N RO By-product Disposal Technical Memoranda

JORDAN VALLEY WATER CONSERVANCY DISTRICT

RO By-product Disposal Technical Memoranda

Alt #	Memo #	Disposal Alternative	Author	Issues/Criteria to be Addressed
	1	Alternative Treatment Technologies (Kathy Van Dame)	Bryant Bench	Feasible TDS Reduction Technologies
	2	Secondary Water Use (Bruce Waddell)	Richard Bay	Consent Decree Requirements, Secondary Water Standards
D	3	Discharge to GSL	Mark Atencio	Cost, Legality
E	4	Discharge to KUCC GSL Outfall Pipeline	Mark Atencio	Cost, Legality
F	5	Zone B to KUCC Tailings Impoundment	Mark Atencio	Cost (extra RO train, loss of economy of scale)
H	6	Distillation	Tom Seacord	NPV Cost, Environmental Soundness, Technically Feasible
H	7	Distillation - disposal of salts	Gary Colgan	Cost,Environmental Soundess, Legality
I	8	Zone B to Tailings Pipeline	Mark Atencio	Cost
F.1	9	Zone B to Tailings Impoundment, Lost Use to GSL	Mark Atencio	Cost
F.2	10	Zone B to Tailings Impoundment, Lost Use to KUCC GSL Outfall	Mark Atencio	Cost
F.3	11	Zone B to Tailings Impoundment, Lost Use Distillation	Mark Atencio, Tom Seacord	Cost
I.1	12	Zone B to Tailings Pipeline, Lost Use to GSL	Mark Atencio	Cost
I.2	13	Zone B to Tailings Pipeline, Lost Use to KUCC GSL Outfall	Mark Atencio	Cost
I.3	14	Zone B to Tailings Pipeline, Lost Use Distillation	Mark Atencio, Tom Seacord	Cost
	15	Water Cost Methodologies	Richard Bay	Wholesale Cost Issues ($/AF, source cost, conveyance cost)
	16	Discharge of Zone B By-product to KUCC Facilties Perpetually	Brian Vinton	Tailings Pipeline, Tailings Impoundment, Tailings Outfall
	18	Selenium Removal Treatment	Bryant Bench	Potential Scaling of the Process
	19	Deep Aquifer Hydrogeology	Bruce Kaliser	Deep Aquifer Injection Concerns

N.1 Alternative Treatment Technologies

carollo engineers

TECHNICAL MEMORANDUM

MEMO No: 1

SUBJECT: Evaluation of Disposal of Reverse Osmosis By-product
Selection of Reverse Osmosis

TO: Stakeholder Forum

COPIES: Richard Bay, JVWCD
Paula Doughty, KUCC
Douglas Bacon, UDEQ

FROM: Bryant Bench

DATE: April 13, 2004

EXECUTIVE SUMMARY

Reverse osmosis (RO) membrane treatment is the selected process for treating the Southwest groundwater supply to remove elevated levels of sulfate and total dissolved solids (TDS). Other potential processes including electrodialysis reversal and ion exchange would not be as efficient nor effective as RO in meeting water treatment objectives and project goals for costs, reliability, and operations. RO membrane treatment of Southwest groundwater has been successfully demonstrated with treatability studies and pilot-scale treatment investigations.

BACKGROUND

Mining activities in southwestern Salt Lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund, which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate	**TDS Concentration**	**Selenium Concentration**
	(cfs)	**(mg/L)**	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,200 -8,300**	**32-47**

PURPOSE

The purpose of this memo is to explain why reverse osmosis is the appropriate membrane process technology for treating the sulfate contaminated Southwest groundwater supply.

AUTHOR'S CREDENTIALS

Bryant Bench is a registered Professional Engineer specializing in the area of water treatment process selection and facility design. Mr. Bench holds a Bachelors degree in Civil Engineering and a Masters degree in Environmental Engineering. For the past 25 years, Mr. Bench has been working as a consulting engineer for public and private water utilities involved in the planning, design, and construction of public water treatment plants. He has provided engineering services for most of the major water

treatment plants located in the Salt Lake Valley and along the Wasatch front. Mr. Bench has engineered advanced treatment technologies for water treatment including high-rate conventional treatment, managed filtration, ozonation, ultraviolet (UV) light disinfection, and reverse osmosis and other membrane separation processes.

TREATMENT OBJECTIVES

Treatment process selection is based upon raw water quality and finished water objectives. The Southwest groundwater contains elevated levels of sulfate and total dissolved solids and requires treatment. The finished or treated water must meet drinking water standards for TDS and sulfates and must be compatible with other municipal drinking water supplies. Specific treatment process objectives for the Southwest groundwater are as follows:

- Reduce sulfate concentration from 800 mg/L to below 500 mg/L.
- Reduce TDS concentration from 1600 mg/L to 250 mg/L.
- Meet all other drinking water quality standards.
- Process and facilities must be cost effective.
- Process must be reliable.

PROCESS SELECTION

Reverse Osmosis is the selected treatment process for restoring the beneficial use of the Southwest groundwater and producing municipal drinking water. RO is a proven, established treatment technology for TDS and sulfate removal. Project advantages for RO treatment include:

- RO is very effective at removing total dissolved solids including sulfate.
- RO is much more efficient in terms of waste generation and recycle requirements compared with other ion removal technologies. An 80% (Zone B) and 85% (Lost Use) recovery rate has been successfully demonstrated for RO treatment of Southwest groundwater.
- RO costs less to construct and operate than other TDS.

Over the past year, bench-scale and pilot-scale treatment studies have been successfully conducted to demonstrate the efficacy and cost effectiveness of reverse osmosis for meeting the specific water quality and project objectives.

Alternative processes to RO for meeting project treatment objectives are limited. Two potential processes are electrodialysis reversal (EDR) and ion exchange (IE). The problem with ion exchange is that, by its name, a simple exchange of one ion for another does not result in a net reduction in TDS. It would be possible to reduce the sulfate concentration, but IE would not reduce TDS to the required treatment level of

250 mg/L. IE also generates a brine waste from media regeneration that would have to be treated for proper recycle and disposal.

Electrodialysis reversal is normally only considered when RO is not practical due to uncontrollable membrane fouling caused by a high mineral and/or silicate content in the feed water. EDR normally costs 50% more than RO and EDR recovery rates are much less efficient than for RO membranes.

Coagulation and chemical precipitation processes are also not possible for sulfate and TDS removal. A lime softening precipitation process could remove the majority of calcium and magnesium ions but such removal would not adequately reduce TDS or sulfate levels to below project goals.

Based upon the treatment objectives and the successful results of previous studies, it is clear that RO is the correct process for treating the Southwest groundwater for TDS and sulfate reduction and for producing drinking water from this supply.

N.2 Secondary Water Use

Jordan Valley Water Conservancy District

TECHNICAL MEMORANDUM

MEMO No: 2

SUBJECT: **Secondary Water Deliveries Alternative**
Zone B/Lost Use Reverse Osmosis By-Product Disposal Alternatives Southwest Jordan Valley Groundwater Remediation Project Stakeholders Forum

TO: Dr. Dianne R. Nielson, NRD Trustee

COPIES: Mark Atencio, JVWCD
Paula Doughty, KUCC
Douglas Bacon, UDEQ

FROM: Richard Bay, JVWCD

DATE: April 8, 2004

EXECUTIVE SUMMARY

A secondary water delivery usage of the extracted Zone B groundwater has been proposed. A comparison with the Consent Decree and with the Joint Proposal indicates four areas of conflict:

1. The Consent Decree contemplates producing municipal quality water through treatment of extracted, contaminated groundwater.

2. The Consent Decree defines municipal quality water as having total dissolved solids (TDS) concentrations not exceeding 500 – 800 mg/L. The Zone B groundwater has TDS concentrations of about 1600 mg/L.

3. An important Utah water quality standard for irrigation uses is TDS not exceeding 1200 mg/L. The Zone B groundwater exceeds this standard.

4. Applying extracted, contaminated groundwater for irrigation uses would create contaminated return flows which could accelerate the spread of aquifer contamination into new areas.

BACKGROUND:

Mining activities in southwestern Salt Lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

Component	**Flow Rate**	**TDS Concentration**	**Selenium Concentration**
	(cfs)	**(mg/L)**	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,240**	**38 - 47**

CREDENTIALS, EXPERTISE AND EXPERIENCE OF AUTHOR

I am a registered professional engineer with a BS degree in civil engineering from the University of Utah. I am employed as the Chief Engineer and Assistant General Manager of the Jordan Valley Water Conservancy District. I have been involved with southwest groundwater treatment issues since 1990, and have served on the EPA Technical Review Committee. I assisted in negotiating the 1995 Consent Decree and have familiarity with that document.

PURPOSE

During the second Stakeholders Forum meeting, Bruce Waddell (U. S. Fish and Wildlife Service) proposed that extracted groundwater be used for secondary water system deliveries, instead of RO treatment for municipal deliveries. Although this agenda was to consider alternatives for disposal of RO by-product water, the Forum asked that I meet with Bruce to further consider this alternative.

DISCUSSION OF SECONDARY WATER CONCEPT

I met with Bruce Waddell on April 2, 2004, together with Paula Doughty and Kelly Payne (KUCC) and Mark Atencio (JVWCD). We further explored the concept Bruce had suggested. Bruce suggested that the water extracted from Zone B be delivered as secondary water supplies to the Affected Municipalities. In making the secondary deliveries, Bruce explained, other municipal water supplies would be postponed and offset, to be available later for deliveries to the public.

ANALYSIS OF SECONDARY WATER CONCEPT

After discussing the concept with Bruce and the others in attendance, I evaluated the secondary water concept in comparison with the 1995 Consent Decree and with the JVWCD / KUCC Joint Proposal. I have concluded that the secondary water concept is in conflict with purposes, requirements and expectations of the Consent Decree and of the Joint Proposal. Those conflicts are explained in the following paragraphs.

1. MUNICIPAL QUALITY WATER PRODUCTION

The secondary water concept conflicts with the Consent Decree requirement and expectation that municipal quality be produced. Section IV.D.2.b requires that in using the trust fund, and specifically the letter of credit, "...at the option of the Trustee, be converted to cash which shall be used by the Trustee to restore, replace, or acquire the equivalent of the natural resource for the benefit of the public in the Affected Area..." The equivalent of the natural resource is a municipal water supply from the underground aquifer.

The Consent Decree provides the ability for Kennecott to propose a project under which it provides municipal quality water, and gains reductions against the letter of credit when it constructs a project. Section IV.D.2.b. of the Consent Decree allows for this system "if Kennecott provides and delivers municipal quality water through treatment of contaminated water to a system of a purveyor of municipal and industrial (M&I) water in a manner acceptable to the Trustee..."

2. MUNICIPAL WATER QUALITY STANDARD

Section I.D.defines: "Municipal quality water means water with chemical concentrations at or below 250 mg/Lsulfate and 500 mg/L TDS for the area west of the Welby Canal or 250 mg/L sulfate and 800 mg/L TDS for the area east of the Welby Canal and which otherwise meets primary drinking water standards for other contaminants."

The proposal for secondary water deliveries would suggest Zone B groundwater, with TDS concentrations of about 1600 mg/L be delivered for irrigation of large outdoor areas. As can be seen above, this is in conflict with the defined term for municipal quality water.

3. STANDARD FOR IRRIGATION AND SECONDARY USES

The Utah water quality standard for irrigation purposes is a TDS concentration of 1200 mg/L. This is the standard to which the District is held for the Jordan River and storm drain systems which discharge to canals are the Jordan River. Therefore, the Zone B groundwater with a TDS concentration of 1600 mg/L is in conflict with this important standard.

4. PREVENT OR REDUCE SPREAD OF AQUIFER CONTAMINATION

An important requirement of the Consent Decree, when utilizing the irrevocable letter of credit for a project to treat contaminated groundwater for producing M&I water is to prevent or reduce the spread of aquifer contamination. This standard is explained in Section IV.D.2.b.ii). The proposal for secondary use would simply reapply much of the untreated, contaminated groundwater to the land surface, with return flows back to the groundwater system. The use of the secondary water would be uncontrolled throughout areas that could then lead to spreading the contamination into uncontaminated areas. This appears to be in direct conflict with an important standard of the Consent Decree.

N.3 Discharge to Great Salt Lake

Jordan Valley Water Conservancy District

TECHNICAL MEMORANDUM

MEMO No: 3

SUBJECT: Cost Estimate for Disposal of Reverse Osmosis By-product
Alternative D - Discharge to Great Salt Lake

TO: Stakeholder Forum

COPIES: Richard Bay, JVWCD
Paula Doughty, KUCC
Douglas Bacon, UDEQ

FROM: Mark Atencio

DATE: April 13, 2004

EXECUTIVE SUMMARY

This alternative consists of pumping the Zone B and Lost Use Roby-product to the south arm of the Great Salt Lake in a 23.7 mile long, 10-inch diameter pipeline using three pump stations. The net present value cost for disposal of Zone B and Lost Use RO by-product is $9.7 million. This includes a capital cost of $9.3 million and an operation cost of $20,000 per year.

BACKGROUND

Mining activities in southwestern Salt Lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate	TDS Concentration	Selenium Concentration
	(cfs)	(mg/L)	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,200 -8,300**	**32-47**

PURPOSE

The purpose of this memo is to describe the net present value cost of disposing of Zone B and Lost Use RO by-product to the Great Salt Lake in a pipeline from the Zone B Lost Use Treatment Plant in West Jordan to the south arm of Great Salt Lake near Salt Air.

AUTHOR'S CREDENTIALS

I am a registered professional engineer specializing in the area of water resources. I have completed Bachelor and Master of Science degrees in civil engineering. Following graduation I have been working at Jordan Valley Water Conservancy District as a civil engineer. My current title is senior engineer, in which I fill project management and supervisory roles. I have been studying and investigating various membrane and TDS reduction treatments for eight years. I have completed a number of well drilling and construction projects. I have completed three years of pilot testing using various membrane and reverse osmosis processes. I have been filling the role of a technical

engineer for the District on the Southwest Groundwater Remediation and Treatment Project since 1999.

DESCRIPTION OF ALTERNATIVE

See the attached Drawing for a visual representation of the alternative.

This alternative consists of a 23.7 mile long, 10-inch diameter PVC pipeline constructed from the Zone B Lost Use Reverse Osmosis (RO) Plant in West Jordan to the Great Salt Lake near Salt Air. Discharge into the lake would be through a new outfall pipeline. Three pump stations would be required; one at the RO plant, the second at 7 to 8 miles from the plant, and the third at 15 to 16 miles from the plant.

SCALING CONCERNS

The RO by-product contains a high concentration of salts, consisting mostly of calcium sulfate (gypsum) and calcium carbonate (calcite IE Timpanogos Cave). The solutions are super-saturated and on the verge of precipitating. This means that if the fluid were to stop moving a scale would start to form on the interior of the pipeline. In the RO plant an antiscalant chemical prevents scale formation; however, the chemical does not last for more than approximately 24 hours.

The formation of scale or precipitation of salts is the same process that occurs in the Great Salt Lake as the tributaries to the lake bring in salts into the lake. In this case the salts are concentrated due to evaporation until the point that saturation is reached and the salts form particles (precipitation) and settle to the bottom. In order to prevent this type of scaling from occurring, the pipeline needs to be kept in continuous operation or drained.

PIPELINE MATERIAL

Polyvinyl chloride (PVC) was selected as material of choice after considering ductile iron, steel, high density polypropylene (HDPE), and PVC. This took into account the actual internal diameter of the various types of pipeline, the working pressure of the pipelines, the hydraulic characteristics of the pipeline materials (friction factor) and the construction cost. Each pipeline material option was evaluated in a large spreadsheet. A copy of this spreadsheet is attached to this memo. The limitations of the pipeline material options considered affected the number and cost of pump stations required, the pressure loss required to be overcome by a pump, pipeline construction cost, and pump station operating cost.

PIPELINE DIAMETER

Six-inch, 8-inch, 10-inch, and 12-inch diameter pipelines were evaluated in the spreadsheet identified above. The size of the pipeline options evaluated affected the pressure loss (smaller pipe = higher pressure loss), the detention time in the pipeline (larger pipe = longer time in transit), pipeline construction cost, and pump station operating cost.

PIPELINE ALIGNMENT

Multiple alignments were considered for this alternative. First, an alignment extending westward, then northward was considered. Second a northern then westward alignment was evaluated. The two alignments were of comparable length. Due to the topography the first alignment required additional pumping to move the fluid uphill, then downhill towards Great Salt Lake. Both alignments utilized property owned by Kennecott Utah Copper Corporation (KUCC) along the east and north sides of its tailings impoundment in the northwest section of Salt Lake County.

SELECTION OF PREFERRED PIPELINE OPTION

Selection of the preferred pipeline option took into account the concerns with scaling and the effects of pipeline material, diameter, and alignment on the capital and operating cost.

The alignment selected for this alternative utilizes public right-of-way and private property, most of which is owned by KUCC. The alignment generally follows an elevation contour line to the north along 1300 West and then to the west along 1300 South to the KUCC tailings impoundment. The alignment then extends to the north and west until reaching Great Salt Lake. This alignment allows for utilizing existing right–of-way corridors. This alignment stays at almost the same elevation along its length. The alignment also avoids increasing in elevation, thereby avoiding additional pumping cost and making it easier to drain the pipeline with a backup pump in the event of a power failure.

Selection of the a 10-inch diameter PVC pipeline with three pump stations allows for the concerns expressed in this memo to be met will obtaining the lowest capital and net present value cost.

REQUIRED FACILITIES

- 23.7 mile long, 10-inch diameter PVC pipeline
- 3 pump stations
- Outfall pipeline

LEGALITY

The legality of this alternative was considered. A review of existing information indicated that a permit for discharge of RO by-product to GSL could be issued which would be protective of Great Salt Lake.

The water quality of the RO by-product was compared against standards for the Jordan River. All of the water quality parameters of the by-product were below the Jordan River standards, with the exception of total dissolved solids (TDS) and selenium. Comparing the TDS of the by-product (8,300) to Great Salt Lake (100,000 plus) it was apparent that TDS in the by-product would not be a concern. In order to understand if the selenium concentration in the by-product would be a concern I researched the files of the Utah State Division of Water Quality. Although selenium is an essential trace element, it has the potential to cause harm to humans or wildlife at very high concentrations. There is an existing permit for a discharge from KUCC to Great Salt Lake with a 54 µg/L (ppb) selenium limitation. The files of the Division contained substantial documentation of the methods used to derive this limitation. The limit required by the Division was based on limiting selenium absorption by algae in Great Salt Lake, which algae are consumed by brine shrimp, which shrimp are then consumed by waterfowl. By limiting selenium accumulation in Great Salt Lake algae the Division of Water Quality is able to prevent reproductive failure in waterfowl that consume Great Salt Lake brine shrimp.

The files also contained concerns expressed by others regarding the permit limitations and responses to these concerns. The issue of selenium has been well researched and a permit limit was already established. The conclusion of my research was that a selenium permit limit for discharge into Great Salt Lake on a firm basis was already established. Comparing the RO by-product selenium concentration of 32-47 µg/L against an existing permit limitation of 54 µg/L indicates that Zone B and Lost Use RO by-product will meet a limit for discharge to Great Salt Lake.

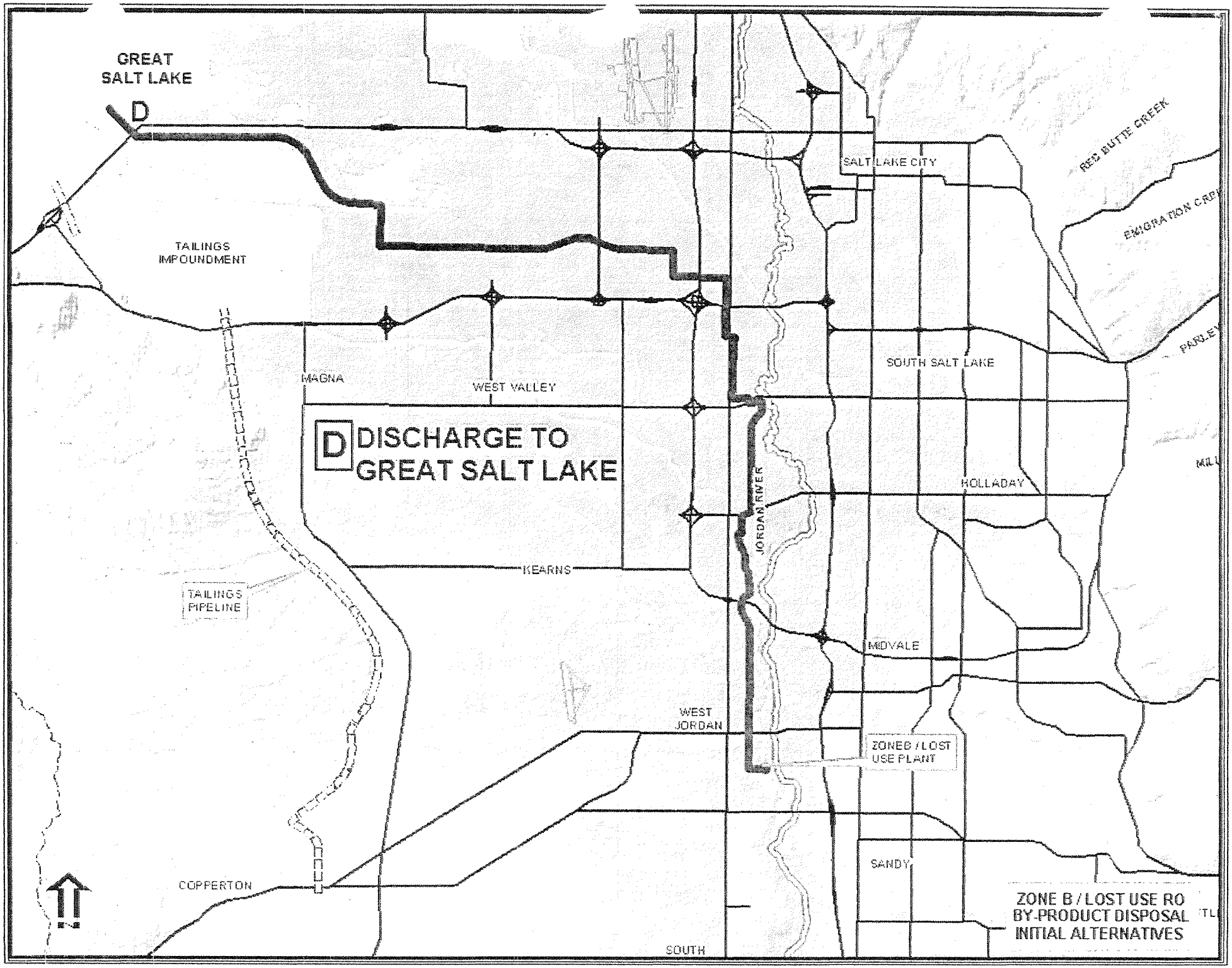
ASSUMPTIONS

- Pump Efficiency: 85%
- Motor Efficiency: 90%
- Pump Station Capital Cost: $500,000 each
- NPV interest rate: 4%
- 25 feet wide easement cost: $14.35/ foot ($50,000/acre)
- Pipeline in roadways installation cost: $47.40/ft
- Pipeline in open areas installation cost: $23.45
- Pipeline costs from two contractors and MWH Engineers
- RO plant operates 330 days per year
- Power Cost $0.055/kW hr

COST ESTIMATE

The cost estimate for this alternative took into account the size of the pipeline, number of pump stations, pumping costs, length of pipeline, length of pipeline in roadways, length of pipeline in open areas, easement acquisition costs, dewatering costs, and engineering costs. The net present value cost for disposal of Zone B and Lost Use RO by-product is $9.7 million. This includes a capital cost of $9.3 million and an operation cost of $20,000 per year.

See the attached spreadsheet for details and calculations of the cost estimate.


GREAT SALT LAKE
D
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MAGNA
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TAILINGS PIPELINE
KEARNS
COPPERTON
SALT LAKE CITY
RED BUTTE CREEK
EMIGRATION CREEK
SOUTH SALT LAKE
HOLLADAY
JORDAN RIVER
MIDVALE
WEST JORDAN
ZONE B / LOST USE PLANT
SANDY
SOUTH
ZONE B / LOST USE RO BY-PRODUCT DISPOSAL INITIAL ALTERNATIVES

SOUTHWEST GROUNDWATER
REVERSE OSMOSIS BY-PRODUCT DISPOSAL OPTIONS

Alternative A
Discharge to GSL

No.	Alignment Descriptions	Project Yield (AF/yr)	Pipeline Material	Pipeline Actual Inside Diameter (Inches)	Zone A Yield (AF/yr)	Zone B Yield (AF/yr)	Zone B Production Rate (cfs)	Lost Use Yield (AF/yr)	Lost Use Production Rate (cfs)	Future Shallow Wells Yield (AF/yr)	Future Shallow Wells Production Rate (cfs)
A	1300 West, 1300 South, 8000 West, KUCC	9300	PVC C-909	10.27	3500	3500	5.35	2300	3.51	0	0

By-product Flow Rate (cfs)	Number of Pipelines (#)	Pressure Rating (psi)	Pipeline Hazen Williams C-factor	Pipeline in Roadways Length (ft)	Roadway Pipeline Unit Cost ($/ft)	Pipeline In Open Field Length (ft)	Open Pipeline Unit Cost ($/ft)	Total Pipeline Length (ft)	Total Pipeline Length (miles)	Dewatering Length (ft)	Dewatering Unit Cost ($/ft)
1.74	1	200	120	90,290	47.40	34,850	23.45	125,140	23.70	42,770	2.00

Pipeline Boring & Additional Costs ($)	Easement Length Required (ft)	Easement Cost ($)	Total Pipeline Cost ($mill)	Velocity (ft/sec)	Detention Time OK? (hrs)	Max Head Loss between Pump Stations (ft)	Max Distance between Pump Stations (ft)	Max Distance between Pump Stations (miles)	Calculated Number of Pump Stations (ft)	Actual Number of Pump Stations (ft)	Total Pump Station Cost ($mill)
0.00	1,850	26,548	5.209	3.03	11.5	416	103,407	19.6	1.2	2	1.000

Total Const Cost ($mill)	Eng Cost ($mill)	20% Contingency ($mill)	**Total Capital Cost ($mill)**	Discharge Hydraulic Gradeline (ft)	Static Pump Lift (ft)	Head Loss (ft)	Total Pump Lift (ft)	Pump Size (HP)	**Annual Pumping Cost ($)**	**NPV of Pumping Costs ($mill)**	**Total NPV Cost ($mill)**
6.209	0.931	2.142	**9.283**	4,215	-267	503	236	61	**19,986**	**0.396**	**9.678**

N.4 Discharge to KUC GSL Outfall Pipeline

Jordan Valley Water Conservancy District

TECHNICAL MEMORANDUM

MEMO No: 4

SUBJECT: Cost Estimate for Disposal of Reverse Osmosis By-product
Alternative E - Discharge to KUCC GSL Outfall

TO: Stakeholder Forum

COPIES: Richard Bay, JVWCD
Paula Doughty, KUCC
Douglas Bacon, UDEQ

FROM: Mark Atencio

DATE: April 13, 2004

EXECUTIVE SUMMARY

This alternative consists of pumping the Zone B and Lost Use RO by-product to the existing Kennecott Utah Copper Corporation (KUCC) tailings impoundment outfall to Great Salt Lake in a 26.7 mile long, 10-inch diameter pipeline using three pump stations. The net present value cost for disposal of Zone B and Lost Use RO by-product is $10.4 million. This includes a capital cost of $9.9 million and an operation cost of $25,000 per year.

BACKGROUND

Mining activities in southwestern Salt Lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate	TDS Concentration	Selenium Concentration
	(cfs)	(mg/L)	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,200 -8,300**	**32-47**

PURPOSE

The purpose of this memo is to describe methods used to estimate the cost of disposing of Zone B and Lost Use RO by-product to the KUCC tailings impoundment outfall to the Great Salt Lake in a pipeline from the Zone B Lost Use Treatment Plant in West Jordan.

AUTHOR'S CREDENTIALS

I am a registered professional engineer specializing in the area of water resources. I have completed Bachelor and Master of Science degrees in civil engineering. Following graduation I have been working at Jordan Valley Water Conservancy District as a civil engineer. My current title is senior engineer, in which I fill project management and supervisory roles. I have been studying and investigating various membrane and TDS

reduction treatments for eight years. I have completed a number of well drilling and construction projects. I have completed three years of pilot testing using various membrane and reverse osmosis processes. I have been filling the role of a technical engineer for the District on the Southwest Groundwater Remediation and Treatment Project since 1999.

DESCRIPTION OF ALTERNATIVE

See the attached Drawing of Alternative E for a visual representation of the alternative.

This alternative consists of a 26.7 mile long, 10-inch diameter PVC pipeline constructed from the Zone B Lost Use Reverse Osmosis (RO) Plant in West Jordan to the existing KUCC tailings impoundment outfall to Great Salt Lake. Discharge into the lake would be through a new outfall pipeline. Three pump stations would be required; one at the RO plant, the second at 7 to 8 miles from the plant, and the third at 16 to 17 miles from the plant.

SCALING CONCERNS

The RO by-product contains a high concentration of salts, consisting mostly of calcium sulfate (gypsum) and calcium carbonate (calcite IE Timpanogos Cave). The solutions are super-saturated and on the verge of precipitating. This means that if the fluid were to stop moving a scale would start to form on the interior of the pipeline. In the RO plant an antiscalant chemical prevents scale formation; however, the chemical does not last for more than approximately 24 hours.

The formation of scale or precipitation of salts is the same process that occurs in the Great Salt Lake as the tributaries to the lake bring in salts into the lake. In this case the salts are concentrated due to evaporation until the point that saturation is reached and the salts form particles (precipitation) and settle to the bottom. In order to prevent this type of scaling from occurring, the pipeline needs to be kept in continuous operation or drained.

PIPELINE MATERIAL

Polyvinyl chloride (PVC) was selected as material of choice after considering ductile iron, steel, high density polypropylene (HDPE), and PVC. This took into account the actual internal diameter of the various types of pipeline, the working pressure of the pipelines, the hydraulic characteristics of the pipeline materials (friction factor) and the construction cost. Each pipeline material option was evaluated in a large spreadsheet. A copy of this spreadsheet is attached to this memo. The limitations of the pipeline material options considered affected the number and cost of pump stations required, the

pressure loss required to be overcome by a pump, pipeline construction cost, and pump station operating cost.

PIPELINE DIAMETER

Six-inch, 8-inch, 10-inch, and 12-inch diameter pipelines were evaluated in the spreadsheet identified above. The size of the pipeline options evaluated affected the pressure loss (smaller pipe = higher pressure loss), the detention time in the pipeline (larger pipe = longer time in transit), pipeline construction cost, and pump station operating cost.

PIPELINE ALIGNMENT

Multiple alignments were considered for this alternative. First, an alignment extending westward, then northward was considered. Second a northern then westward alignment was evaluated. The two alignments were of comparable length. Due to the topography the first alignment required additional pumping to move the fluid uphill, then downhill towards Great Salt Lake. Both alignments utilized property owned by Kennecott Utah Copper Corporation (KUCC) along the east and north sides of its tailings impoundment in the northwest section of Salt Lake County.

SELECTION OF PREFERRED PIPELINE OPTION

Selection of the preferred pipeline option took into account the concerns with scaling and the effects of pipeline material, diameter, and alignment on the capital and operating cost.

The alignment selected for this alternative utilizes public right-of-way and private property, most of which is owned by KUCC. The alignment generally follows an elevation contour line to the north along 1300 West and then to the west along 1300 South to the KUCC tailings impoundment. The alignment then extends to the north and west until reaching Great Salt Lake. This alignment allows for utilizing existing right–of-way corridors. This alignment stays at almost the same elevation along its length. The alignment also avoids increasing in elevation, thereby avoiding additional pumping cost and making it easier to drain the pipeline with a backup pump in the event of a power failure.

Selection of the a 10-inch diameter PVC pipeline with three pump stations allows for the concerns expressed in this memo to be met will obtaining the lowest capital and net present value cost.

REQUIRED FACILITIES

- 23.7 mile long, 10-inch diameter PVC pipeline
- 3 pump stations
- Outfall pipeline

LEGALITY

The legality of this alternative was considered. A review of existing information indicated that a permit for discharge of RO by-product to GSL could be issued which would be protective of Great Salt Lake.

The water quality of the RO by-product was compared against standards for the Jordan River. All of the water quality parameters of the by-product were below the Jordan River standards, with the exception of total dissolved solids (TDS) and selenium. Comparing the TDS of the by-product (8,300) to Great Salt Lake (100,000 plus) it was apparent that TDS in the by-product would not be a concern. In order to understand if the selenium concentration in the by-product would be a concern I researched the files of the Utah State Division of Water Quality. Although selenium is an essential trace element, it has the potential to cause harm to humans or wildlife at very high concentrations. There is an existing permit for a discharge from KUCC to Great Salt Lake with a 54 µg/L (ppb) selenium limitation. The files of the Division contained substantial documentation of the methods used to derive this limitation. The limit required by the Division was based on limiting selenium absorption by algae in Great Salt Lake, which algae are consumed by brine shrimp, which shrimp are then consumed by waterfowl. By limiting selenium accumulation in Great Salt Lake algae the Division of Water Quality is able to prevent reproductive failure in waterfowl that consume Great Salt Lake brine shrimp.

The files also contained concerns expressed by others regarding the permit limitations and responses to these concerns. The issue of selenium has been well researched and a permit limit was already established. The conclusion of my research was that a selenium permit limit for discharge into Great Salt Lake on a firm basis was already established. Comparing the RO by-product selenium concentration of 32-47 µg/L against an existing permit limitation of 54 µg/L indicates that Zone B and Lost Use RO by-product will meet a limit for discharge to Great Salt Lake.

Discussions with the Division of Water Quality have led to a conclusion that if this alternative were selected, the District would apply for a new discharge permit. This permit would allow the discharge of Zone B and Lose Use by-product to be discharged into Great Salt Lake via the existing KUCC tailings impoundment outfall.

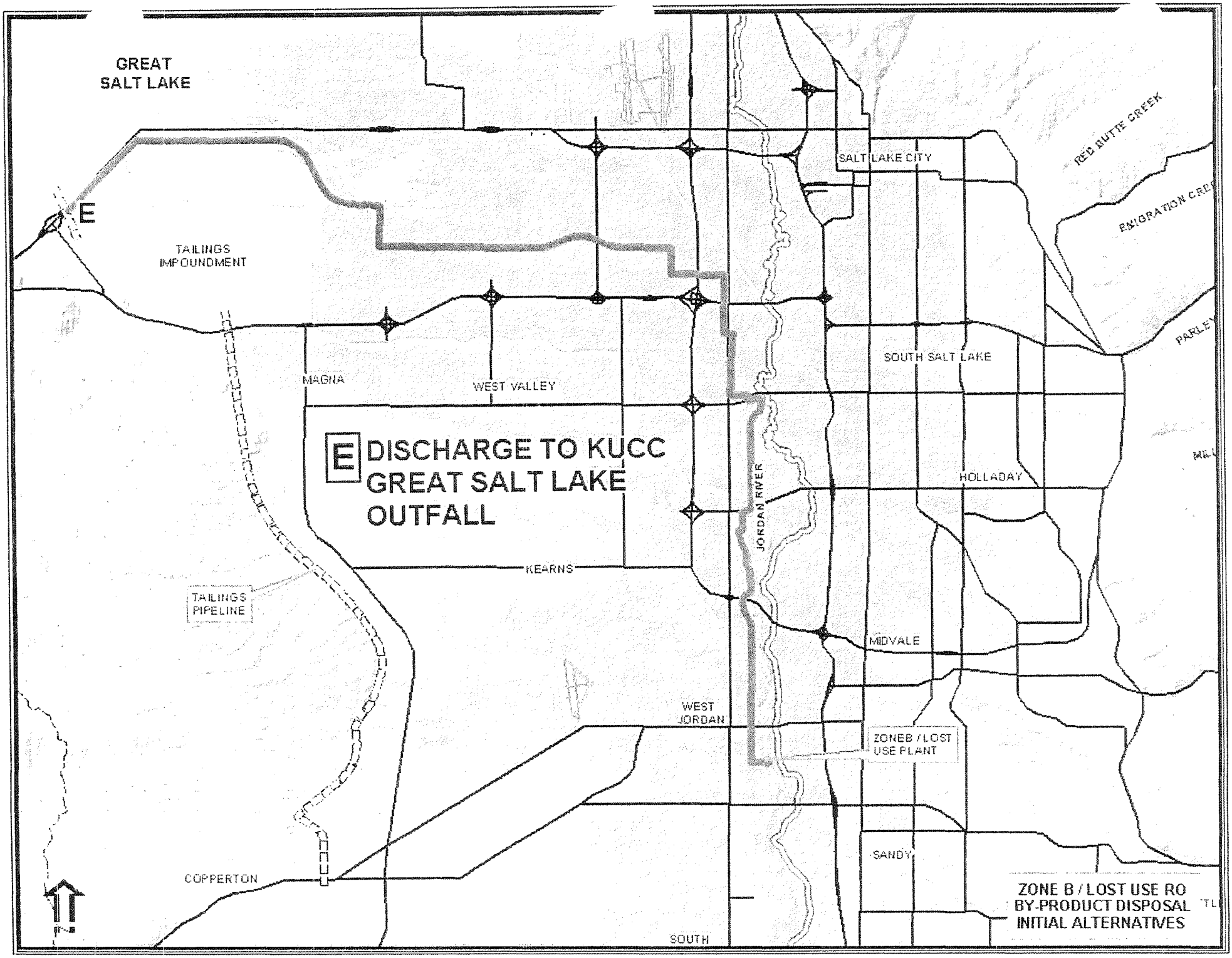
ASSUMPTIONS

- Pump Efficiency: 85%
- Motor Efficiency: 90%
- Pump Station Capital Cost: $500,000 each
- NPV interest rate: 4%
- 25 feet wide easement cost: $14.35/ foot ($50,000/acre)
- Pipeline in roadways installation cost: $47.40/ft
- Pipeline in open areas installation cost: $23.45
- Pipeline costs from two contractors and MWH Engineers
- RO plant operates 330 days per year
- Power Cost $0.055/kW hr

COST ESTIMATE

The cost estimate for this alternative took into account the size of the pipeline, number of pump stations, pumping costs, length of pipeline, length of pipeline in roadways, length of pipeline in open areas, easement acquisition costs, dewatering costs, and engineering costs. The net present value cost for disposal of Zone B and Lost Use RO by-product is $10.4 million. This includes a capital cost of $9.9 million and an operation cost of $25,000 per year.

See the attached spreadsheet for details and calculations of the cost estimate.


GREAT
SALT LAKE
E
TAILINGS
IMPOUNDMENT
MAGNA
WEST VALLEY
E DISCHARGE TO KUCC
GREAT SALT LAKE
OUTFALL
KEARNS
TAILINGS
PIPELINE
COPPERTON
SALT LAKE CITY
RED BUTTE CREEK
SOUTH SALT LAKE
JORDAN RIVER
HOLLADAY
MIDVALE
WEST
JORDAN
ZONE B / LOST
USE PLANT
SANDY
SOUTH
ZONE B / LOST USE RO
BY-PRODUCT DISPOSAL
INITIAL ALTERNATIVES

SOUTHWEST GROUNDWATER
REVERSE OSMOSIS BY-PRODUCT DISPOSAL OPTIONS

Alternative E
Discharge to KUCC GSL Outfall

Alt. No.	Disposal Alternative	Project Yield (AF/yr)	Pipeline Material	Pipeline Actual Inside Diameter (Inches)	Zone A Yield (AF/yr)	Zone B Yield (AF/yr)	Zone B Production Rate (cfs)	Lost Use Yield (AF/yr)	Lost Use Production Rate (cfs)	Future Shallow Wells Yield (AF/yr)	Future Shallow Wells Production Rate (cfs)
E	Discharge to KUCC GSL Outfall	9300	PVC C-909	10.27	3500	3500	5.35	2300	3.51	0	0

By-product Flow Rate (cfs)	Number of Pipelines (#)	Pressure Rating (psi)	Pipeline Hazen Williams C-factor	Pipeline in Roadways Length (ft)	Roadway Pipeline Unit Cost ($/ft)	Pipeline In Open Field Length (ft)	Open Pipeline Unit Cost ($/ft)	Total Pipeline Length (ft)	Total Pipeline Length (miles)	Dewatering Length (ft)	Dewatering Unit Cost ($/ft)
1.74	1	200	120	90,290	47.40	50,690	23.45	140,980	26.70	58,610	2.00

Pipeline Boring & Additional Costs ($)	Easement Length Required (ft)	Easement Cost ($)	Total Pipeline Cost ($mill)	Velocity (ft/sec)	Detention Time OK? (hrs)	Max Head Loss between Pump Stations (ft)	Max Distance between Pump Stations (ft)	Max Distance between Pump Stations (miles)	Calculated Number of Pump Stations (ft)	Actual Number of Pump Stations (ft)	Total Pump Station Cost ($mill)
0.00	1,850	26,548	5.612	3.03	12.9	416	103,407	19.6	1.4	2	1.000

Total Const Cost ($mill)	Eng Cost ($mill)	20% Contingency ($mill)	**Total Capital Cost ($mill)**	Discharge Hydraulic Gradeline (ft)	Static Pump Lift (ft)	Head Loss (ft)	Total Pump Lift (ft)	Pump Size (HP)	**Annual Pumping Cost ($)**	**NPV of Pumping Costs ($mill)**	**Total NPV Cost ($mill)**
6.612	0.992	2.281	**9.885**	4,215	-267	567	300	78	**25,375**	**0.502**	**10.388**

N.5 Zone B to KUC Tailings Impoundment

Jordan Valley Water Conservancy District

TECHNICAL MEMORANDUM

MEMO No: 5

SUBJECT: Cost Estimate for Disposal of Reverse Osmosis By-product
Alternative F
Discharge of Zone B by-product to KUCC Tailings Impoundment

TO: Stakeholder Forum

COPIES: Richard Bay, JVWCD
Paula Doughty, KUCC
Douglas Bacon, UDEQ

FROM: Mark Atencio

DATE: April 13, 2004

EXECUTIVE SUMMARY

This alternative consists of pumping the Zone B and Lost Use RO by-product to the south arm of the Great Salt Lake in a 23.7 mile long, 8-inch diameter pipeline using three pump stations. The net present value cost for disposal of Zone B and Lost Use RO by-product is $8.2 million. This includes a capital cost of $7.7 million and an operation cost of $25,000 per year.

BACKGROUND

Mining activities in southwestern Salt Lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate	TDS Concentration	Selenium Concentration
	(cfs)	(mg/L)	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,200 -8,300**	**32-47**

PURPOSE

The purpose of this memo is to describe the methods used to estimate the cost of disposing of Zone B RO by-product to the existing KUCC tailings impoundment in a pipeline from the Zone B Lost Use Treatment Plant in West Jordan.

AUTHOR'S CREDENTIALS

I am a registered professional engineer specializing in the area of water resources. I have completed Bachelor and Master of Science degrees in civil engineering. Following graduation I have been working at Jordan Valley Water Conservancy District as a civil engineer. My current title is senior engineer, in which I fill project management and supervisory roles. I have been studying and investigating various membrane and TDS

reduction treatments for eight years. I have completed a number of well drilling and construction projects. I have completed three years of pilot testing using various membrane and reverse osmosis processes. I have been filling the role of a technical engineer for the District on the Southwest Groundwater Remediation and Treatment Project since 1999.

DESCRIPTION OF ALTERNATIVE

See the attached Drawing for a visual representation of the alternative.

This alternative consists of a 20 mile long, 8-inch diameter PVC pipeline constructed from the Zone B Lost Use Reverse Osmosis (RO) Plant in West Jordan to the Great Salt Lake near Salt Air. Discharge into the lake would be through a new outfall pipeline. Three pump stations would be required; one at the RO plant, the second at 6 to 7 miles from the plant, and the third at 13 to 14 miles from the plant.

SCALING CONCERNS

The RO by-product contains a high concentration of salts, consisting mostly of calcium sulfate (gypsum) and calcium carbonate (calcite IE Timpanogos Cave). The solutions are super-saturated and on the verge of precipitating. This means that if the fluid were to stop moving a scale would start to form on the interior of the pipeline. In the RO plant an antiscalant chemical prevents scale formation; however, the chemical does not last for more than approximately 24 hours.

The formation of scale or precipitation of salts is the same process that occurs in the Great Salt Lake as the tributaries to the lake bring in salts into the lake. In this case the salts are concentrated due to evaporation until the point that saturation is reached and the salts form particles (precipitation) and settle to the bottom. In order to prevent this type of scaling from occurring, the pipeline needs to be kept in continuous operation or drained.

PIPELINE MATERIAL

Polyvinyl chloride (PVC) was selected as material of choice after considering ductile iron, steel, high density polypropylene (HDPE), and PVC. This took into account the actual internal diameter of the various types of pipeline, the working pressure of the pipelines, the hydraulic characteristics of the pipeline materials (friction factor) and the construction cost. Each pipeline material option was evaluated in a large spreadsheet. A copy of this spreadsheet is attached to this memo. The limitations of the pipeline material options considered affected the number and cost of pump stations required, the pressure loss required to be overcome by a pump, pipeline construction cost, and pump station operating cost.

PIPELINE DIAMETER

Six-inch, 8-inch, 10-inch, and 12-inch diameter pipelines were evaluated in the spreadsheet identified above. The size of the pipeline options evaluated affected the pressure loss (smaller pipe = higher pressure loss), the detention time in the pipeline (larger pipe = longer time in transit), pipeline construction cost, and pump station operating cost.

PIPELINE ALIGNMENT

Multiple alignments were considered for this alternative. First, an alignment extending westward, then northward was considered. Second a northern then westward alignment was evaluated. The two alignments were of comparable length. Due to the topography the first alignment required additional pumping to move the fluid uphill, then downhill towards Great Salt Lake. Both alignments utilized property owned by Kennecott Utah Copper Corporation (KUCC) along the east and north sides of its tailings impoundment in the northwest section of Salt Lake County.

SELECTION OF PREFERRED PIPELINE OPTION

Selection of the preferred pipeline option took into account the concerns with scaling and the effects of pipeline material, diameter, and alignment on the capital and operating cost.

The alignment selected for this alternative utilizes public right-of-way and private property, most of which is owned by KUCC. The alignment generally follows an elevation contour line to the north along 1300 West and then to the west along 1300 South to the KUCC tailings impoundment. The alignment then extends to the north and west until reaching Great Salt Lake. This alignment allows for utilizing existing right–of-way corridors. This alignment stays at almost the same elevation along its length. The alignment also avoids increasing in elevation, thereby avoiding additional pumping cost and making it easier to drain the pipeline with a backup pump in the event of a power failure.

Selection of the a 8-inch diameter PVC pipeline with three pump stations allows for the concerns expressed in this memo to be met will obtaining the lowest capital and net present value cost.

REQUIRED FACILITIES

- 20 mile long, 8-inch diameter PVC pipeline
- 3 pump stations

LEGALITY

The legality of this alternative was considered. A review of existing information indicated that a permit for discharge of RO by-product to GSL could be issued which would be protective of Great Salt Lake.

The water quality of the RO by-product was compared against standards for the Jordan River. All of the water quality parameters of the by-product were below the Jordan River standards, with the exception of total dissolved solids (TDS) and selenium. Comparing the TDS of the by-product (8,300) to Great Salt Lake (100,000 plus) it was apparent that TDS in the by-product would not be a concern. In order to understand if the selenium concentration in the by-product would be a concern I researched the files of the Utah State Division of Water Quality. Although selenium is an essential trace element, it has the potential to cause harm to humans or wildlife at very high concentrations. There is an existing permit for a discharge from KUCC to Great Salt Lake with a 54 µg/L (ppb) selenium limitation. The Zone B RO by-product will meet this limitation.

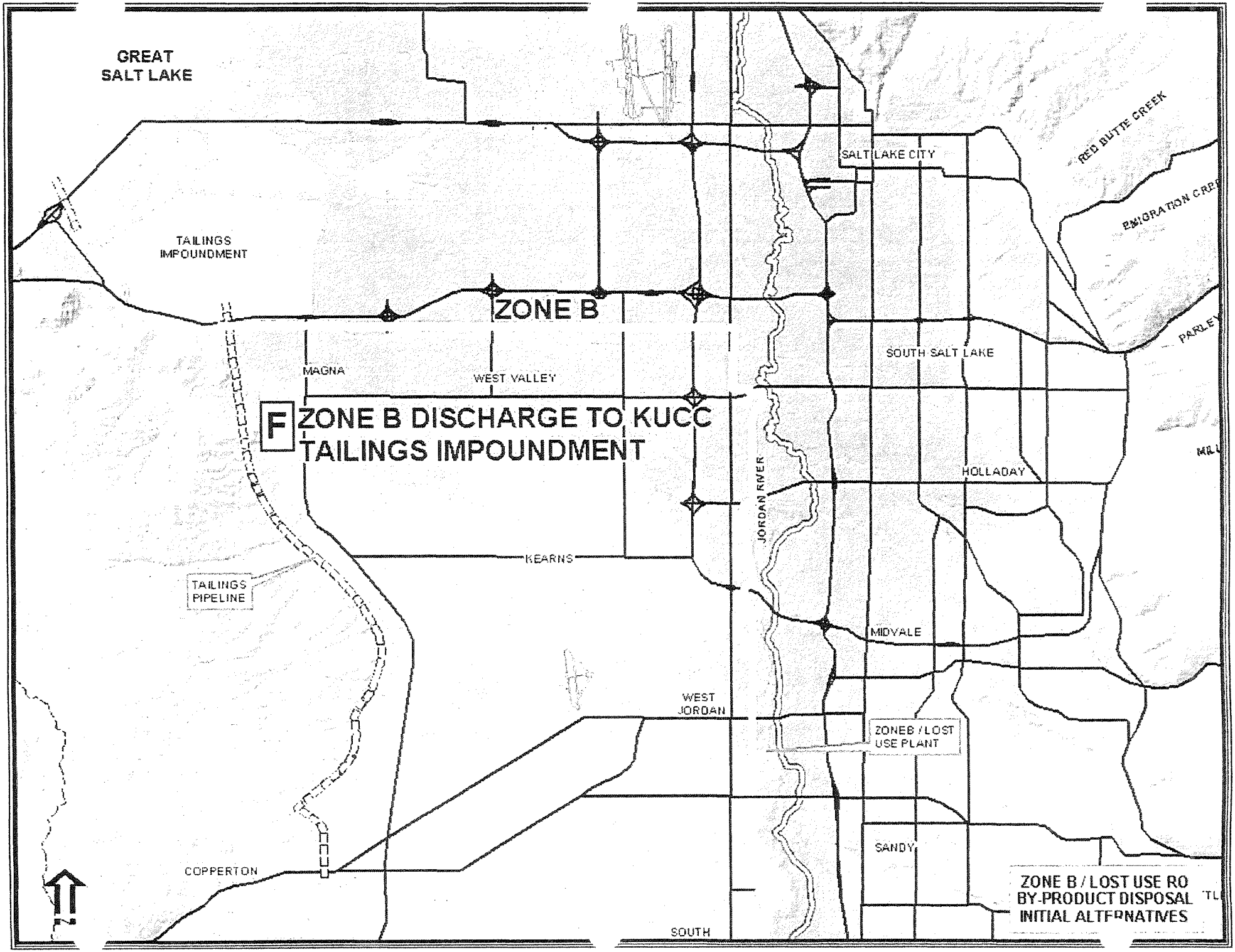
ASSUMPTIONS

- Pump Efficiency: 85%
- Motor Efficiency: 90%
- Pump Station Capital Cost: $500,000 each
- NPV interest rate: 4%
- 25 feet wide easement cost: $14.35/ foot ($50,000/acre)
- Pipeline in roadways installation cost: $39.90/ft
- Pipeline in open areas installation cost: $18.65/ft
- Pipeline costs from two contractors and MWH Engineers
- RO plant operates 330 days per year
- Power Cost $0.055/kW hr

COST ESTIMATE

The cost estimate for this alternative took into account the size of the pipeline, number of pump stations, pumping costs, length of pipeline, length of pipeline in roadways, length of pipeline in open areas, easement acquisition costs, dewatering costs, and engineering costs. The net present value cost for disposal of Zone B and Lost Use RO by-product is $8.2 million. This includes a capital cost of $7.7 million and an operation cost of $25,000 per year.

See the attached spreadsheet for details and calculations of the cost estimate.


GREAT
SALT LAKE
TAILINGS
IMPOUNDMENT
ZONE B
F ZONE B DISCHARGE TO KUCC
TAILINGS IMPOUNDMENT
MAGNA
WEST VALLEY
KEARNS
TAILINGS
PIPELINE
COPPERTON
SALT LAKE CITY
RED BUTTE CREEK
EMIGRATION CREEK
SOUTH SALT LAKE
PARLEY
HOLLADAY
JORDAN RIVER
MIDVALE
WEST
JORDAN
ZONEB / LOST
USE PLANT
SANDY
SOUTH
ZONE B / LOST USE RO
BY-PRODUCT DISPOSAL
INITIAL ALTERNATIVES

SOUTHWEST GROUNDWATER
REVERSE OSMOSIS BY-PRODUCT DISPOSAL OPTIONS

Alternative F
Discharge to Tailings Impoundment
Zone B Only

Alt. No.	Disposal Alternative	Project Yield (AF/yr)	Pipeline Material	Pipeline Actual Inside Diameter (Inches)	Zone A Yield (AF/yr)	Zone B Yield (AF/yr)	Zone B Production Rate (cfs)	Lost Use Yield (AF/yr)	Lost Use Production Rate (cfs)	Future Shallow Wells Yield (AF/yr)	Future Shallow Wells Production Rate (cfs)
F	Zone B to KUCC Tailings Impoundment	7000	PVC C-909	8.29	3500	3500	5.35	0	0	0	0

By-product Flow Rate (cfs)	Number of Pipelines (#)	Pressure Rating (psi)	Pipeline Hazen Williams C-factor	Pipeline in Roadways Length (ft)	Roadway Pipeline Unit Cost ($/ft)	Pipeline In Open Field Length (ft)	Open Pipeline Unit Cost ($/ft)	Total Pipeline Length (ft)	Total Pipeline Length (miles)	Dewatering Length (ft)	Dewatering Unit Cost ($/ft)
1.23	1.00	200	120	88,440	39.90	17,050	18.65	105,490	19.98	36,850	2.00

Pipeline Boring & Additional Costs ($)	Easement Length Required (ft)	Easement Cost ($)	Total Pipeline Cost ($mill)	Velocity (ft/sec)	Detention Time OK? (hrs)	Max Head Loss between Pump Stations (ft)	Max Distance between Pump Stations (ft)	Max Distance between Pump Stations (miles)	Calculated Number of Pump Stations (ft)	Actual Number of Pump Stations (ft)	Total Pump Station Cost ($mill)
231,000	1,850	26,548	4.178	3.29	8.9	416	69,018	13.1	1.5	2	1.000

Total Const Cost ($mill)	Eng Cost ($mill)	20% Contingency ($mill)	**Total Capital Cost ($mill)**	Discharge Hydraulic Gradeline (ft)	Static Pump Lift (ft)	Head Loss (ft)	Total Pump Lift (ft)	Pump Size (HP)	**Annual Pumping Cost ($)**	**NPV of Pumping Costs ($mill)**	**Total NPV Cost ($mill)**
5.178	0.777	1.786	**7.741**	4,270	-212	636	424	78	**25,375**	**0.502**	**8.244**

N.6 Distillation

carollo engineers

TECHNICAL MEMORANDUM

Memorandum No. 6

SUBJECT:	Evaluation of Reverse Osmosis By-product Disposal **Alternative H:** Disposal to a Landfill by Thermal Zero Liquid Discharge Processing
TO:	Mark Atencio and Stakeholder Forum Members
COPIES:	Richard Bay, JVWCD Paula Doughty, KUCC Douglas Bacon, UDEQ
FROM:	Thomas F. Seacord, P.E. - Carollo Engineers, P.C.
DATE:	April 13, 2004

EXECUTIVE SUMMARY

This alternative consists of converting the RO by-product water to a solid waste by evaporating and recovering the water in a sequence of mechanically enhanced thermal desalination processes. This conversion is referred to as Zero Liquid Discharge (ZLD) and the final waste product (i.e., salt) is disposed to a landfill. This evaluation considered treating waste from both a combined Zone B and Lost Use facility, referred to as the West Jordan Treatment Plant, and a Lost Use only facility. The net present values and estimated capital and operating costs for each alternative are:

- Combined Zone B and Lost Use ZLD Facility
  - Capital Cost: $22.1-million
  - O&M Cost: $3.2-million
  - Net Present Value: $93.9-million

- Lost Use only ZLD Facility
  - Capital Cost: $10.4-million
  - O&M Cost: $1.1-million
  - Net Present Value: $34.7-million

Due to the high cost of ZLD processing, combined with conflicts with community values (i.e., aesthetics) established during the stakeholder forums, further consideration of this alternative is not warranted.

BACKGROUND

Mining activities in southwestern Salt lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust

Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use of the contaminated aquifer by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate	TDS Concentration	Selenium Concentration
	(cfs)	(mg/L)	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Weighted Average		**8,240**	**38 - 47**

PURPOSE

The purpose of this memo is to estimate the net present value and feasibility of processing the following RO by-product waters by ZLD treatment and disposing residual salts to a landfill:

- Zone B and Lost Use RO by-product waters from a combine facility referred to as the West Jordan Treatment Plant, and
- Lost Use RO by-product water

AUTHOR'S CREDENTIALS

Thomas Seacord is a licensed professional engineer in the state of Utah and specializes in the field of desalination. Tom is a senior project engineer with Carollo Engineers, P.C. and has a B.S. and M.S. in Civil Engineering from Clarkson University. He has been involved in

the planning, design, construction and start-up of desalination plants in California, Florida, Kansas, South Carolina, Texas, and Utah. Tom is a Director of the American Membrane Technology Association (AMTA) and chairs the desalination by-product disposal committee. Tom also serves as a technical advisor for the largest research project the American Water Works Association Research Foundation (AwwaRF) has ever funded on the topic of zero liquid discharge and volume minimization for disposal of desalination by-product waters for inland applications.

DESCRIPTION OF ALTERNATIVE

Zero liquid discharge (ZLD) processing of RO by-product waters consists of a mechanically enhanced thermal evaporation process and a final crystallization process. The final waste product is a solid waste (i.e., 40 dry tons of salt per day, 5 to 15% moisture content) that can be disposed of in a landfill. Typically, the final crystallization process takes place within an evaporation pond that may vary in size from 3 to 5 acres. Evaporation ponds are most frequently used because it is the most cost effective crystallization alternative. However, due to potential environmental impacts such as liner failure and water fowl exposure to toxic inorganic compounds, the District has eliminated evaporation ponds from consideration. Therefore, final crystallization for this project also uses a mechanically enhanced thermal process.

Figure 1 depicts a process flow diagram for a typical ZLD process. As indicated, it consists of a brine concentrator followed by a crystallization process. Each ZLD process equipment supplier has their own variation on this basic concept. However, each supplier's technology uses a combination of heat and pressure (i.e., positive or negative pressure) to enhance the evaporation and crystallization process. The example presented in Figure 1 uses vapor compression (e.g., heat pump) to enhance the thermodynamics of the evaporation/distillation process. A combination of chemical conditioning and a brine slurry recirculation is also commonly used prevent mineral scale build-up within the equipment and on the heat exchanging surfaces.

ESTIMATION METHODS

Since this project will be built using public money, it is in the public interest to make certain that the technologies evaluated are feasible and the supplier of the equipment is capable of providing service for this application. Carollo issued a Request for Budgetary Quotations (Appendix A) to the following ZLD equipment suppliers:

- ALAQUA, Inc., Guttenberg, NJ
- AquaTek, Inc., Canonsburg, PA
- IWS/Equus Environmental, Auckland, New Zealand
- Ionics RCC, Bellevue, WA
- Swenson Technology, Inc., Monee, IL

Only those suppliers providing responsive quotations with the appropriate experience and finances were considered. These responses were comparable to published cost data (Mickley, 2001) and therefore, deemed acceptable for estimating purposes.

[INSERT FIGURE 1]

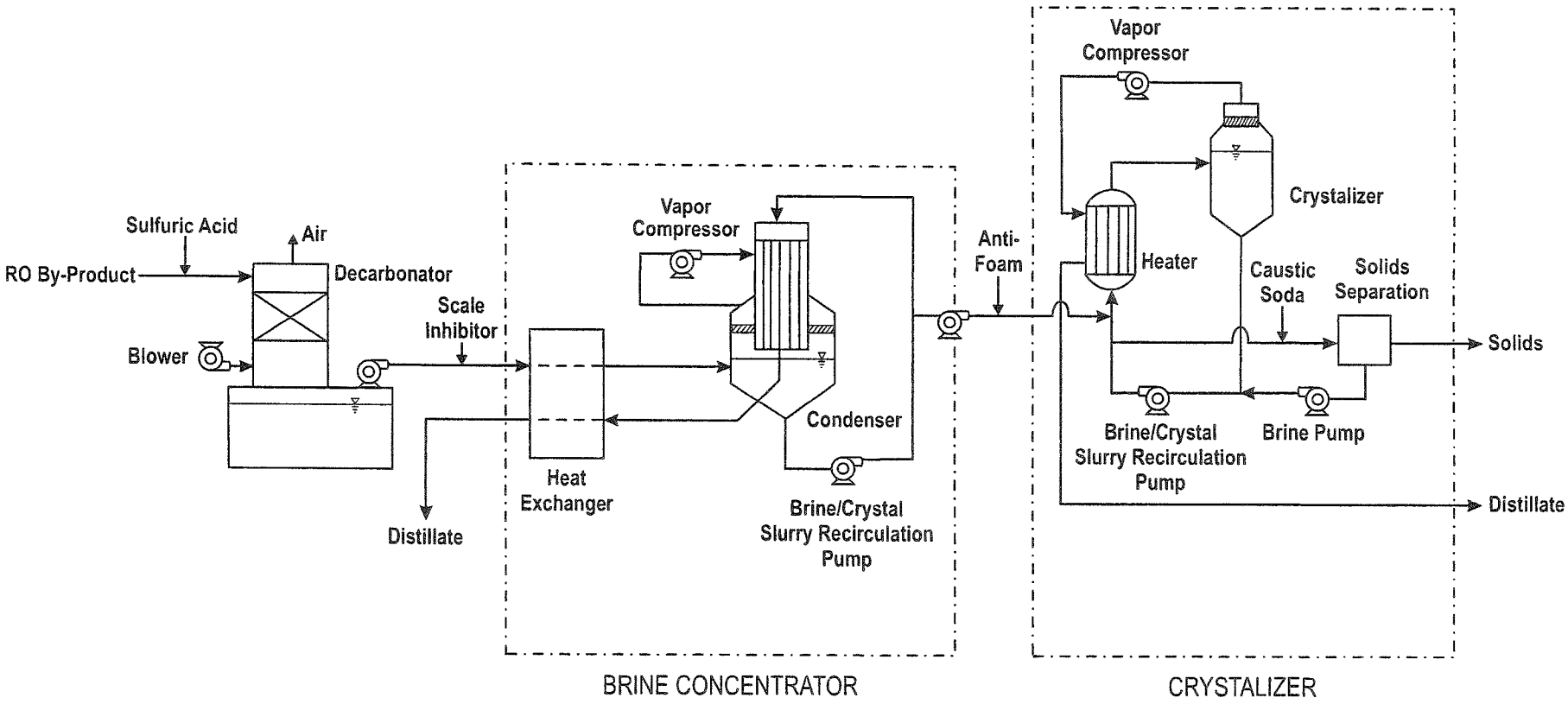


Figure 1
Example ZLD Process Flow Diagram
TECH MEMO NO. 6
JORDAN VALLEY WATER CONSERVANCY DISTRICT

DESIGN CRITERIA

Design criteria for a ZLD process used to treat RO by-product from the Southwest Groundwater Treatment Project is presented in Table 1. Unit costs are also presented for key components related to operations and maintenance (O&M) of the ZLD facility.

Table 1 ZLD Process Design Criteria
Southwest Groundwater Treatment Project
Jordan Valley Water Conservancy District

Criteria	Value
Unit Costs	
Power	0.055 per kW-hr
Sulfuric Acid	\$0.10 per pound (as H_2SO_4)
Anti-scalant	\$1.5 per pound
Anti-foam	\$1.5 per pound
Caustic Soda	\$0.21 per pound (as NaOH)
Labor	\$40,000/person/year
Waste Disposal	\$42 per ton
Conditions	
RO Plant Operation	330 days/year
NPV Interest Rate	4%
ZLD Equipment Life	20 years
Operating Power Demand	3800 kW
Sulfuric Acid Demand	18,400 lbs/day
Anti-scalant Demand	45 lbs/day
Anti-foam Demand	12 lbs/day
Caustic Soda Demand	50 lbs/day
Labor	
Operators	3
Mechanics	1
Sludge Production	40 dry tons per day (5 to 15% moisture)

COST ESTIMATE

Estimated capital costs, operations and maintenance (O&M) costs, and Net Present Values (NPV) for a ZLD process used to treat RO by-product produced as a result of the Southwest Groundwater Treatment project are presented in Table 2. These costs reflect the operation costs associated with a typical vapor compression type brine concentrator and crystallizer. Itemized estimates are presented in Appendix B for each alternative.

Table 4	Estimated Costs for RO By-product Disposal via ZLD Processing Southwest Groundwater Treatment Project Jordan Valley Water Conservancy District
	Cost (2004 $)
Combined Zone B & Lost Use ZLD	
Capital Cost	$22,114,000
Annual Operating Costs	$3,197,100
Net Present Value	$93,876,000
Lost Use ZLD	
Capital Cost	$10,405,400
Annual Operating Costs	$1,036,300
Net Present Value	$34,736,600

It is important to note that due to this height of the ZLD process equipment (i.e., up to 90-feet), only the electrical, HVAC and chemical facilities are enclosed within the structure. Also, it is important to note that no redundancy is provided as part of this estimate. Redundancy would include an additional brine concentrator capable of treating 50% of the RO by-product flow and an additional crystallizer capable of treating 100% of the effluent from two brine concentrators. This redundancy would increase the capital cost estimates by the following:

- Combined Zone B & Lost Use Facility: $9.9-million
- Lost Use only Facility: $4.8-million

The NPVs presented in Table 2 can be used to compare the ZLD process to other alternatives. Consistent with the District's methods for calculating NPV, this calculation considers the project life, life of the ZLD equipment, and the interest rate for borrowed money. All of these criteria are specified in Table 1. It is important to note that the this selected method NPV calculation does not account for the impact of inflation over time. If inflation is accounted for, at a rate of 3.2% annually, the NPV for a ZLD process capable of treating both Zone B and Lost Use RO by-product waters is $144,236,000, and $52,000,000 for a ZLD process capable of treating Lost Use RO by-product only.

ENVIRONMENTAL IMPACTS

Salts produced from the ZLD plant are a primary environmental concern. These salts will consist primarily of calcium sulfate, however, trace concentrations of toxic inorganic contaminants (e.g., selenium) will persist. The fate of these toxic contaminants must be evaluated to assess the options available for final disposal of the waste salts produced. For disposal of the waste salts to a landfill, fate of the toxic contaminants is assessed by the following methods:

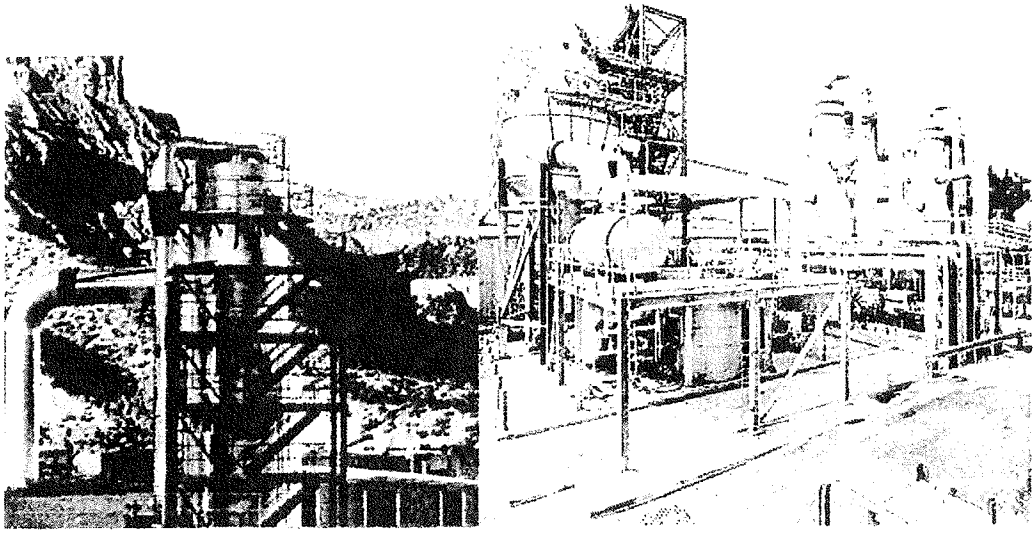
- EPA Paint Filter Test: Determines if the waste is a solid or liquid waste.
- Toxic Contaminant Leachate Potential (TCLP) Test: Determines if the toxic contaminants can leach from the solid waste.

Waste from the ZLD process is expected to pass both of these tests. The TCLP test is expected to be passed since the primary waste constituent is calcium sulfate and not calcium carbonate (carbonate is completely removed during primary chemical conditioning). However, before implementing a ZLD process, we recommend that a sample waste be produced and analyzed by the TCLP method.

AESTHETIC ISSUES

The District is committed to being a good neighbor to those adjacent to all of their treatment facilities. With this in mind, it is important to consider what aesthetic impacts the ZLD process may have and what people near 8215 South 1300 West in West Jordan may see and feel about this type of facility. Such issues as appearance and traffic generated by waste hauling and chemical delivery trucks must therefore be considered.

While the footprint for a ZLD plant can be quite compact, the profile can often be too tall to enclose within a structure. As presented in Figure 2, ZLD process equipment of similar capacity can reach 90 feet in height. Therefore, as presented in previously in the cost estimate, process equipment is proposed to be located outside of building. This profile view will create an industrial appearance to the District's facility, which may not be acceptable to neighbors adjacent to the treatment plant.



225-gpm Brine Concentrator
Utah Power & Light, Huntington, Utah

2, 150-gpm Brine Concentrators & 1, 50-gpm Crystallizer
Bechtel/US Generating Co., Cedar Bay, Florida

Figure 2
Example Photos of ZLD Process Equipment
Jordan Valley Water Conservancy District

Public opinion may not be limited to the appearance of the ZLD process equipment. Traffic created by chemical delivery and salt hauling trucks, carrying waste from the ZLD plant to a landfill may also draw negative attention and must be considered before implementing this type of disposal alternative.

RECOVERABLE BY-PRODUCTS FROM ZLD

As indicated in Request for Budgetary Quotation (Appendix A), Carollo asked ZLD equipment suppliers to consider recovery of beneficial by-products when developing process concepts. However, only one supplier provided concepts to this effect. This supplier noted that the additional cost for processing the RO by-product to produce a beneficial by-product would not be recovered through sale of such recoverable by-products. Therefore, for the purpose of this evaluation, no cost credits from the sale of recoverable by-products are assumed.

FEASIBILITY

ZLD by the methods described in this memo is a proven technology that has been widely used in the chemical processing and power industries for several decades. Key to the robustness and cost-effectiveness of these processes are chemical conditioning and brine slurry recirculation techniques used to control mineral scale build-up on the heat exchanging surfaces. Based on the methods and concepts presented within this memorandum, ZLD is technologically feasible.

A feasibility assessment must also consider environmental impacts and community values related to the aesthetics of the ZLD process. Fate of the toxic inorganic impurities, found naturally in the Southwest Groundwater is a concern for when considering the final disposal of the salts generated from the ZLD process. To be landfilled, the waste must pass both TCLP and EPA Paint Filter Tests. While we expect these tests may be passed, a sample waste must first be generated and evaluated by these test methods before further consideration may be given to this alternative. However, based on the criteria presented in the District's stakeholder forum memorandum, appearance of the ZLD process equipment and traffic generated by chemical delivery and waste disposal trucks will likely not meet with community values. This combined with the high NPV cost, make ZLD disposal of RO by-product water less feasible than other viable alternatives and further consideration of this alternative is not required.

REFERNCES

Mickley, M. 2001. Membrane Concentrate Disposal: Practices and Regulation. USBR Desalination and Water Purification Program Report No. 69.

APPENDIX A

Request for Budgetary Quotation

carollo engineers

To:	ZLD Equipment Suppliers		
From:	Thomas F. Seacord, P.E.		
Date:	March 24, 2004	**WO#:**	6710C.00 T05
Subject:	ZLD Equipment Budgetary Quotation - ***Revision 1***		

Carollo Engineers is assisting the Jordan Valley Water Conservancy District with an evaluation of reverse osmosis (RO) by-product disposal via Zero Liquid Discharge at a location adjacent to the District's main office in West Jordan, Utah.

REQUEST FOR INFORMATION

Carollo requests the following information, itemized as presented below, from ZLD equipment suppliers to treat a flow of 557-gpm of Zone B and 229-gpm of Lost Use RO by-product water. Water quality analyses presented in Tables 1 and 2 for Zone B and Lost Use RO by-product, respectively. Waters may be mingled at the discretion of the ZLD equipment supplier.

- **Process Flow Diagram:** Include a description of scale control to protect integrity of the heat transfer surface (e.g., calcium sulfate slurry circulation, acidification/decarbonation, etc.). Note that based upon the District's *Good Neighbor Policy*, discharge to an evaporation pond is not an acceptable means of final stage processing.

- **Budgetary Quotation for ZLD Treatment Equipment:** Complete ZLD trains with all on-skid piping, pumping, valves and instrumentation. All heat transfer surfaces and surfaces exposed to non-recovered RO by-product, brine, and harsh chemicals shall be titanium. All other metallic parts shall be, at a minimum, electropolished 316L stainless steel. Also include chemical feed equipment (include day storage, but not including bulk chemical storage), and chemical cleaning equipment. Assume one redundant chemical feed pump per chemical feed system, per the requirements of *Recommended Standards for Waterworks*. Include as part of the treatment equipment cost, the cost of a warrantee, prorated over the expected life of the equipment. State the expected life of the equipment.

- **Budgetary Quotation for Redundant ZLD Treatment Equipment:** Equal to 20% of the total flow, but not less than the size of the largest treatment train, per the requirements of *Recommended Standards for Waterworks*. Include as part of the treatment equipment cost, the cost of a warrantee, prorated over the expected life of the equipment.

- **Chemical Dose Requirements:** State type of and dose for each chemical used during the continuous operation of the treatment equipment. The engineer will use this information to estimate chemical consumption costs and estimate costs and size of the chemical storage facilities per the requirements of *Recommended Standards for Waterworks.*

- **Electrical Requirements:** Size of electrical power demand in Kilowatts. Include pump or heat transfer inefficiencies in this requirement. Engineer will use this number to estimate the cost of electrical switchgear and other ancillary electrical equipment supplying power to the ZLD process.

- **Shipping and Installation Costs:** State cost of shipping and point of origin. Delivery will be to West Jordan, Utah. Installation costs should include any field service representatives required through start-up of the equipment.

- **Estimated Maintenance Costs:** Estimated annual costs for

    - chemical cleaning,
    - replacement parts, and
    - consumables.

- **Labor Requirements:** State the number of operators and mechanics required to operate your equipment each day. Operators and mechanics are assumed not to perform overlapping duties. This number will be adjusted to reflect staffing for each week.

- **Cost of Performance Bond:** Estimate the cost of providing a performance bond for the:

    - First year of operation.
    - First five years of operation

  Conditions of the performance bond will be based upon annual O&M estimates. If O&M is higher than estimated, bond conditions will require ZLD supplier to pay the difference.

- **Description of Final By-product:** Estimate volume and percent solids of final salt by-products for engineer to determine costs for final disposal.

- **Foot Print Size:** For the ZLD equipment, redundant ZLD equipment, and Chemical Cleaning Equipment.

- **Installation List:** Provide a list of installations treating water of similar quality, their capacity, and year installed.

- **Company Information:** Provide information on your company, including but not limited to:
    - years in business under the name you currently use, and
    - an annual financial statement of earnings.

BENEFICIAL USE OF ZLD BY-PRODUCTS

ZLD Equipment suppliers are encouraged to identify innovative ways to create beneficial use of ZLD by-products. We ask, however, that you assume a 40 ppb concentration of selenium in the by-product. Therefore, any beneficial use must be qualified by the appropriate removal of selenium. If beneficial use is presumed, state its use and estimate the value of the salt product. Provide a reference to qualify any assumed value of salt used for resale.

While the District is open to alternatives that may result in the production of beneficial by-products from ZLD processes, we wish to remind ZLD Equipment Suppliers that we still intend to evaluate disposal of by-products by conventional means. Please be certain to provide a description of the by-products as requested in the above itemized list.

ESTIMATED BY ENGINEER

Using the information provided in the above request, Carollo will estimate the total capital costs including structural, site civil, electrical, HVAC, chemical storage, and cost effective disinfection required to meet appropriate state standards (e.g., UV, chlorine, etc.). Carollo will also estimate annual O&M costs for power and chemicals based upon local conditions. Along with other annual O&M costs/credits provided by the ZLD supplier (i.e., chemical cleaning, maintenance, resale of salts, etc.), a present value analysis will be completed.

QUESTIONS

Please direct your questions to:

Thomas F. Seacord, P.E.
Carollo Engineers, P.C.
12592 West Explorer Drive, Suite 200
Boise, ID 83713
Email: tseacord@carollo.com
Phone: (208) 376-2288
Fax: (208) 376-2251
Mobile: (208) 863-0525

TIME OF RESPONSE

Please respond with the itemized information requested above by April 7, 2004.

Table 1 **Zone B Pilot Test - Average Water Quality**
Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Parameter	Unit	Well Water	Permeate	By-product
Alkalinity	mg/L as $CaCO_3$	378	13.3	1876
pH	S.U.	6.96	5.76	7.51
Temperature	°C (°F)	16 (61)	-	-
Conductivity	mS/cm	2.37	0.067	9.73
TDS	mg/L	1630	17	8680
Total Hardness	mg/L as $CaCO_3$	1115	7.2	5890
Turbidity	NTU	0.24	NA	NA
Silt Density Index	-	1.02	NA	NA
Calcium	mg/L	305	< 1.0	1500
Magnesium	mg/L	89.5	0.2	540
Sodium	mg/L	130	3.7	500
Potassium	mg/L	4.8	< 1.0	18
Barium	mg/L	0.028	< 0.002	0.15
Strontium	mg/L	0.93	< 0.01	4.7
Carbon Dioxide	mg/L	82 [a]	82 [b]	99 [a]
Carbonate	mg/L	0.2	0.0	2.0
Bicarbonate	mg/L	378	16.2	2010
Sulfate	mg/L	737	< 2.0	3100
Chloride	mg/L	200	2.5	920
Fluoride	mg/L	0.08	< 0.05	0.29
Silica				
Reactive	mg/L as SiO_2	26.0	< 1.0	210
Total	mg/L as SiO_2	33.5	< 1.0	220
LSI		+ 0.2	- 4.8	+ 2.3
$CaSO_4$ Saturation	%	34.4	0.0	256
$BaSO_4$ Saturation	%	332.9	0.0	2430
$SrSO_4$ Saturation	%	6.7	0.0	51
SiO_2 Saturation	%	27.5	0.0	135

Notes:
NA Not available
a Equilibrium concentration of $CO_{2(g)}$ based on alkalinity, pH, and temperature
b Based on feed water concentrations of $CO_{2(g)}$

Table 2 **Lost Use Pilot Test - Average Water Quality**
Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Parameter	Unit	Well Water	Permeate	By-product
Alkalinity	mg/L as $CaCO_3$	290	9.6	1930
pH	S.U.	7.15	6.03	7.69
Temperature	°C (°F)	16 (61)	-	-
Conductivity	mS/cm	1.79	0.036	10.0
TDS	mg/L	1200	19	7860
Total Hardness	mg/L as $CaCO_3$	690	7.0	4515
Turbidity	NTU	0.24	NA	NA
Silt Density Index	-	0.76	NA	NA
Calcium	mg/L	176	< 1.0	970
Magnesium	mg/L	59	0.11	390
Sodium	mg/L	146	6.0	860
Potassium	mg/L	6.8	< 1.0	46
Barium	mg/L	0.027	< 0.02	0.180
Strontium	mg/L	0.79	< 0.01	4.5
Carbon Dioxide	mg/L	53 [a]	53 [b]	73 [a]
Carbonate	mg/L	0.2	0.0	3.0
Bicarbonate	mg/L	353	11.7	2144
Sulfate	mg/L	341	< 2.0	1800
Chloride	mg/L	234	5.0	1300
Fluoride	mg/L	0.58	< 0.05	1.3
Silica				
Reactive	mg/L as SiO_2	26.0	< 1.0	220
Total	mg/L as SiO_2	33.5	< 1.0	255
LSI		0.1	- 5.0	+ 2.3
$CaSO_4$ Saturation	%	12.1	0.0	111
$BaSO_4$ Saturation	%	199.9	0.0	2067
$SrSO_4$ Saturation	%	3.5	0.0	38
SiO_2 Saturation	%	28.9	0.0	190

Notes:
NA Not available
a Equilibrium concentration of $CO_{2(g)}$ based on alkalinity, pH, and temperature
b Based on feed water concentrations of $CO_{2(g)}$

APPENDIX B

Cost Estimate Summary

Table 3	ZLD Process Capital Cost - Zone B & Lost Use Southwest Groundwater Treatment Project Jordan Valley Water Conservancy District			
	Quantity	**Units**	**Unit Cost**	**Extended Cost**
Building				
Foundation	2100	CY	$400	$840,000
Structural/Architectural	3100	SF	$100	$310,000
Electrical	1	LS	$1,200,000	$1,200,000
HVAC/Plumbing	1	LS	$200,000	$200,000
Brine Concentrator	2	EA	$4,000,000	$8,000,000
Crystallizer	1	EA	$1,725,000	$1,725,000
Equipment Installation [a]	1	LS	$7,780,000	$7,780,000
Post Treatment				
Cartridge Filtration	2	EA	$40,000	$80,000
UV Disinfection	2	EA	$150,000	$300,000
Chemical Storage/Feed				
Sulfuric Acid	1	LS	$450,000	$450,000
Scale Inhibitor	1	LS	$100,000	$100,000
Anti-foam	1	LS	$50,000	$50,000
Caustic Soda	1	LS	$100,000	$100,000
Site Work				
Over Excavation	29,500	CY	$12	$354,000
Structural Fill	29,500	CY	$20	$590,000
Other	1	LS	$35,000	$35,000
			Subtotal	**$22,114,000**

a Per vendor quotations, field erection and assembly of ZLD equipment is equal to 80% of the ZLD equipment costs.

Table 4	ZLD Process Annual O&M Cost - Zone B & Lost Use Southwest Groundwater Treatment Project Jordan Valley Water Conservancy District	
		Annual O&M Costs (2004 $)
Electrical Costs (Subtotal)		*$1,655,300*
Sulfuric Acid		$607,200
Scale Inhibitor		$22,300
Anti-foam		$6,000
Caustic Soda		$3,500
Chemical Costs (Subtotal)		*$638,900*
Labor [a]		$160,000
Sludge/Salt Disposal		$595,500
Chemical & Mechanical Cleaning		$60,000
Replacement Parts		$90,000
Consumables		$30,000
Indirect Operating Costs (Subtotal)		*$902,900*
Total Annual O&M		**$3,197,100**

a Assumes labor is shared with RO WTP.

Table 5	ZLD Process Capital Cost - Lost Use Southwest Groundwater Treatment Project Jordan Valley Water Conservancy District			
	Quantity	**Units**	**Unit Cost**	**Extended Cost**
Building				
Foundation	1400	CY	$400	$560,000
Structural/Architectural	2100	SF	$100	$210,000
Electrical	1	LS	$500,000	$500,000
HVAC/Plumbing	1	LS	$100,000	$100,000
Brine Concentrator	2	EA	$1,750,000	$3,500,000
Crystallizer	1	EA	$750,000	$750,000
Equipment Installation [a]	1	LS	$3,400,000	$3,400,000
Post Treatment				
Cartridge Filtration	2	EA	$20,000	$40,000
UV Disinfection	2	EA	$100,000	$200,000
Chemical Storage/Feed				
Sulfuric Acid	1	LS	$300,000	$300,000
Scale Inhibitor	1	LS	$50,000	$50,000
Anti-foam	1	LS	$50,000	$50,000
Caustic Soda	1	LS	$80,000	$80,000
Site Work				
Over Excavation	19,700	CY	$12	$236,400
Structural Fill	19,700	CY	$20	$394,000
Other	1	LS	$35,000	$35,000
			Subtotal	**$10,405,400**

a Per vendor quotations, field erection and assembly of ZLD equipment is equal to 80% of the ZLD equipment costs.

Table 6	ZLD Process Annual O&M Cost - Lost Use Southwest Groundwater Treatment Project Jordan Valley Water Conservancy District	
		Annual O&M Costs (2004 $)
Electrical Costs (Subtotal)		*$483,500*
Sulfuric Acid		$177,400
Scale Inhibitor		$6,600
Anti-foam		$1,800
Caustic Soda		$1,100
Chemical Costs (Subtotal)		*$186,600*
Labor [a]		$160,000
Sludge/Salt Disposal		$173,900
Chemical & Mechanical Cleaning		$17,600
Replacement Parts		$26,300
Consumables		$8,800
Indirect Operating Costs (Subtotal)		*$366,200*
Total Annual O&M		**$1,036,300**
a Assumes labor is shared with RO WTP.		

N.7 Distillation - disposal of salts

Evaluation of Disposal of Reverse Osmosis By-Product; Alternative H - Distillation and Disposal of Salts

PREPARED FOR: Mark Atencio/JVWCD

PREPARED BY: Sandy Rhea/CH2M HILL

DATE: April 12, 2004

EXECUTIVE SUMMARY

This alternative consists of distilling the Zone B and Lost Use Reverse Osmosis (RO) by-product on-site and disposing the remaining dry salts at an off-site landfill. The distillation process will result in approximately 40 tons per day of solids (salts), which require disposal. This memorandum focuses on disposal options at an EPA-approved landfills within Salt Lake County. This option includes transport of the salts to the landfill and disposal. Assuming the reverse osmosis plant will operate 330 days per year, the approximate annual cost for transport and disposal of the salts ranges from $413,000 to $623,000. The cost is dependent on the water content of the salts and mode of transport. The cost range assumes water content of zero to 15 percent.

BACKGROUND

Mining activities in southwestern Salt Lake Valley have created groundwater contamination with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater

remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate (cfs)	TDS Concentration (mg/L)	Selenium Concentration (µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,200 -8,300**	**32-47**

Notes: cfs – cubic feet per second
mg/L – milligram per liter
µg/L – microgram per liter

PURPOSE

The purpose of this memo is to describe the cost of transporting and disposing of Zone B and Lost Use RO by-product after distillation.

AUTHOR'S CREDENTIALS

I am an Engineer in Training (E.I.T.) specializing in the area of environmental compliance and remediation. I have completed Bachelor and Master of Science degrees in civil engineering. Following graduation, I have been working at CH2M HILL as a civil engineer for the last 3 years. My current title is project engineer, in which I manage project tasks and provide support on environmental and water resource projects. I have worked on several Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) projects, developing remedial alternatives to handle contaminated soils and sediments. I have written Engineering Evaluation/Cost Analysis Reports, discussing remediation technologies and providing cost estimates to implement the technologies. I have an understanding of the Resource, Conservation, and Recovery Act (RCRA) program under the U.S. Environmental Protection Agency (EPA), which regulates waste disposal and have used this knowledge for several environmental projects.

DESCRIPTION OF ALTERNATIVE

This alternative consists of distilling the discharge by-product from the Zone B/ Lost Use Reverse Osmosis (RO) Plant in West Jordan. The salts remaining from the distillation process would be transported to roll-off containers for storage. The containers would then be transported daily to a non-hazardous landfill within Salt Lake County.

Based on the concentration of Total Dissolved Solids (TDS) and a total flow rate of 1.75 cfs, approximately 78,000 pounds (40 tons) per day of solids would remain after distillation. The solids contain a high concentration of salts, consisting mostly of calcium sulfate (gypsum) and calcium carbonate (calcite). Forty tons per day assumes that the solids are dry, although the actual water content may range between 5 and 15 percent. As the water content increases, the

mass of the solids increase, thereby, increasing the cost of transport and disposal. Transport and disposal costs are based on the tonnage of waste. For this alternative, costs are provided for a water content range of zero to 15 percent.

TRANSPORTATION

At this point, it is assumed that the salts would be transported to the landfill in lined 25 cubic yard roll-off containers or end dump trucks. After the distillation process, the salts would either be placed directly in the lined roll-off containers or in a lined end dump truck. It is unknown what technique will be used to load the salts. The liners are used to prevent leakage during storage and transport. The benefit of using roll-off containers is that the salts can be stored onsite prior to transport. End dump trucks would require loading into the dump truck at the time of transport.

To comply with Utah Department of Transportation regulations, the maximum load limit is 80,000 pounds (40 tons), which includes the transport vehicle. Dry salts weigh approximately 40 tons and salts with 15 percent water content weigh approximately 45 tons. The capacity of a single roll-off container is about 17 tons and the capacity of an end dump truck is about 20 tons. Therefore, 3 trips would be required for the roll-off containers and 2 trips with an end dump truck. Again, the weight and the number of trips increase as the water content increases.

The cost to transport the salts is based on the weight. TW Company, a local transporter, quoted $10 per ton for transport via end dump trucks and $20 per ton for transport via roll-off containers. With this rate, the daily transportation costs range from $400 to $900, depending upon the water content of the material and the mode of transport.

LANDFILL OPTIONS

Trans-Jordan Landfill in South Jordan, Utah will accept the solid waste, upon compliance with their permit. Dwayne Woolley of Trans-Jordan stated that Trans-Jordan has a strict requirement for wastes containing arsenic and lead above background concentrations. Mr. Woolley has been provided the preliminary metals profile of the salts waste for review. Based on RCRA criteria, the salts are considered non-hazardous and can be disposed accordingly. Trans-Jordan Landfill meets EPA requirements for classification as a Subtitle D Facility, which accept non-hazardous waste.

The disposal fee at Trans-Jordan Landfill is $22 per ton. The disposal cost for landfilling the salts ranges from $860 to $1,000 per day depending on the water content of the salts.

ENVIRONMENTAL CONCERNS

Landfilling is a proven technique for disposing of wastes, although environmental concerns do exist. An environmental concern with landfilling is burying large volumes of waste within the landfill, which shortens the life of the landfill. Landfilling does not reduce the volume or mass of the waste. With the current assumed loading rate of 300,000 tons per year, this alternative will increase the annual loading of the Trans-Jordan Landfill by approximately 5 percent. The projected life of the Trans-Jordan Landfill is 25 years, which may be reduced with the influx of the salts wastestream.

Another environmental concern is the leachability of the salts. The landfilled salts are susceptible to being leached by infiltrating precipitation, which will make the salts mobile within the subsurface of the landfill. The Trans-Jordan Landfill is lined with impermeable material and is equipped with a leachate collection system, but the possibility still exists for the compounds to leach into the subsurface and potentially reach the water table. This is unlikely, but is still a possibility.

LEGALITY

No regulatory problems appear to exist with the alternative of disposing the salts in the Trans-Jordan Landfill. This alternative of disposing the salts in the Trans-Jordan Landfill was discussed with a representative from the Utah Department of Solid and Hazardous Waste, which did not object to landfilling the salts. Calls are currently in to two representatives at the Salt Lake Valley Health Department to discuss the feasibility of this alternative.

Trans-Jordan Landfill meets U.S. Environmental Protection Agency's (EPA) requirements for classification as a Subtitle D Facility. Subtitle D facilities accept wastes that are classified as non-hazardous. The Trans-Jordan Landfill contains a double composite liner system constructed of a 3/8-inch Geosynthetic Clay Liner (GCL) overlaid with a 60-mil high density polyethylene (HDPE) liner. The landfill is equipped with a leachate collection system, which utilizes evaporation for disposal. The design of the Trans-Jordan Landfill is more than adequate to meet the regulations for disposing the salts from the distillation process.

COST

As discussed above, cost for transport and disposal are based on the mass of the waste. The cost for transport is $10 per ton via end dump truck and $20 per ton via roll-off containers. Disposal cost is $22 per ton. These are preliminary cost quotes, which may vary. It is assumed that the reverse osmosis plant will operate 330 days per year, therefore the annual transportation costs range from approximately $129,000 to $297,000. The annual disposal costs range from approximately $284,000 to $327,000. The combined annual cost ranges from approximately $413,000 to $623,000. The least cost being the salt waste with zero water content, with a daily load of 40 tons and transportation via a dump truck. The highest cost is for transport via roll-off containers and disposal of salts with 15 percent water content.

See the attached spreadsheet for details and calculations of the cost estimate.

Table 1
Cost Estimate for Alternative H - Disposal of Salt Waste
Memorandum 7 - Jordan Valley Water Conservancy District

Assumptions	
Total Dissolved Solids (TDS) (lbs/day)	78,122
Total Dissolved Solids (TDS) (tons/day)	39
Transportation Cost per Ton (end dump truck)	10
Transportation Cost per Ton (roll-offs)	20
Disposal Cost per Ton (Trans Jordan)	22
Operational Days per Year	330

Daily Costs

Water Content (%)	Daily Load (tons)	Transportation Cost (end dump trucs)	Transportation Cost (roll-offs)	Trans Jordan Disposal Cost	Total Daily Cost (end dump truck)	Total Daily Cost (roll-offs)
0	39	$390.61	$781.22	$859.34	$1,249.95	$1,640.56
5	41	$410.14	$820.28	$902.31	$1,312.45	$1,722.59
10	43	$429.67	$859.34	$945.28	$1,374.95	$1,804.62
15	45	$449.20	$898.40	$988.24	$1,437.44	$1,886.65

Annual Costs

Water Content (%)	Annual Load (tons)	Transportation Cost (end dump truck)	Transportation Cost (roll-offs)	Trans Jordan Disposal Cost	Total Annual Cost (end dump truck)	Total Annual Cost (roll-offs)
0	12,890	$128,901.30	$257,802.60	$283,582.86	$412,484.16	$541,385.46
5	13,535	$135,346.37	$270,692.73	$297,762.00	$433,108.37	$568,454.73
10	14,179	$141,791.43	$283,582.86	$311,941.15	$453,732.58	$595,524.01
15	14,824	$148,236.50	$296,472.99	$326,120.29	$474,356.78	$622,593.28

Notes:
water content = (water weight/solid weight)*100

N.8 Zone B to Tailings Pipeline

Jordan Valley Water Conservancy District

TECHNICAL MEMORANDUM

MEMO No: 8

SUBJECT: Cost Estimate for Disposal of Reverse Osmosis By-product
Alternative I - Discharge of Zone B to KUCC Tailings Pipeline

TO: Stakeholder Forum

COPIES: Richard Bay, JVWCD
Paula Doughty, KUCC
Douglas Bacon, UDEQ

FROM: Mark Atencio

DATE: April 13, 2004

EXECUTIVE SUMMARY

This alternative consists of pumping the Zone B RO by-product to the KUCC Tailings Pipeline at 7800 South in a nine mile long, 8-inch diameter pipeline using two pump stations. There is no Lost Use component of this project. The net present value cost for disposal of Zone B and Lost Use RO by-product is $5.0 million. This includes a capital cost of $3.6 million and an operation cost of $72,000 per year.

BACKGROUND

Mining activities in southwestern Salt Lake Valley have created groundwater contamination, with elevated sulfate concentrations. A 1995 federal Consent Decree negotiated by Jordan Valley Water Conservancy District (JVWCD), Kennecott Utah Copper Corporation (KUCC) and Utah Department of Environmental Quality (UDEQ), established a natural resource damage Trust Fund which was paid by KUCC. The Consent Decree established purposes for use of the Trust Fund as:

- remediating the aquifer
- containing the contamination plumes; and
- restoring the beneficial use by producing municipal quality water through treatment.

Dr. Dianne R. Nielson, Executive Director of UDEQ, has been appointed as Trustee of the Trust Fund and of projects to accomplish the Consent Decree purposes.

JVWCD and KUCC have submitted a Joint Proposal project to the Trustee to accomplish the Consent Decree purposes. The Joint Proposal involves one reverse osmosis (RO) treatment plant and facilities to treat western Zone A deep groundwater; and one RO plant to treat eastern Zone B deep groundwater and Lost Use shallow groundwater. The Trustee held a public information and public comment period during August through November 2003.

As a result of the public comments, JVWCD withdrew its Zone B/Lost Use RO by-product water discharge permit to the Jordan River and renewed efforts to find a better disposal alternative. The Trustee established a Stakeholder Forum for southwest groundwater remediation issues in early 2004. JVWCD has sought input from the Stakeholders Forum as it considers various alternatives for disposal of Zone B/Lost Use RO by-product water.

Zone B/Lost Use by-product water is projected to have the following characteristics:

	Flow Rate	TDS Concentration	Selenium Concentration
	(cfs)	(mg/L)	(µg/L)
Zone B	1.24	8,300	25
Lost Use	0.51	8,200	47
Total	**1.75**		
Common Range		**8,200 -8,300**	**32-47**

PURPOSE

The purpose of this memo is to describe the methods used to estimate the cost of disposing of Zone B RO by-product to the KUCC Tailings Pipeline at 7800 South in a pipeline from the Zone B Lost Use Treatment Plant in West Jordan.

AUTHOR'S CREDENTIALS

I am a registered professional engineer specializing in the area of water resources. I have completed Bachelor and Master of Science degrees in civil engineering. Following graduation I have been working at Jordan Valley Water Conservancy District as a civil engineer. My current title is senior engineer, in which I fill project management and supervisory roles. I have been studying and investigating various membrane and TDS

reduction treatments for eight years. I have completed a number of well drilling and construction projects. I have completed three years of pilot testing using various membrane and reverse osmosis processes. I have been filling the role of a technical engineer for the District on the Southwest Groundwater Remediation and Treatment Project since 1999.

DESCRIPTION OF ALTERNATIVE

See the attached Drawing of Alternative I for a visual representation of the alternative.

This alternative consists of a 9.4 mile long, 8-inch diameter PVC pipeline constructed from the Zone B Lost Use Reverse Osmosis (RO) Plant in West Jordan to the KUCC Tailings Pipeline at 7800 South. Two pump stations would be required.

SCALING CONCERNS

The RO by-product contains a high concentration of salts, consisting mostly of calcium sulfate (gypsum) and calcium carbonate (calcite IE Timpanogos Cave). The solutions are super-saturated and on the verge of precipitating. This means that if the fluid were to stop moving a scale would start to form on the interior of the pipeline. In the RO plant an antiscalant chemical prevents scale formation; however, the chemical does not last for more than approximately 24 hours.

The formation of scale or precipitation of salts is the same process that occurs in the Great Salt Lake as the tributaries to the lake bring in salts into the lake. In this case the salts are concentrated due to evaporation until the point that saturation is reached and the salts form particles (precipitation) and settle to the bottom. In order to prevent this type of scaling from occurring, the pipeline needs to be kept in continuous operation or drained.

The same concerns for formation of scale exist in the KUCC tailings pipeline.

PIPELINE MATERIAL

Polyvinyl chloride (PVC) was selected as material of choice after considering ductile iron, steel, high density polypropylene (HDPE), and PVC. This took into account the actual internal diameter of the various types of pipeline, the working pressure of the pipelines, the hydraulic characteristics of the pipeline materials (friction factor) and the construction cost. Each pipeline material option was evaluated in a large spreadsheet. A copy of this spreadsheet is attached to this memo. The limitations of the pipeline material options considered affected the number and cost of pump stations required, the pressure loss required to be overcome by a pump, pipeline construction cost, and pump station operating cost.

PIPELINE DIAMETER

Six-inch, 8-inch, 10-inch, and 12-inch diameter pipelines were evaluated in the spreadsheet identified above. The size of the pipeline options evaluated affected the pressure loss (smaller pipe = higher pressure loss), the detention time in the pipeline (larger pipe = longer time in transit), pipeline construction cost, and pump station operating cost.

PIPELINE ALIGNMENT

One alignment was considered for this alternative, the shortest distance and an existing corridor, 7800 South. This roadway is currently being expanded. A review of the plans shows limited space for new utilities. Other potential corridors include 9000 South and 7000 South.

SELECTION OF PREFERRED PIPELINE OPTION

Selection of the preferred pipeline option took into account the concerns with scaling and the effects of pipeline material, diameter, and alignment on the capital and operating cost.

The alignment selected for this alternative utilizes public right-of-way and private property, most of which is owned by KUCC. The alignment follows an elevation contour line to the north along 1300 West and then to the west along 7800 South to the KUCC tailings pipeline. This alignment allows for utilizing existing right–of-way corridors. The alignment also requires increasing in elevation, thereby creating additional pumping cost requirements.

In the event of power failure, the pipeline would, of necessity, be drained into the Jordan River.

Selection of the a 8-inch diameter PVC pipeline with two pump stations allows for the concerns expressed in this memo to be met will obtaining the lowest capital and net present value cost.

REQUIRED FACILITIES

- 9.4 mile long, 10-inch diameter PVC pipeline
- 2 pump stations

LEGALITY

The legality of this alternative was considered. A review of existing information indicated that a permit for discharge from KUCC's tailings pipeline, through the tailings impoundment, exists. The Zone B RO by-product meets the limitations of this permit.

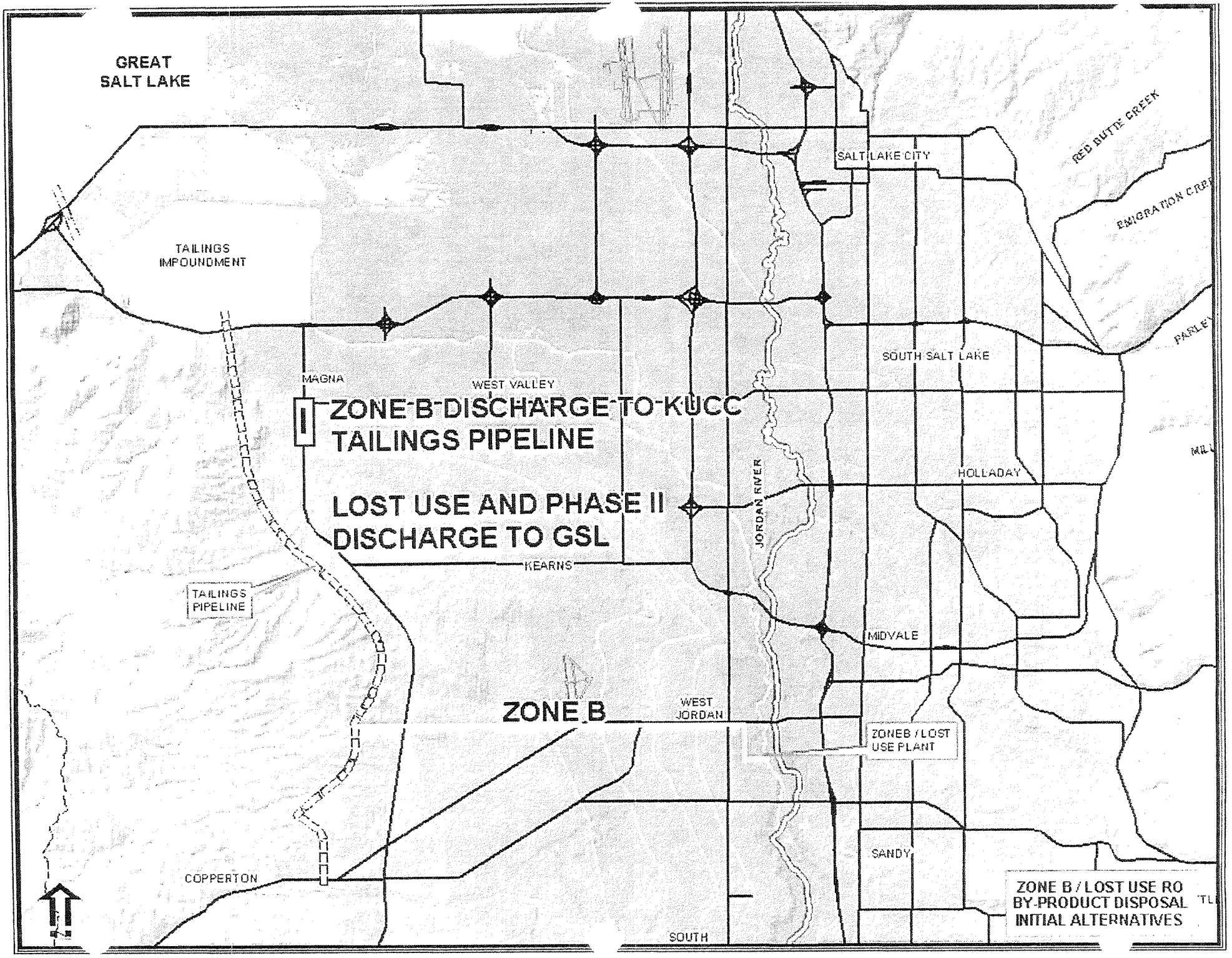
ASSUMPTIONS

- Pump Efficiency: 85%
- Motor Efficiency: 90%
- Pump Station Capital Cost: $500,000 each
- NPV interest rate: 4%
- 25 feet wide easement cost: $14.35/ foot ($50,000/acre)
- Pipeline in roadways installation cost: $39.90/ft
- Pipeline in open areas installation cost: $18.65/ft
- Pipeline costs from two contractors and MWH Engineers
- RO plant operates 330 days per year
- Power Cost $0.055/kW hr

COST ESTIMATE

The cost estimate for this alternative took into account the size of the pipeline, number of pump stations, pumping costs, length of pipeline, length of pipeline in roadways, length of pipeline in open areas, easement acquisition costs, dewatering costs, and engineering costs. The net present value cost for disposal of Zone B and Lost Use RO by-product is $5.0 million. This includes a capital cost of $3.6 million and an operation cost of $72,000 per year.

See the attached spreadsheet for details and calculations of the cost estimate.


GREAT SALT LAKE
TAILINGS IMPOUNDMENT
MAGNA
WEST VALLEY
ZONE B DISCHARGE TO KUCC TAILINGS PIPELINE
LOST USE AND PHASE II DISCHARGE TO GSL
KEARNS
TAILINGS PIPELINE
ZONE B
WEST JORDAN
COPPERTON
SOUTH
SALT LAKE CITY
RED BUTTE CREEK
EMIGRATION CREEK
SOUTH SALT LAKE
HOLLADAY
JORDAN RIVER
MIDVALE
ZONEB / LOST USE PLANT
SANDY
ZONE B / LOST USE RO BY-PRODUCT DISPOSAL INITIAL ALTERNATIVES

SOUTHWEST GROUNDWATER
REVERSE OSMOSIS BY-PRODUCT DISPOSAL OPTIONS

Alternative I
Discharge to KUCC Tailings Pipeline
Zone B Only

Alt. No.	Disposal Alternative	Project Yield (AF/yr)	Pipeline Material	Pipeline Actual Inside Diameter (Inches)	Zone A Yield (AF/yr)	Zone B Yield (AF/yr)	Zone B Production Rate (cfs)	Lost Use Yield (AF/yr)	Lost Use Production Rate (cfs)	Future Shallow Wells Yield (AF/yr)	Future Shallow Wells Production Rate (cfs)
I	Zone B to Tailings Pipeline	7000	PVC C-909	8.29	3500	3500	5.35	0	0	0	0

By-product Flow Rate (cfs)	Number of Pipelines (#)	Pressure Rating (psi)	Pipeline Hazen Williams C-factor	Pipeline in Roadways Length (ft)	Roadway Pipeline Unit Cost ($/ft)	Pipeline In Open Field Length (ft)	Open Pipeline Unit Cost ($/ft)	Total Pipeline Length (ft)	Total Pipeline Length (miles)	Dewatering Length (ft)	Dewatering Unit Cost ($/ft)
1.23	1	200	120	38,544	39.90	10,850	18.65	49,394	9.35	1,850	2.00

Pipeline Boring & Additional Costs ($)	Easement Length Required (ft)	Easement Cost ($)	Total Pipeline Cost ($mill)	Velocity (ft/sec)	Detention Time OK? (hrs)	Max Head Loss between Pump Stations (ft)	Max Distance between Pump Stations (ft)	Max Distance between Pump Stations (miles)	Calculated Number of Pump Stations (ft)	Actual Number of Pump Stations (ft)	Total Pump Station Cost ($mill)
134,750	0	0	2	3	4	416	69,018	13	0.7	1	0.500

Total Const Cost ($mill)	Eng Cost ($mill)	20% Contingency ($mill)	**Total Capital Cost ($mill)**	Discharge Hydraulic Gradeline (ft)	Static Pump Lift (ft)	Head Loss (ft)	Total Pump Lift (ft)	Pump Size (HP)	**Annual Pumping Cost ($)**	**NPV of Pumping Costs ($mill)**	**Total NPV Cost ($mill)**
2.379	0.357	0.821	**5.556**	5,385	903	298	1,201	220	**71,929**	**1.424**	**6.980**