230	5.13	3825	0	158,643	0.0
11-Jan	158,643	1,923	0	230	5.20	3833	0	160,796	0.0
12-Jan	160,796	1,923	0	230	5.27	3842	0	162,949	0.0
13-Jan	162,949	1,923	0	230	5.35	3851	0	165,102	0.0
14-Jan	165,102	1,923	0	230	5.42	3860	0	167,255	0.0
15-Jan	167,255	1,923	0	230	5.49	3869	0	169,407	0.0
16-Jan	169,407	1,923	0	230	5.56	3877	0	171,560	0.0
17-Jan	171,560	1,923	0	230	5.63	3886	0	173,713	0.0
18-Jan	173,713	1,923	0	230	5.70	3895	0	175,866	0.0
19-Jan	175,866	1,923	0	230	5.77	3904	0	178,019	0.0
20-Jan	178,019	1,923	0	230	5.84	3913	0	180,171	0.0
21-Jan	180,171	1,923	0	230	5.91	3921	0	182,324	0.0
22-Jan	182,324	1,923	0	230	5.98	3930	0	184,477	0.0
23-Jan	184,477	1,923	0	230	6.05	3939	0	186,630	0.0
24-Jan	186,630	1,923	0	230	6.12	3948	0	188,783	0.0
25-Jan	188,783	1,923	0	230	6.19	3957	0	190,935	0.0
26-Jan	190,935	1,923	0	230	6.26	3966	0	193,088	0.0
27-Jan	193,088	1,923	0	230	6.33	3975	0	195,241	0.0
28-Jan	195,241	1,923	0	230	6.40	3984	0	197,394	0.0
29-Jan	197,394	1,923	0	230	6.48	3992	0	199,547	0.0
30-Jan	199,547	1,923	0	230	6.55	4001	0	201,700	0.0
31-Jan	201,700	1,923	0	230	6.62	4010	0	203,852	0.0

Date	Pond Volume in Gallons	Discharge Added in Gallons	Evaporation in Gallons	Precipitation in Gallons	Water Depth in Feet	Depth Specific Surface Area, ft^2	WAIV Evaporation in Gallons	Total Storage Required in Gallons	WAIV Enhanc. (x greater than conventional evap)
1-Feb	203,852	2,178	0	499	6.69	4019	0	206,529	0.0
2-Feb	206,529	2,178	0	499	6.78	4030	0	209,205	0.0
3-Feb	209,205	2,178	0	499	6.86	4042	0	211,881	0.0
4-Feb	211,881	2,178	0	499	6.95	4053	0	214,558	0.0
5-Feb	214,558	2,178	0	499	7.04	4064	0	217,234	0.0
6-Feb	217,234	2,178	0	499	7.13	4075	0	219,910	0.0
7-Feb	219,910	2,178	0	499	7.21	4086	0	222,586	0.0
8-Feb	222,586	2,178	0	499	7.30	4098	0	225,263	0.0
9-Feb	225,263	2,178	0	499	7.39	4109	0	227,939	0.0
10-Feb	227,939	2,178	0	499	7.48	4120	0	230,615	0.0
11-Feb	230,615	2,178	0	499	7.57	4131	0	233,292	0.0
12-Feb	233,292	2,178	0	499	7.65	4143	0	235,968	0.0
13-Feb	235,968	2,178	0	499	7.74	4154	0	238,644	0.0
14-Feb	238,644	2,178	0	499	7.83	4165	0	241,321	0.0
15-Feb	241,321	2,178	0	499	7.92	4177	0	243,997	0.0
16-Feb	243,997	2,178	0	499	8.00	4188	0	246,673	0.0
17-Feb	246,673	2,178	0	499	8.09	4199	0	249,350	0.0
18-Feb	249,350	2,178	0	499	8.18	4211	0	252,026	0.0
19-Feb	252,026	2,178	0	499	8.27	4222	0	254,702	0.0
20-Feb	254,702	2,178	0	499	8.36	4234	0	257,378	0.0
21-Feb	257,378	2,178	0	499	8.44	4245	0	260,055	0.0
22-Feb	260,055	2,178	0	499	8.53	4256	0	262,731	0.0
23-Feb	262,731	2,178	0	499	8.62	4268	0	265,407	0.0
24-Feb	265,407	2,178	0	499	8.71	4279	0	268,084	0.0
25-Feb	268,084	2,178	0	499	8.79	4291	0	270,760	0.0
26-Feb	270,760	2,178	0	499	8.88	4302	0	273,436	0.0
27-Feb	273,436	2,178	0	499	8.97	4314	0	276,113	0.0
28-Feb	276,113	2,178	0	499	9.06	4325	0	278,789	0.0
1-Mar	278,789	2,435	0	252	9.15	4337	0	281,477	0.0
2-Mar	281,477	2,435	0	252	9.23	4349	0	284,164	0.0
3-Mar	284,164	2,435	0	252	9.32	4360	0	286,852	0.0
4-Mar	286,852	2,435	0	252	9.41	4372	0	289,539	0.0
5-Mar	289,539	2,435	0	252	9.50	4384	0	292,227	0.0
6-Mar	292,227	2,435	0	252	9.59	4395	0	294,915	0.0
7-Mar	294,915	2,435	0	252	9.67	4407	0	297,602	0.0
8-Mar	297,602	2,435	0	252	9.76	4419	0	300,290	0.0
9-Mar	300,290	2,435	0	252	9.85	4430	0	302,977	0.0
10-Mar	302,977	2,435	0	252	9.94	4442	0	305,665	0.0
11-Mar	305,665	2,435	0	252	10.03	4454	0	308,353	0.0
12-Mar	308,353	2,435	0	252	10.12	4466	0	311,040	0.0
13-Mar	311,040	2,435	0	252	10.20	4477	0	313,728	0.0
14-Mar	313,728	2,435	0	252	10.29	4489	0	316,416	0.0
15-Mar	316,416	2,435	0	252	10.38	4501	0	319,103	0.0
16-Mar	319,103	2,435	0	252	10.47	4513	0	321,791	0.0
17-Mar	321,791	2,435	0	252	10.56	4525	0	324,478	0.0
18-Mar	324,478	2,435	0	252	10.64	4537	0	327,166	0.0
19-Mar	327,166	2,435	0	252	10.73	4549	0	329,854	0.0
20-Mar	329,854	2,435	0	252	10.82	4560	0	332,541	0.0
21-Mar	332,541	2,435	0	252	10.91	4572	0	335,229	0.0
22-Mar	335,229	2,435	0	252	11.00	4584	0	337,916	0.0
23-Mar	337,916	2,435	0	252	11.09	4596	0	340,604	0.0
24-Mar	340,604	2,435	0	252	11.17	4608	0	343,292	0.0
25-Mar	343,292	2,435	0	252	11.26	4620	0	345,979	0.0
26-Mar	345,979	2,435	0	252	11.35	4632	0	348,667	0.0
27-Mar	348,667	2,435	0	252	11.44	4644	0	351,355	0.0
28-Mar	351,355	2,435	0	252	11.53	4656	0	354,042	0.0
29-Mar	354,042	2,435	0	252	11.61	4668	0	356,730	0.0
30-Mar	356,730	2,435	0	252	11.70	4680	0	359,417	0.0
31-Mar	359,417	2,435	0	252	11.79	4692	0	362,105	0.0
1-Apr	362,105	2,692	694	105	11.88	4704	5,081	359,127	7.3
2-Apr	359,127	2,692	692	105	11.78	4691	5,081	356,151	7.3
3-Apr	356,151	2,692	690	105	11.68	4678	5,081	353,176	7.4
4-Apr	353,176	2,692	688	105	11.59	4664	5,081	350,204	7.4
5-Apr	350,204	2,692	686	105	11.49	4651	5,081	347,234	7.4
6-Apr	347,234	2,692	684	105	11.39	4638	5,081	344,266	7.4
7-Apr	344,266	2,692	682	105	11.29	4625	5,081	341,299	7.4
8-Apr	341,299	2,692	680	105	11.20	4611	5,081	338,335	7.5
9-Apr	338,335	2,692	678	105	11.10	4598	5,081	335,372	7.5
10-Apr	335,372	2,692	676	105	11.00	4585	5,081	332,412	7.5
11-Apr	332,412	2,692	674	105	10.90	4572	5,081	329,453	7.5
12-Apr	329,453	2,692	673	105	10.81	4559	5,081	326,497	7.6
13-Apr	326,497	2,692	671	105	10.71	4546	5,081	323,542	7.6
14-Apr	323,542	2,692	669	105	10.61	4533	5,081	320,589	7.6
15-Apr	320,589	2,692	667	105	10.52	4520	5,081	317,638	7.6
16-Apr	317,638	2,692	665	105	10.42	4507	5,081	314,689	7.6
17-Apr	314,689	2,692	663	105	10.32	4494	5,081	311,742	7.7
18-Apr	311,742	2,692	661	105	10.23	4481	5,081	308,797	7.7
19-Apr	308,797	2,692	659	105	10.13	4468	5,081	305,854	7.7
20-Apr	305,854	2,692	657	105	10.03	4455	5,081	302,913	7.7
21-Apr	302,913	2,692	655	105	9.94	4442	5,081	299,973	7.8
22-Apr	299,973	2,692	653	105	9.84	4429	5,081	297,036	7.8
23-Apr	297,036	2,692	651	105	9.74	4416	5,081	294,100	7.8
24-Apr	294,100	2,692	650	105	9.65	4403	5,081	291,167	7.8
25-Apr	291,167	2,692	648	105	9.55	4391	5,081	288,235	7.8
26-Apr	288,235	2,692	646	105	9.46	4378	5,081	285,305	7.9
27-Apr	285,305	2,692	644	105	9.36	4365	5,081	282,377	7.9
28-Apr	282,377	2,692	642	105	9.26	4353	5,081	279,450	7.9
29-Apr	279,450	2,692	640	105	9.17	4340	5,081	276,526	7.9
30-Apr	276,526	2,692	638	105	9.07	4327	5,081	273,604	8.0

Date	Pond Volume in Gallons	Discharge Added in Gallons	Evaporation in Gallons	Precipitation in Gallons	Water Depth in Feet	Depth Specific Surface Area, ft^2	WAIV Evaporation in Gallons	Total Storage Required in Gallons	WAIV Enhanc. (x greater than conventional evap)

1-May	273,604	2,948	847	59	8.98	4315	6,759	269,005	8.0
2-May	269,005	2,948	843	59	8.82	4295	6,759	264,411	8.0
3-May	264,411	2,948	839	59	8.67	4275	6,759	259,820	8.1
4-May	259,820	2,948	835	59	8.52	4255	6,759	255,234	8.1
5-May	255,234	2,948	831	59	8.37	4236	6,759	250,651	8.1
6-May	250,651	2,948	827	59	8.22	4216	6,759	246,072	8.2
7-May	246,072	2,948	824	59	8.07	4197	6,759	241,497	8.2
8-May	241,497	2,948	820	59	7.92	4177	6,759	236,925	8.2
9-May	236,925	2,948	816	59	7.77	4158	6,759	232,358	8.3
10-May	232,358	2,948	812	59	7.62	4139	6,759	227,794	8.3
11-May	227,794	2,948	808	59	7.47	4119	6,759	223,234	8.4
12-May	223,234	2,948	805	59	7.32	4100	6,759	218,678	8.4
13-May	218,678	2,948	801	59	7.17	4081	6,759	214,125	8.4
14-May	214,125	2,948	797	59	7.02	4062	6,759	209,576	8.5
15-May	209,576	2,948	793	59	6.87	4043	6,759	205,031	8.5
16-May	205,031	2,948	790	59	6.73	4024	6,759	200,490	8.6
17-May	200,490	2,948	786	59	6.58	4005	6,759	195,952	8.6
18-May	195,952	2,948	782	59	6.43	3987	6,759	191,418	8.6
19-May	191,418	2,948	779	59	6.28	3968	6,759	186,888	8.7
20-May	186,888	2,948	775	59	6.13	3949	6,759	182,362	8.7
21-May	182,362	2,948	771	59	5.98	3930	6,759	177,839	8.8
22-May	177,839	2,948	768	59	5.83	3912	6,759	173,319	8.8
23-May	173,319	2,948	764	59	5.69	3893	6,759	168,804	8.8
24-May	168,804	2,948	760	59	5.54	3875	6,759	164,292	8.9
25-May	164,292	2,948	757	59	5.39	3856	6,759	159,783	8.9
26-May	159,783	2,948	753	59	5.24	3838	6,759	155,279	9.0
27-May	155,279	2,948	750	59	5.09	3820	6,759	150,778	9.0
28-May	150,778	2,948	746	59	4.95	3802	6,759	146,280	9.1
29-May	146,280	2,948	742	59	4.80	3783	6,759	141,786	9.1
30-May	141,786	2,948	739	59	4.65	3765	6,759	137,295	9.1
31-May	137,295	2,948	735	59	4.50	3747	6,759	132,808	9.2
1-Jun	132,808	3,204	876	77	4.36	3729	8,093	127,120	9.2
2-Jun	127,120	3,204	871	77	4.17	3706	8,093	121,437	9.3
3-Jun	121,437	3,204	866	77	3.98	3684	8,093	115,759	9.3
4-Jun	115,759	3,204	860	77	3.80	3661	8,093	110,087	9.4
5-Jun	110,087	3,204	855	77	3.61	3639	8,093	104,419	9.5
6-Jun	104,419	3,204	850	77	3.43	3616	8,093	98,757	9.5
7-Jun	98,757	3,204	845	77	3.24	3594	8,093	93,101	9.6
8-Jun	93,101	3,204	839	77	3.05	3572	8,093	87,449	9.6
9-Jun	87,449	3,204	834	77	2.87	3550	8,093	81,803	9.7
10-Jun	81,803	3,204	829	77	2.68	3528	8,093	76,162	9.8
11-Jun	76,162	3,204	824	77	2.50	3506	8,093	70,526	9.8
12-Jun	70,526	3,204	819	77	2.31	3484	8,093	64,895	9.9
13-Jun	64,895	3,204	814	77	2.13	3462	8,093	59,269	9.9
14-Jun	59,269	3,204	808	77	1.94	3440	8,093	53,649	10.0
15-Jun	53,649	3,204	803	77	1.76	3419	8,093	48,033	10.1
16-Jun	48,033	3,204	798	77	1.58	3397	8,093	42,423	10.1
17-Jun	42,423	3,204	793	77	1.39	3376	8,093	36,817	10.2
18-Jun	36,817	3,204	788	77	1.21	3355	8,093	31,217	10.3
19-Jun	31,217	3,204	783	77	1.02	3333	8,093	25,622	10.3
20-Jun	25,622	3,204	778	77	0.84	3312	8,093	20,031	10.4
21-Jun	20,031	3,204	773	77	0.66	3291	8,093	14,446	10.5
22-Jun	14,446	3,204	768	77	0.47	3270	8,093	8,865	10.5
23-Jun	8,865	3,204	764	77	0.29	3249	8,093	3,289	10.6
24-Jun	3,289	3,204	759	77	0.11	3228	8,093	0	10.7
25-Jun	0	3,204	756	77	0.00	3216	8,093	0	10.7
26-Jun	0	3,204	756	77	0.00	3216	8,093	0	10.7
27-Jun	0	3,204	756	77	0.00	3216	8,093	0	10.7
28-Jun	0	3,204	756	77	0.00	3216	8,093	0	10.7
29-Jun	0	3,204	756	77	0.00	3216	8,093	0	10.7
30-Jun	0	3,204	756	77	0.00	3216	8,093	0	10.7
1-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
2-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
3-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
4-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
5-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
6-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
7-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
8-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
9-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
10-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
11-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
12-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
13-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
14-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
15-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
16-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
17-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
18-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
19-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
20-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
21-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
22-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
23-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
24-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
25-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
26-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
27-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
28-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
29-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
30-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7
31-Jul	0	3,204	670	176	0.00	3216	7,174	0	10.7

Date	Pond Volume in Gallons	Discharge Added in Gallons	Evaporation in Gallons	Precipitation in Gallons	Water Depth in Feet	Depth Specific Surface Area, ft^2	WAIV Evaporation in Gallons	Total Storage Required in Gallons	WAIV Enhanc. (x greater than conventional evap)
1-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
2-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
3-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
4-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
5-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
6-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
7-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
8-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
9-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
10-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
11-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
12-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
13-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
14-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
15-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
16-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
17-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
18-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
19-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
20-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
21-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
22-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
23-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
24-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
25-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
26-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
27-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
28-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
29-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
30-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
31-Aug	0	2,948	595	217	0.00	3216	6,371	0	10.7
1-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
2-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
3-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
4-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
5-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
6-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
7-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
8-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
9-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
10-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
11-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
12-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
13-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
14-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
15-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
16-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
17-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
18-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
19-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
20-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
21-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
22-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
23-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
24-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
25-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
26-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
27-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
28-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
29-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
30-Sep	0	2,692	495	184	0.00	3216	5,302	0	10.7
1-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
2-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
3-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
4-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
5-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
6-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
7-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
8-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
9-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
10-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
11-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
12-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
13-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
14-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
15-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
16-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
17-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
18-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
19-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
20-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
21-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
22-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
23-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
24-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
25-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
26-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
27-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
28-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
29-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
30-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7
31-Oct	0	2,435	329	108	0.00	3216	3,518	0	10.7

GHD Inc.

7600 North 16th Street
Suite 205

Phoenix, Arizona 85020
T: 602.216.7200 F: 602.216.7201 W: www.ghd.com

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Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date