Chapter 6

TREATMENT FACILITY

6.1 INTRODUCTION

The material presented in this section details the design criteria developed during pilot testing and the resulting capital and operations cost estimates for the following combined Zone B/Lost Use treatment plant alternatives:

- **Zone B (800 mg/L):** Zone B (i.e., produces 800 mg/L TDS) / Shallow Aquifer (i.e., produces 250 mg/L TDS);
- **Separate Design (August 2003 Agreement):** Zone B/Shallow Aquifer (i.e., each source produces 250 mg/L TDS);
- **Minimum Integrated Design:** Zone B RO Facility/Shallow Aquifer RO By-pass (i.e., produces 250 mg/L TDS). *Note that this option does not meet the full production objectives of the remediation project since the full annual volume of Lost Use water is not produced.*
- **Integrated Design:** Zone B and Deep Aquifer RO Facility/Shallow Aquifer RO By-pass (i.e., produces 250 mg/L TDS).

Conveyance and disposal system costs are also presented.

As indicated by the options presented above, the District also wishes to quantify the incremental cost of treating the Zone B supply from a finished water TDS of 800 mg/L to 250 mg/L. The information in this section also presents a breakdown of these incremental treatment costs.

6.2 DESIGN CRITERIA

Prior to this study, little was known about the Zone B, Deep Aquifer or Shallow Aquifer water supplies and their suitability to provide water for RO treatment. Limited data was available that detailed SDI and turbidity for these supplies. Pilot tests were conducted to determine if fouling would occur and to determine design criteria for required pretreatment, chemical cleaning, and membrane life. Additionally, the District required determination of an appropriate Shallow Aquifer by-pass treatment system. A by-pass treatment system concept was developed and presented previously in Section 3. Design criteria for this system were developed based on water quality data, regulatory requirements, and industry standard practice.

Table 6.1 presents design criteria for the various treatment facility alternatives based on the work previously performed by the District and the pilot study data presented in Section 5.

Zone B design criteria are broken down based on the treated water TDS of 800 mg/L and 250 mg/L. The design criteria for the Shallow Aquifer RO systems only result in the production of 250 mg/L water.

As indicated in **Table 6.1**, compared to the Zone B 800 mg/L option, treatment to the 250 mg/L finished water TDS goal requires more Zone B RO capacity. However, blending flows are reduced, thus resulting in the same treated water capacity. Additionally, cleaning chemical RO process flows increase when the finished water TDS goal is lowered to 250 mg/L. These design criteria are all important due to their impact to both capital and operations costs.

The Integrated Design alternatives include more Zone B RO treatment and no Shallow Aquifer RO treatment. All by-pass for the Integrated Design alternatives is from the Shallow Aquifer. Additional Deep Aquifer treatment is included for the full Integrated Design option, but excluded from the Minimum Integrated Design option.

As indicated in **Table 6.1,** a Zone B membrane cleaning frequencies and membrane life are assumed to be longer than for the Shallow Aquifer RO systems. This is based upon the results of pilot testing presented in Section 5. High calcium concentrations were thought to have interfered with silica inhibitors. Silica fouling was experienced and required cleaning once every two months. The District plans to conduct more pilot testing to find an inhibitor that will produce less frequent cleanings, however, for the purposes of this estimate, the shorter membrane life and more frequent cleanings are assumed.

Table 6.1 Reverse Osmosis Treatment Process Design Criteria
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

		Zone B 800 mg/L		Separate Design (August 2003 Agreement)		Minimum Integrated Design		Integrated Design		
Parameter	**Unit**	**Zone B 800 mg/L**	**Shallow Aquifer**	**Zone B 250 mg/L**	**Shallow Aquifer [a]**	**Zone B 250 mg/L**	**Shallow Aquifer**	**Zone B 250 mg/L**	**Deep Aquifer**	**Shallow Aquifer**
Treatment Plant Operation										
Operating Days per Year	days/year	330	330	330	330	330	330	330	330	330
RO Recovery [b]	%	80	85	80	85	80	NA	80		NA
Treatment System Recovery [c]	%	86	87	82	87	80	100	91		100
Blend Ratio [d]	%	66	82	91	82	100	NA	100		NA
Annual Production	AF/yr	3500	2300	3500	2300	3445	750	3890		842
Process Flow Rates										
Raw Water	mgd	4.03	2.57	4.26	2.57	4.25	0.74	4.25	0.56	0.83
Process Feed	mgd	2.84	2.17	3.98	2.17	4.25	NA	4.81		NA
RO Capacity/Permeate	mgd	2.28	1.84	3.18	1.84	3.40	NA	3.85		NA
By-pass Water	mgd	1.18	0.40	0.28	0.40	0	0.74	0		0.83
Finished Water	mgd	3.46	2.24	3.46	2.24	3.40	0.74	3.85		0.83
Concentrate	mgd	0.57	0.33	0.80	0.33	0.85	NA	0.96		NA
Cartridge Filtration										
Cartridge Filter Loading Rate										
RO Feed	gpm/10-in.	2.5	2.5	2.5	2.5	2.5	NA	2.5		NA
Blend Water	gpm/ft^2	NA	0.125	NA	0.125	NA	0.125	NA		0.125
Cartridge Filter Replacement Frequency	days	183	183	183	183	183	183	183		183
RO Equipment										
Pressure Vessel Array		38:14	28:14	48:24	28:14	50:25	NA	56:28		NA
Membranes per Vessel	No.	7	7	7	7	7	NA	7		NA
Flux Rate	gfd	16	16	16	16	16	NA	16		NA
Cleaning Frequency	No./year	3	6	3	6	3	NA	3		NA
Membrane Life	years	5	1.5	5	1.5	5	NA	5		NA
RO Feed Pressure [e,f]	psi	150	145	150	145	150	NA	150		NA
Interstage Pump Pressure	psi	50	50	50	50	50	NA	50		NA

Table 6.1 Reverse Osmosis Treatment Process Design Criteria
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

		Zone B 800 mg/L		Separate Design (August 2003 Agreement)		Minimum Integrated Design		Integrated Design		
Parameter	**Unit**	**Zone B 800 mg/L**	**Shallow Aquifer**	**Zone B 250 mg/L**	**Shallow Aquifer [a]**	**Zone B 250 mg/L**	**Shallow Aquifer**	**Zone B 250 mg/L**	**Deep Aquifer**	**Shallow Aquifer**
Decarbonation										
Decarbonation Efficiency	%	90	90	90	90	90	NA	90		NA
Decarbonator Loading Rate [g]	gpm/ft^2	20	20	20	20	20	NA	20		NA
Air to Water Ratio		30:1	30:1	30:1	30:1	30:1	NA	30:1		NA
Chemical Feed System										
Scale Inhibitor Dose [h]	mg/L	4	4.3	4	4.3	4	NA	4		NA
Sodium Hypochlorite Dose [i]	mg/L	1	0.5	0.5	0.5	0.5	1.5	0.5		1.5
Sodium Hydroxide Dose [j]	mg/L	-	-	14.3	14.3	14.3	14.3	14.3		14.3
Membrane Cleaning Chemicals										
Low pH	lbs./year	2000	6060	5250	6060	6000	NA	6800		NA
High pH	lbs./year	2000	6060	5250	6060	6000	NA	6800		NA
Silica	lbs./year	NA	6060	NA	6060	NA	NA	NA		NA
UV Disinfection System										
UV Dose	mJ/cm^2	NA	40	NA	40	NA	40	NA		40
UV Transmittance	%	NA	90	NA	90	NA	90	NA		90
No. of UV Lamps	No./Reactor	NA	7	NA	7	NA	14	NA		14
UV Lamp Replacement Freq.	hours	NA	10,000	NA	10,000	NA	10,000	NA		10,000
UV Electrical Draw	kW	NA	1.33	NA	1.33	NA	2.66	NA		2.66
UV Cleaning Frequency [k]	No./yr	NA	TBD	NA	TBD	NA	TBD	NA		TBD
UV Cleaning Chemical Demand [l]	lbs/yr	NA	280	NA	280	NA	280	NA		280

Table 6.1 **Reverse Osmosis Treatment Process Design Criteria**
Cont'd **Zone B Reverse Osmosis Pilot Study**
Jordan Valley Water Conservancy District

		Zone B 800 mg/L		Separate Design (August 2003 Agreement)		Minimum Integrated Design		Integrated Design		
Parameter	**Unit**	**Zone B 800 mg/L**	**Shallow Aquifer**	**Zone B 250 mg/L**	**Shallow Aquifer [a]**	**Zone B 250 mg/L**	**Shallow Aquifer**	**Zone B 250 mg/L**	**Deep Aquifer**	**Shallow Aquifer**

Notes:
NA Not applicable
TBD To be determined

a Based on Lost Use blended water TDS of 250 mg/L

b $R_{RO} = Q_{Permeate} / Q_{RO\ Feed}$

c $R_{RO} = Q_{Finished\ Water} / Q_{Well\ Water}$

d $r_{Blend} = Q_{Permeate} / Q_{Finished\ Water} = (C_{Feed} - C_{Goal}) / (C_{Feed} - C_{Permeate})$

e Modeled Using RODESIGN V.7.0 (assumes ESPA1 membrane or equivalent)
f Feed pressure at ½ of membrane life (i.e., year 2.5 of 5 year membrane life) at fouling rate estimated by pilot testing
g Blended Zone B and Lost Use permeate water.
h Modeled using Water Wizard KLT V.1.1
i Based on $SDS_{48\ hr}$-Chlorine Demand presented in **Table 5.6**
j Modeled Using The Rothberg Tamburini and Winsor Model for Water Process and Corrosion Chemistry V. 4.0
k To be determined during start-up testing.
l Solution can be re-used in off-line low-pressure UV cleaning. Demand based on other applications of similar quality.

Unit costs for consumable items that will be used during the operation of the combined Zone B and Lost Use treatment plant are presented in **Table 6.2**. It should be noted that cartridge filters for the RO membranes are estimated to be significantly less expensive than those used for the Shallow Aquifer by-pass treatment system. Cartridge filters used for RO pretreatment are of the glass fiber wound variety that will provide basic protection for the RO membranes if there were an up-set in the well field or a failure of a well screen. The by-pass cartridge filters are specially engineered and highly efficient at removing particles within the 2 to 5-μm size range. The filters that are used for the purpose of this estimate are approved in the States of Alaska and Idaho for *Giardia* and *Cryptosporidium* removal. Material specification sheets are provided in **Appendix C**.

Included in the unit costs of consumable items in **Table 6.2** is a patent royalty fee for the UV disinfection process. The certified UV systems that are currently included in Carollo's standard specifications are subject to this royalty fee. However, this patent is currently being challenged in several states and may only apply to medium and high pressure UV technologies. Carollo's specifications include one low pressure UV system that may be exempt from this patent royalty fee. Regardless, this fee has been included in the cost estimate to provide a realistic interpretation of what the operations costs of UV treatment may be.

Table 6.2 Operations and Maintenance Unit Costs
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Description	Unit Cost
Membrane Element Replacement	$500 per element
Cartridge Filter Replacement	$3 per 10-inches of filter length
By-pass Cartridge Filter Replacement	$355 per filter
Electrical Power	$0.055 per kW-hr
Scale Inhibitor	$0.98 per lb.
Caustic Soda	$0.21 per lb. as NaOH
Sodium Hypochlorite [a]	3.5 kW per lb. Cl_2
Membrane Cleaning Chemicals	
Low pH	$2.80 per lb.
High pH	$3.18 per lb.
Silica	$4.14 per lb.
UV Lamps	$200 each
UV Cleaning Chemical	$5.00 per lb.
UV Patent Royalty [b]	$0.015 per 1,000 gallons

Notes:
a On-site generation of hypochlorite
b Patent currently under contest review. Vendors that have validated performance do not hold patent.

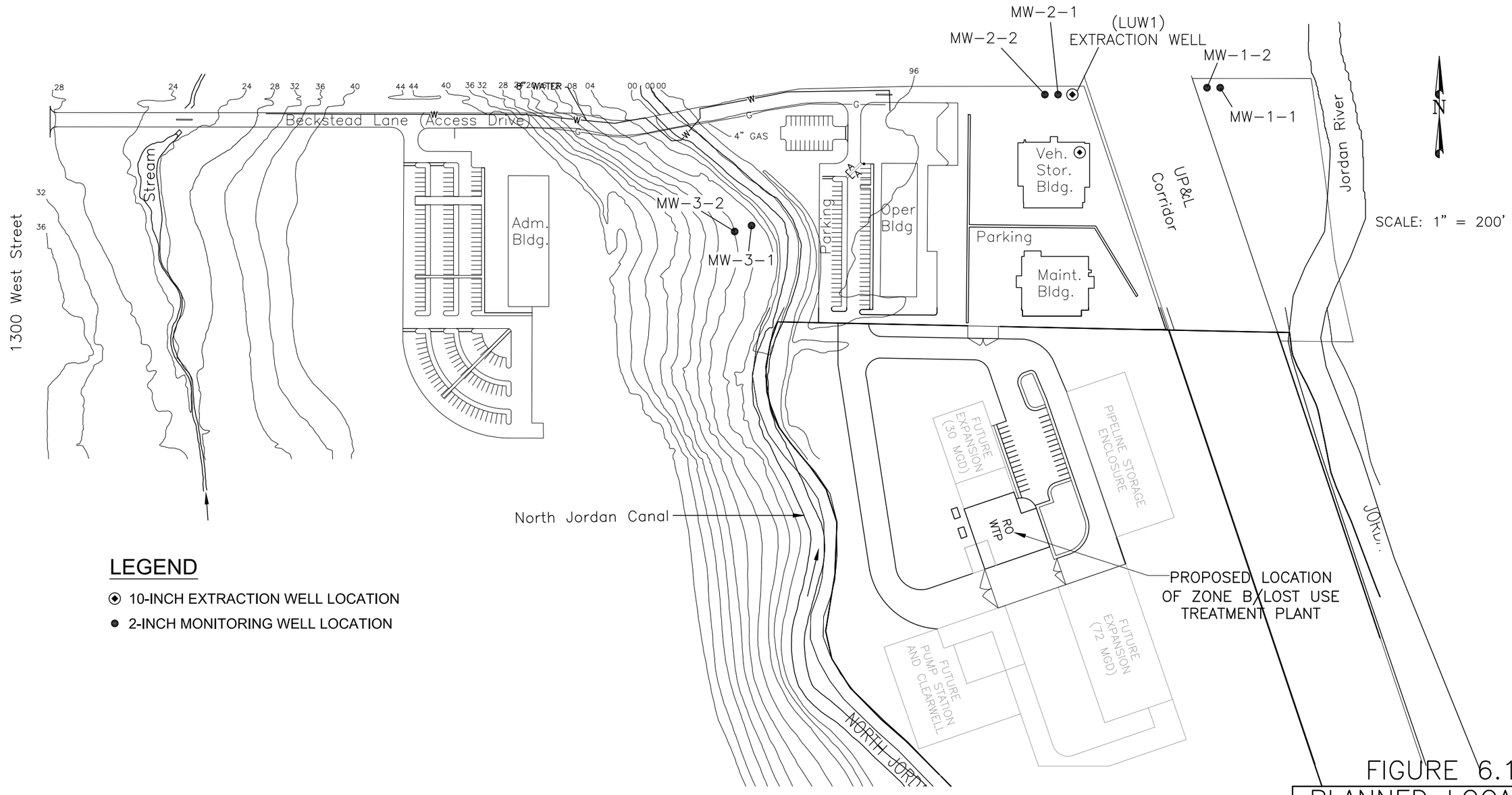
6.3 FACILITY LAYOUT

Before capital costs can be estimated, a site plan and facility layout are required to more closely estimate the costs for site work and building materials. **Figures 6.1 and 6.2** present the location and site plan of the combined Zone B/Lost Use treatment facility (i.e., as depicted in the Separate Design Option (August 2003 Agreement)). This site is located near the District's main office on 8215 South 1300 West, West Jordan, Utah.

As indicated in **Figure 6.1**, the planned Zone B/Lost Use treatment plant will be located in the southwest portion of the District's property, in an area that is currently used as a cattle pasture. This area is assumed to have a similar soils composition as the adjacent area where the maintenance, vehicle storage, and operations buildings are located. Based on a soils study conducted by the District and previous construction in the adjacent area, this site requires over excavation to 20-feet and structural fill under the building foundations due to the potential for liquefaction. Roadways are assumed to be excavated to 1.25-feet and filled to 12-inches with road base and 3-inches of asphalt. These costs were previously unaccounted for in studies commissioned by the District and should be included in the capital cost estimate for the Zone B/Lost Use treatment facility.

Figure 6.2 presents a site plan for the planned Zone B/Lost Use treatment facility. This site covers approximately 5.6-acres. Access to the Zone B/Lost Use treatment plant building is provided on the south side for chemical deliveries and equipment maintenance. As indicated in **Figure 6.3**, the equipment has been placed in the building in such a fashion that the Shallow Aquifer RO treatment and the decarbonation processes may be easily expanded to the north and southwest side of property. A wet well to capture water after decarbonation, blending and post treatment, that would also provide water for the finished water pump station is located sub-grade to the planned facility, under the finished water pumps and decarbonation tower.

It should be noted that alternate locations for the placement of this facility have been identified. These sites include the hill located between the Administration building and the North Jordan Canal, and the hill between 1300 West and the Administration building. It may be possible to build a two-story treatment plant into the side of these hills and maximize the use of any hydraulic gradients that occur naturally. Additionally, soils conditions may be better in these locations, which will minimize the site work costs associated with over excavation and structural fill that will be incurred at the site presented in **Figures 6.1 and 6.2**. These alternatives should be visited during the pre-design phase of this project.



LEGEND

- 10-INCH EXTRACTION WELL LOCATION
- 2-INCH MONITORING WELL LOCATION

FIGURE 6.1

PLANNED LOCATION (8215 SOUTH 1300 WEST)

JORDON VALLEY RO PILOT STUDY

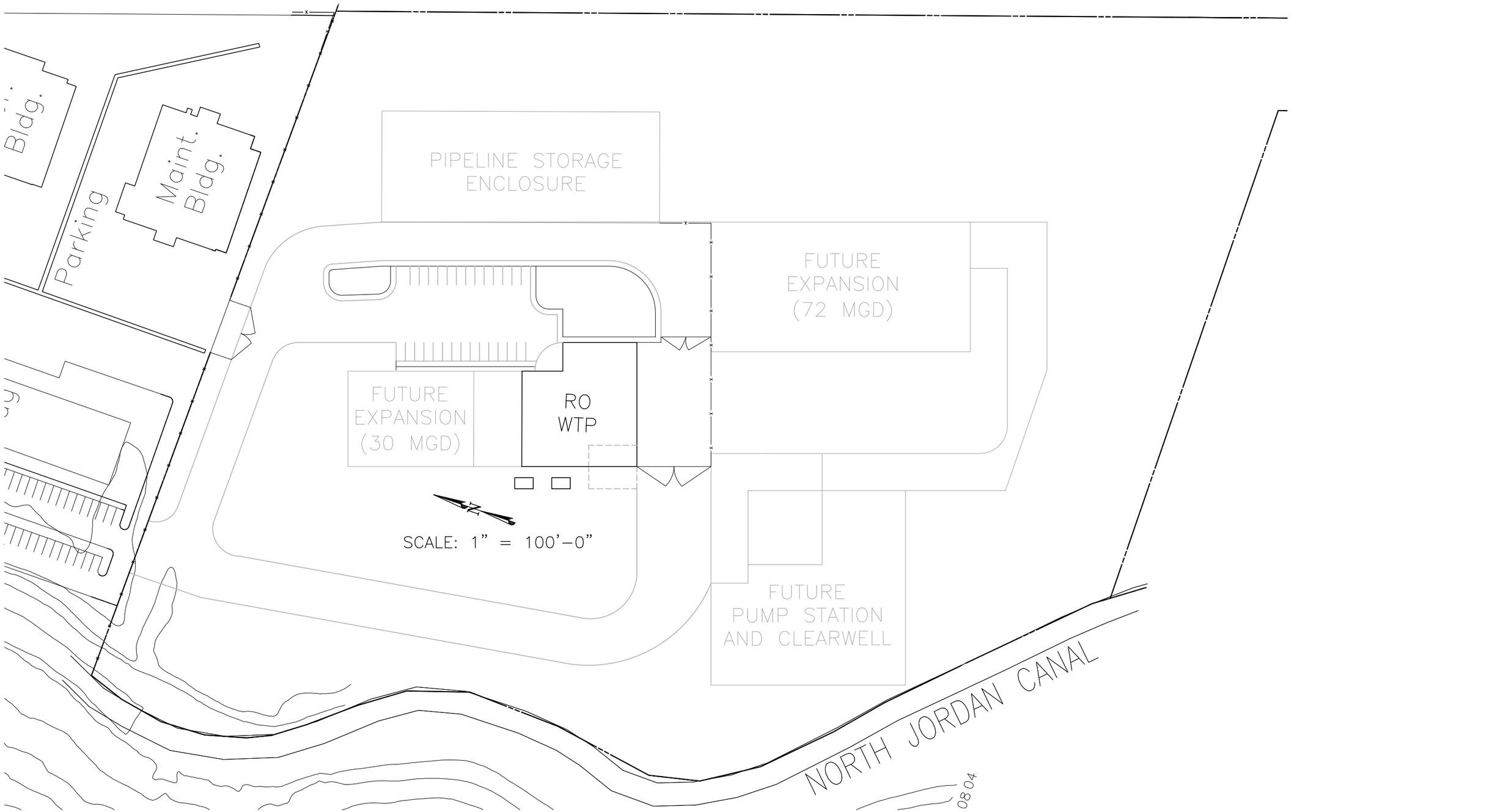
DESIGNED BY: T. SEACORD

DATE: MARCH 2002

carollo engineers

Last Saved: 9-27-02 10:02am

D:\JVWCD_BOI\6170A00\DRAWINGS\PREDESIGN\FIGURE6-1 5-27-04 03:54pm SBennett ; JV1117BDR.dwg; jvsite03; jvnsiterotated; jvxsite1



SCALE: 1" = 100'-0"

FIGURE 6.2
SITE PLAN

JORDON VALLEY RO
PILOT STUDY

DESIGNED BY: T. SEACORD

DATE: MARCH 2002

carollo engineers

Last Saved: 9-27-02 10:03am

D:\JVWCD_BOI\6170A00\DRAWINGS\PREDESIGN\FIGURE6-2 5-27-04 03:58pm SBennett ; JV1117BDRdwg; figure6-1; jvnsiterotated; jvxsite1; jvsite03

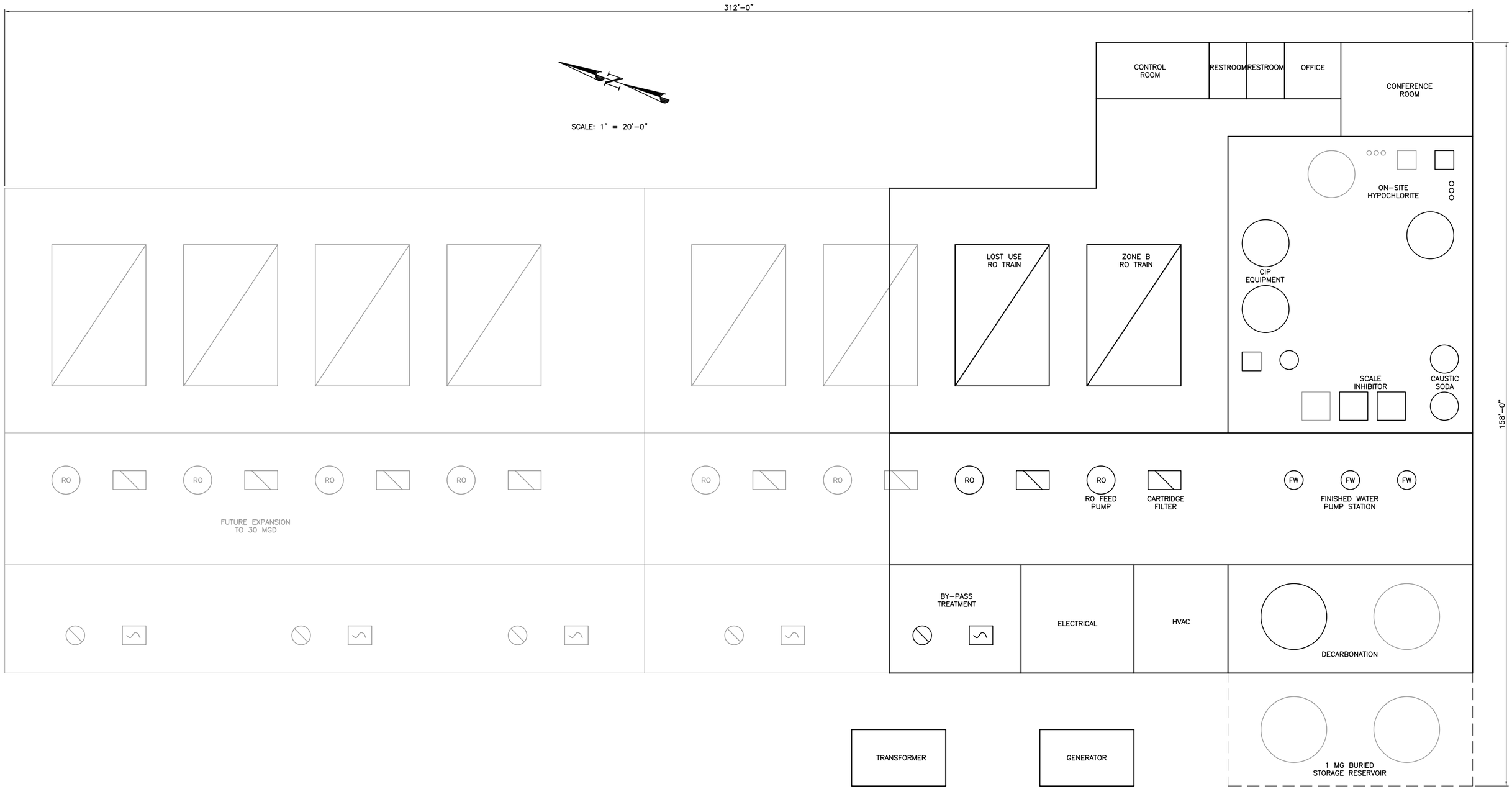


FIGURE 6.3
FACILITY PLAN

JORDON VALLEY RO PILOT STUDY

DESIGNED BY: T. SEACORD

DATE: MARCH 2002

carollo engineers

Last Saved: 9-27-02 10:00am

D:\JVWCD_BOI\6170A00\DRAWINGS\PREDESIGN\FIGURE6-3 5-27-04 03:59pm SBennett ; JV1117BDR.dwg

6.4 CAPITAL COST ESTIMATE

Capital costs for the various treatment facility alternatives and the conveyance and by-product water disposal systems are detailed in **Tables 6.3 through 6.10** as follows:

- **Tables 6.3 and 6.4** detail the capital costs associated with the Zone B 800 mg/L TDS alternative;
- **Tables 6.5 and 6.6** detail the capital costs associated with the Separate Design (August 2003) alternative;
- **Tables 6.7 and 6.8** detail the capital costs associated with the Minimum Integrated Design alternative;
- **Tables 6.9 and 6.10** detail the capital costs associated with the Integrated Design alternative.

Some of the capital costs presented in these tables are adapted from the District's previous study in 1999. These costs were adjusted using the *Engineering News Record* (ENR) 20 City Average Construction Cost Index (CCI). The 1999 costs increased by approximately 8% when this correction is applied. The District should be interested in these indices in order to determine the present day cost of previous capital cost estimates to determine if this project still meets their criteria for participation. All costs are presented in October 2003 dollars. A cost correction for the total capital cost to May 2004 dollars is also provided.

Capital costs can be summarized (in May 2004 dollars) by option as follows:

- Zone B 800 mg/L: Treatment Plant = $17,315,000
Conveyance System = $27,022,000
Total Project = $44,337,000
- Separate Design: Treatment Plant = $18,672,000
Conveyance System = $27,022,000
Total Project = $45,694,000
- Minimum Integrated Design: Treatment Plant = $14,387,000
Conveyance System = $24,386,000
Total Project = $38,773,000
- Integrated Design: Treatment Plant = $15,469,000
Conveyance System = $24,386,000
Total Project = $39,855,000

As indicated, the incremental capital cost in treatment from the 800 mg/L TDS to 250 mg/L TDS goal is estimated to vary from approximately minus $5,564,000 to $1,357,000 depending upon the treatment option. It should be noted however that the Minimum Integrated Design does not meet the objectives of the project since the full volume of Lost Use capacity is not produced. Therefore, to meet the objectives of the project, the range of incremental cost is actually minus $4,482,000 to $1,357,000. These costs include the incremental costs for the treatment and required infrastructure for conveyance of raw, finished and by-product water. Integrated Design capital costs are reduced from the Zone B 800 mg/L and Separate design alternatives by using Shallow Aquifer water as the only source of by-pass.

Table 6.3 Zone B (800 mg/L) - Treatment Facility Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Building				
Foundation	900	CY	$400	$360,000
Structural & Architectural	15250	SF	$100	$1,525,000
Electrical [1]	1	LS	$960,000	$960,000
HVAC/Plumbing	1	LS	$400,000	$400,000
Instrumentation	1	LS	$625,000	$625,000
RO Equipment = 2.28 + 1.88	4.12	MGD	$740,000	$3,049,000
Cartridge Filters	2	EA	$40,000	$80,000
Decarbonator	1	LS	$300,000	$300,000
Chemical Storage/Feed System				
Scale Inhibitor	2	LS	$50,000	$100,000
On-site Hypochlorite	1	LS	$120,000	$120,000
Caustic Soda	1	LS	$180,000	$180,000
By-pass Treatment System				
Cartridge Filter	1	LS	$80,000	$80,000
UV Disinfection	1	LS	$150,000	$150,000
Product Water Pumps (770 hp) [2]	1	LS	$160,000	$165,000
Contact Tank (30 minutes)	640	CY	$624	$400,000

Table 6.3 Cont'd
Zone B (800 mg/L) - Treatment Facility Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Site Work				
Over Excavation	17200	CY	$12	$207,000
Structural Fill	16350	CY	$20	$327,000
Paving & Sidewalks	125740	SF	$2.10	$265,000
Other	1	LS	$35,000	$35,000
Subtotal				$9,328,000
Contractors Overhead & Profit			27%	$2,519,000
Construction Cost Subtotal				$11,847,000
Design Contingency			10%	$1,185,000
Change Order Allowance			5%	$593,000
Total Construction Cost				**$13,625,000**
Pre-design & Final Design Engineering			10%	$1,185,000
Engineering Services During Construction			5%	$593,000
On-site Construction Services & Administration			5%	$593,000
Total Engineering Services				**$2,371,000**
TOTAL PROJECT COST ESTIMATE (October 2002)				**$15,996,000**
TOTAL PROJECT COST ESTIMATE (May 2004) [3]				**$17,315,000**

Notes:
1. Does not include standby power or off-site improvements
2. Includes one redundant pump
3. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.4 Zone B (800 mg/L) - Pipeline Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost	Source
Zone B Wells and Pump Houses	7	EA	$320,000	$2,240,000	District
Lost Use Wells and Pump Houses	4	EA	$81,000	$324,000	CDM
Raw Water Conveyance					
Zone B (8 to 16-inch)	52,800	per foot	$64	$3,380,000	Carollo
Lost Use (8 to 12-inch)	10,000	per foot	$43	$410,000	CDM
Treated Water Pipe (24-inch)	14,000	per foot	$130	$1,820,000	Carollo
Concentrate Pipe (8-inch)	105,600	per foot	$73	$7,741,000	District
Construction Cost Subtotal				$17,457,000	
Construction Cost + 10% Contingency			10%	$19,203,000	
Construction plus Engineering			30%	$24,964,000	
TOTAL PROJECT COST ESTIMATE (October 2002)				**$24,964,000**	
TOTAL PROJECT COST ESTIMATE (May 2004) [1]				**$27,022,000**	

Notes:
1. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.5 Separate Design (Aug 2003 Agrmt.) - Treatment Plant Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Building				
Foundation	900	CY	$400	$360,000
Structural & Architectural	15250	SF	$100	$1,525,000
Electrical [1]	1	LS	$960,000	$960,000
HVAC/Plumbing	1	LS	$400,000	$400,000
Instrumentation	1	LS	$625,000	$625,000
RO Equipment = 3.14 + 1.88	4.98	MGD	$740,000	$3,686,000
Cartridge Filters	2	EA	$50,000	$100,000
Decarbonator	1	LS	$400,000	$400,000

Table 6.5 Cont'd
Separate Design (Aug 2003 Agrmt.) - Treatment Plant Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Chemical Storage/Feed System				
Scale Inhibitor	2	LS	$50,000	$100,000
On-site Hypochlorite	1	LS	$120,000	$120,000
Caustic Soda	1	LS	$180,000	$180,000
By-pass Treatment System				
Cartridge Filter	1	LS	$80,000	$80,000
UV Disinfection	1	LS	$125,000	$125,000
Product Water Pumps (770 hp) [2]	1	LS	$165,000	$165,000
Contact Tank (30 minutes)	640	CY	$624	$400,000
Site Work				
Over Excavation	17200	CY	$12	$207,000
Structural Fill	16350	CY	$20	$327,000
Paving & Sidewalks	125740	SF	$2.10	$265,000
Other	1	LS	$35,000	$35,000
Subtotal				$10,060,000
Contractors Overhead & Profit			27%	$2,717,000
Construction Cost Subtotal				$12,777,000
Design Contingency			10%	$1,278,000
Change Order Allowance			5%	$639,000
Total Construction Cost				**$14,694,000**
Pre-design & Final Design Engineering			10%	$1,278,000
Engineering Services During Construction			5%	$639,000
On-site Construction Services & Administration			5%	$639,000
Total Engineering Services				**$2,556,000**
TOTAL PROJECT COST ESTIMATE (October 2002)				**$17,250,000**
TOTAL PROJECT COST ESTIMATE (May 2004) [3]				**$18,672,000**

Notes:
1. Does not include standby power or off-site improvements
2. Includes one redundant pump
3. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.6 Separate Design (Aug 2003 Agrmt.) - Pipeline Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost	Source
Zone B Wells and Pump Houses	7	EA	$320,000	$2,240,000	District
Lost Use Wells and Pump Houses	4	EA	$81,000	$324,000	CDM
Raw Water Conveyance					
Zone B (8 to 16-inch)	52,800	per foot	$64	$3,380,000	Carollo
Lost Use (8 to 12-inch)	10,000	per foot	$43	$410,000	CDM
Treated Water Pipe (24-inch)	14,000	per foot	$130	$1,820,000	Carollo
Concentrate Pipe (10-inch)	105,600	per foot	$88	$9,283,000	District
Construction Cost Subtotal				$17,457,000	
Construction Cost + 10% Contingency			10%	$19,203,000	
Construction plus Engineering			30%	$24,964,000	
TOTAL PROJECT COST ESTIMATE (October 2002)				**$24,964,000**	
TOTAL PROEJCT COST ESTIMATE (May 2004) [1]				**$27,022,000**	

Notes:
1. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.7 Minimum Integrated Design - Treatment Plant Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Building				
Foundation	800	CY	$400	$320,000
Structural & Architectural	13400	SF	$100	$1,340,000
Electrical [1]	1	LS	$750,000	$750,000
HVAC/Plumbing	1	LS	$375,000	$375,000
Instrumentation	1	LS	$475,000	$475,000
RO Equipment = 3.40	3.40	MGD	$740,000	$2,514,000
Cartridge Filters	2	EA	$35,000	$70,000
Decarbonator	1	LS	$230,000	$230,000

Table 6.7 Cont'd
Minimum Integrated Design - Treatment Plant Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Chemical Storage/Feed System				
Scale Inhibitor	1	LS	$50,000	$50,000
On-site Hypochlorite	1	LS	$100,000	$100,000
Caustic Soda	1	LS	$150,000	$150,000
By-pass Treatment System				
Cartridge Filter	1	LS	$120,000	$120,000
UV Disinfection	1	LS	$160,000	$160,000
Product Water Pumps (770 hp) [2]	1	LS	$150,000	$150,000
Contact Tank (30 minutes)	350	CY	$624	$219,000
Site Work				
Over Excavation	13800	CY	$12	$166,000
Structural Fill	13000	CY	$20	$260,000
Paving & Sidewalks	125740	SF	$2.10	$265,000
Other	1	LS	$35,000	$35,000
Subtotal				$7,749,000
Contractors Overhead & Profit			27%	$2,093,000
Construction Cost Subtotal				$9,842,000
Design Contingency			10%	$985,000
Change Order Allowance			5%	$493,000
Total Construction Cost				**$11,320,000**
Pre-design & Final Design Engineering			10%	$985,000
Engineering Services During Construction			5%	$493,000
On-site Construction Services & Administration			5%	$493,000
Total Engineering Services				**$1,971,000**
TOTAL PROJECT COST ESTIMATE (October 2002)				**$13,291,000**
TOTAL PROJECT COST ESTIMATE (May 2004) [3]				**$14,387,000**

Notes:
1. Does not include standby power or off-site improvements
2. Includes one redundant pump
3. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.8 Minimum Integrated Design - Pipeline Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost	Source
Zone B Wells and Pump Houses	7	EA	$320,000	$2,240,000	District
Lost Use Wells and Pump Houses	2	EA	$81,000	$162,000	CDM
Raw Water Conveyance					
Zone B (8 to 16-inch)	52,800	per foot	$64	$3,380,000	Carollo
Lost Use (8 to 12-inch)	10,000	per foot	$43	$410,000	CDM
Treated Water Pipe (24-inch)	14,000	per foot	$130	$1,820,000	Carollo
Concentrate Pipe (8-inch)	105,600	per foot	$73	$7,741,000	District
Construction Cost Subtotal				$15,753,000	
Construction Cost + 10% Contingency			10%	$17,329,000	
Construction plus Engineering			30%	$22,528,000	
TOTAL PROJECT COST ESTIMATE (October 2002)				**$22,528,000**	
TOTAL PROJECT COST ESTIMATE (May 2004) [1]				**$24,386,000**	

Notes:
1. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.9 Integrated Design - Treatment Plant Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Building				
Foundation	800	CY	$400	$320,000
Structural & Architectural	134000	SF	$100	$1,340,000
Electrical [1]	1	LS	$800,000	$800,000
HVAC/Plumbing	1	LS	$375,000	$375,000
Instrumentation	1	LS	$500,000	$500,000
RO Equipment = 3.84	3.84	MGD	$740,000	$2,846,000
Cartridge Filters	2	EA	$35,000	$70,000
Decarbonator	1	LS	$270,000	$270,000

Table 6.9 Cont'd
Integrated Design - Treatment Plant Capital Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Classification	Quantity	Units	Unit Cost	Extended Cost
Chemical Storage/Feed System				
Scale Inhibitor	1	LS	$50,000	$50,000
On-site Hypochlorite	1	LS	$120,000	$120,000
Caustic Soda	1	LS	$180,000	$180,000
By-pass Treatment System				
	1	LS	$120,000	$120,000
Cartridge Filter	1	LS	$160,000	$160,000
UV Disinfection				
Product Water Pumps (770 hp) [2]	1	LS	$155,000	$155,000
Contact Tank (30 minutes)	400	CY	$624	$250,000
Site Work				
Over Excavation	13800	CY	$12	$166,000
Structural Fill	13000	CY	$20	$260,000
Paving & Sidewalks	125740	SF	$2.10	$265,000
Other	1	LS	$35,000	$35,000
Subtotal				$8,332,000
Contractors Overhead & Profit			27%	$2,250,000
Construction Cost Subtotal				$10,582,000
Design Contingency			10%	$1,059,000
Change Order Allowance			5%	$530,000
Total Construction Cost				**$12,171,000**
Pre-design & Final Design Engineering			10%	$1,059,000
Engineering Services During Construction			5%	$530,000
On-site Construction Services & Administration			5%	$530,000
Total Engineering Services				**$2,119,000**
TOTAL PROJECT COST ESTIMATE (October 2002)				**$14,290,000**
TOTAL PROJECT COST ESTIMATE (May 2004) [3]				**$15,469,000**

Notes:
1. Does not include standby power or off-site improvements
2. Includes one redundant pump
3. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

Table 6.10 Integrated Design - Pipeline Capital Cost Estimate Zone B Reverse Osmosis Pilot Study Jordan Valley Water Conservancy District					
Classification	**Quantity**	**Units**	**Unit Cost**	**Extended Cost**	**Source**
Zone B Wells and Pump Houses	7	EA	$320,000	$2,240,000	District
Lost Use Wells and Pump Houses	2	EA	$81,000	$162,000	CDM
Raw Water Conveyance					
Zone B (8 to 16-inch)	52,800	per foot	$64	$3,380,000	Carollo
Lost Use (8 to 12-inch)	10,000	per foot	$43	$410,000	CDM
Treated Water Pipe (24-inch)	14,000	per foot	$130	$1,820,000	Carollo
Concentrate Pipe (8-inch)	105,600	per foot	$73	$7,741,000	District
Construction Cost Subtotal				$15,753,000	
Construction Cost + 10% Contingency			10%	$17,329,000	
Construction plus Engineering			30%	$22,528,000	
TOTAL PROJECT COST ESTIMATE (October 2002)				**$22,528,000**	
TOTAL PROJECT COST ESTIMATE (May 2004) [1]				**$24,386,000**	

Notes:
1. ENR 20 City Average CCI (October 2002) = 6526
   ENR 20 City Average CCI (May 2004) = 7064

6.5 OPERATIONS AND MAINTENANCE COST ESTIMATE

Operations and maintenance (O&M) costs for the various treatment plant alternatives are presented in **Table 6.11** and can be summarized (in May 2004 dollars) as follows:

- Zone B 800 mg/L: $4,021 per day ($705 per MG)
- Separate Design: $4,379 per day ($768 per MG)
- Minimum Integrated Design: $3,329 per day ($805 per MG)
- Integrated Design: $3,677 per day ($786 per MG)

O&M costs for the Zone B and Lost Use treatment systems are based on design criteria and unit costs presented previously in **Tables 6.1 and 6.2**.

As indicated in **Table 6.11**, pumping costs represent approximately fifty percent of the total O&M cost. Labor, membrane replacement and chemical costs represent between thirty to forty percent of the remaining O&M cost. This distribution of cost is not uncommon for other RO treatment facilities.

Incremental treatment costs from the Zone B 800 mg/L option vary from minus $692 per day to $358 per day. Both the Integrated Design options are less expensive to operate than the Zone B 800 mg/L alternative. This is because no Shallow Aquifer RO treatment is required and all Shallow Aquifer water is used as the sole source of raw water by-pass for blending. It should be noted that the Minimum Integrated Design does not meet the full requirement for annual water production. Therefore, the incremental cost of treatment, for alternatives that meet both the 250 mg/L treatment goal and the annual production requirements is minus $344 per day to $692 per day.

It is important to distinguish that the while the Integrate Design alternatives have a lower operating cost, the per unit volume product cost is actually greater for these alternatives. This is because less water is produced from these alternatives.

Operations and maintenance is the largest component of cost over the life of an RO treatment plant. Therefore, by finding ways to reduce these costs, the process can become more economical. O&M cost for the Zone B 800 mg/L and Separate Design treatment alternative may be reduced by either lowering the Shallow Aquifer RO recovery from 85% to reduce the silica saturation or by finding an alternate scale inhibitor that prevents silica fouling. The anticipated resulting O&M cost savings would primarily be associated with a reduced membrane replacement and chemical cleaning cost. However, pumping costs would increase when recovery is lowered. Further analysis of to determine estimated costs from a lower Shallow Aquifer RO recovery is required to weigh increased pumping costs versus savings from less cleaning and longer membrane life, but is outside the scope of this study.

While pilot tests indicated that the Inhibitor 2 was not successful at controlling scale formation at a recovery rate of 85%, the industry is frequently developing new scale inhibitors that may be able to control scale (i.e., silica) formation at this recovery rate. The District should consider including pilot equipment in their RO treatment equipment procurement contract documents to test the latest developments in the RO industry. An 85% Shallow Aquifer RO recovery would lower the overall O&M costs if scale formation can be successfully controlled.

Table 6.11 Zone B/Lost Use Treatment Facility O&M Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Description	Daily Costs (2004 $)											
	Zone B 800 mg/L			Separate Design (August 2003 Agreement)			Minimum Integrated Design			Integrated Design		
	Zone B 800 mg/L	Shallow Aquifer	Total Project	Zone B 250 mg/L	Shallow Aquifer	Total Project	Zone B 250 mg/L	Shallow Aquifer	Total Project	Zone B 250 mg/L	Deep Aquifer	Shallow Aquifer	Total Project
Well Water Pumping [a, b]	360	180	540	380	180	560	380	45	425	445		55	500
RO Feed Pumping [a]	200	145	345	280	145	425	300	NA	300	340		NA	340
Interstage Pumping [c]	40	30	70	60	30	90	65	NA	65	70		NA	70
Product Water Pumping [a, d]			610			610			435				495
Concentrate Pumping [a, e]			180			110	155	NA	155	220		NA	220
Electrical Pumping Costs			*1,745*			*1,795*			*1,380*				*1,625*
Cost per MG			*306*			*315*			*334*				*348*
General Building Electric Load			79			79			79				79
Decarbonation Blower			25			25			25				25
Electrical Operating Costs (not including pumping)			*104*			*104*			*104*				*104*
Cost per MG			*22*			*22*			*22*				*22*
Cartridge Filters	17	13	30	24	13	37	26	NA	26	29		NA	29
Scale Inhibitor	93	76	169	128	76	204	139	NA	139	156		NA	156
Sodium Hydroxide			-			143		NA	103			NA	117
Sodium Hypochlorite [f]			46			28		NA	28			NA	32
Membrane Chemical Cleaning	36	186	222	95	186	281	109	NA	109	123		NA	123
Chemical Operating Costs			*467*			*693*			*405*				*457*
Cost per MG			*82*			*122*			*98*				*98*
By-pass Cartridge Filters	NA	62	62	NA	62	62	NA	124	124	NA		124	124
By-pass UV Power	NA	2	2	NA	2	2	NA	4	4	NA		4	4
By-pass UV Lamp Replacement	NA	3	3	NA	3	3	NA	7	7	NA		7	7
By-pass UV Chemical Cleaning	NA	4	4	NA	4	4	NA	4	4	NA		4	4
Patent Royalty [g]	NA	6	6	NA	6	6	NA	11	11	NA		12	12
By-pass Operating Costs			*77*			*77*			*124*				*151*
Cost per MG			*14*			*14*			*36*				*32*

Table 6.11 Cont'd
Zone B/Lost Use Treatment Facility O&M Cost Estimate
Zone B Reverse Osmosis Pilot Study
Jordan Valley Water Conservancy District

Description	Daily Costs (2004 $)											
	Zone B 800 mg/L			Separate Design (August 2003 Agreement)			Minimum Integrated Design			Integrated Design			
	Zone B 800 mg/L	Shallow Aquifer	Total Project	Zone B 250 mg/L	Shallow Aquifer	Total Project	Zone B 250 mg/L	Shallow Aquifer	Total Project	Zone B 250 mg/L	Deep Aquifer	Shallow Aquifer	Total Project
Membrane Replacement [h]	160	368	528	220	368	588	239		239	270			270
Labor [i]			732			732			732				732
Laboratory Testing			65			65			65				65
General Building Utilities			21			21			21				21
Equipment Replacement Parts and Consumables			283			305			235				252
Indirect Operating Costs			*1,628*			*1,710*			*1,291*				*1,340*
Cost per MG			*285*			*300*			*312*				*287*
JVWCD Overhead Allocation			*100*			*100*			*100*				*100*
Cost per MG			*18*			*18*			*24*				*21*
TOTAL COST (w/o pumping)			**2,276**			**2,584**			**1,949**				**2,052**
COST PER MG (w/o pumping)			**399**			**453**			**471**				**439**
TOTAL COST (with pumping)			**4,021**			**4,379**			**3,329**				**3,677**
COST PER MG (with pumping)			**705**			**768**			**805**				**786**

Notes
a Power cost = \$0.055/kW-hr; η_{pump} = 0.75; η_{motor} = 0.9; Hazen & William's C = 130 (PVC = 150 psi max.)
b 30 psi residual pressure at RO WTP
c Interstage pumping provided to balance hydraulics, reduce overall system horsepower, lower cleaning frequency, and improve permeate water quality.
d Finished water to Jordan Aqueduct, hydraulic gradient = 4700 ft H_2O
e 8-inch by-product pipe for 800 mg/L; 10-inch by-product pipe for 250 mg/L
f On-site generation of hypochlorite
g Vendors that have certified (i.e., by DVGW) reactor performance do not hold patent. Patent is currently being challenged.
h Interest/Inflation = 2.5%
i Includes 2 operators and one supervisor.

6.6 SUMMARY

Design criteria, facility layouts and cost estimates were presented in this section based on pilot testing data presenting previously in this report. The incremental costs of RO treatment for a finished water TDS of 800 mg/L to 250 mg/L, for a project that meets all the annual production requirements, range from minus $4,482,000 to $1,357,000 in capital costs and minus $344 per day to $692 per day in operations costs. Integrated Design alternatives present the lowest capital costs of all treatment alternatives, and while they have a lower operating cost, because less water is produced, they have a higher per unit volume treatment cost.

The District should consider that additional alternatives exist that hold further potential for reducing both capital and operating costs. During the pre-design phase of this project the District should consider:

- Alternate sites for the treatment facility. Locating the treatment plant in a two story structure on the hill to the east or west side of the District's main office may provide cost savings due to better soils conditions and less site work and also by utilizing the hydraulic gradient of the hill to move water from the RO through the post treatment processes.
- Operating the Lost Use treatment facility at a lower recovery. Operating the Shallow Aquifer RO system at a lower recovery may lower O&M costs. These savings are the result of an estimated reduction in chemical cleaning frequency and an extended membrane life.
- Conduct further pilot testing to select a more effective scale inhibitor. Operating costs for the Shallow Aquifer RO system are high due to the silica fouling that was experienced during pilot testing. Additional pilot testing may indicate that a more effective scale inhibitor exists and costs can be reduced while still operating at an 85% recovery.