EVALUATION OF TWO CONCENTRATE DISPOSAL ALTERNATIVES FOR THE PHOENIX METROPOLITAN AREA: EVAPORATION PONDS AND DISCHARGE TO THE GULF OF CALIFORNIA

Prepared for the
Sub-Regional Operating Group (SROG) of the Arizona Municipal Water Users Association

Desalination and Water Purification Research and Development Program Report No. 54

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U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Water Treatment Engineering and Research Group

Bureau of Reclamation
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U. S. Department of the Interior
Mission Statement

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1.0 Introduction

This study was accomplished by the Bureau of Reclamation (Reclamation) at the request of the Sub-Regional Operating Group (SROG) of the Arizona Municipal Water Users Association to study two concentrate disposal alternatives for the Phoenix metropolitan area.

1.1 Background

The salinity or total dissolved solids (TDS) content of the groundwater aquifer which serves the Phoenix metropolitan area increases every year. The salinity increase is attributed primarily to the following processes:

- There is a significant volume of surface flow (i.e., Colorado River surface water via the Central Arizona Project [CAP] canal) into the Phoenix area and insignificant surface flow out of the area.

- Municipal and agricultural use of the local water resources subjects these waters to evaporation and evapotranspiration which increases the TDS concentration. The resulting high-TDS wastewaters percolate to the water table or are discharged to local surface waters that are hydraulically connected to the groundwater.

SROG recommends that the TDS concentration of effluent flows from wastewater treatment plants not exceed 1200 mg/L. SROG anticipates that several advanced water treatment plants (AWTs) will be constructed during the next 20 years by communities in the Phoenix area to remove excess TDS (>1200 mg/L) from wastewater flows. It is expected that these AWTs will utilize a membrane treatment process that desalts the wastewater to produce a low-TDS product water flow and a high-TDS, brackish reject flow (concentrate) that requires disposal. SROG predicts that AWTs will be constructed and generate concentrate flows during the next 20 years as shown in Table 1.1 (Greeley and Hansen, 1997).

The first AWT plant has been constructed in Scottsdale and will begin operating at reduced capacity, discharging its concentrate into the municipal sewer during 1999. The Scottsdale Water Campus reclamation plant only uses membranes during winter or other periods when turf irrigation demands are low. The excess effluent is treated by membranes and then recharged using dry wells. The high-TDS concentrate will flow to the 91st Ave. wastewater treatment plant (WWTP) and further encroach upon the 1200 mg/L limit on TDS concentration for effluent discharge into the Gila River.

Future AWT concentrate flows are expected to increase the TDS concentration of WWTP effluent beyond the 1200 mg/L limit.

Table 1.1 Projected Locations of AWTs and Concentrate Flows

Location of AWT	Projected Concentrate Flow (mgd)
City of Scottsdale	10
City of Phoenix at North Gateway	1
City of Phoenix at Cave Creek	3
City of Glendale	2
City of Mesa	4
Total	**20**

The purpose of this study is to evaluate two potential alternatives for disposing of the projected AWT concentrate flows:

1) Evaporation of concentrate flows at evaporation ponds to be constructed about 25 miles southwest of Phoenix.

2) Conveyance of concentrate flows via pipeline across the international border with Mexico for discharge into the Gulf of California.

The concentrate flows would originate at the locations shown in Table 1.1 and would require pipeline conveyance within the city toward a common junction (the 91st Ave. WWTP) for disposal by either one of the two alternatives. This study also considered two options for conveying the concentrate from the AWTs to the 91st Ave. WWTP:

A) Construction of new pipelines to convey just the concentrate flows from the AWTs to a location near the 91st Ave. WWTP where a pipeline would convey the concentrate to the final disposal facility above.

B) Utilization of existing sewer pipelines between the AWTs and the 91st Ave. WWTP. Concentrate flows would be discharged into the sewer system where they would be mixed with municipal wastewater flows. A new membrane treatment plant would be constructed at the 91st Ave. WWTP to remove the excess TDS (added by the AWTs) from the combined sewer/concentrate flows so the discharge from the WWTP can meet the required 1200 mg/L TDS limit. A pipeline would convey the concentrate from the new membrane treatment plant to one of the final disposal facilities above.

Options A and B were compared to determine which would be more economical; i.e., constructing new pipelines (Option A) or constructing and operating a new membrane treatment plant (Option B). Estimated costs for both concentrate disposal alternatives, as well as Options A and B are presented in 1999 dollars. Sub-appraisal cost estimates are typically accurate within +50/-30 percent, because of the limited design information that is available, but are useful in determining the most promising alternatives.

2.0 Concentrate Conveyance Options between AWTs and the 91st Ave. WWTP

2.1 Construction of New Pipelines - Option A

The locations of the proposed AWTs and the pipeline routes were provided by SROG (Figure 2-1). A hydraulic analysis was conducted to determine the required pipe diameters. This sub-appraisal design and cost estimate assumes high density polyethylene (HDPE) pipe and gravity flow, except near Scottsdale where a pump station would be required. Costed items include furnishing and installation of pipe, earthwork, and the pump station. Unlisted items and contingencies are estimated as 15% and 25% of the listed items, respectively. Capital costs are amortized using a 40-year project life and the current Federal discount rate of 7.125 percent for federally assisted water projects. The estimated annual O&M cost for the pipeline is calculated as 0.3 percent of the construction cost (Smith, 1998). These costs are summarized in Table 2.1 below:

Table 2.1 Summary of Costs for Concentrate Pipeline to 91st Ave. WWTP

Item	Capital Cost	Annual Cost
HDPE Pipe	$32,762,000	
Earthwork	5,104,000	
Pump Station	400,000	
Mobilization	1,900,000	
Unlisted Items (15%)	6,000,000	
Contract Cost	**46,000,000**	
Contingencies (25%)	11,500,000	
Engineering (5%)	2,300,000	
Construction Management (12%)	5,500,000	
Total Capital Cost	**$65,000,000**	
Amortized Capital (7.125%, 40 yrs)		$4,947,000
Pipeline O&M		174,000
Total Annualized Cost		**$5,100,000**

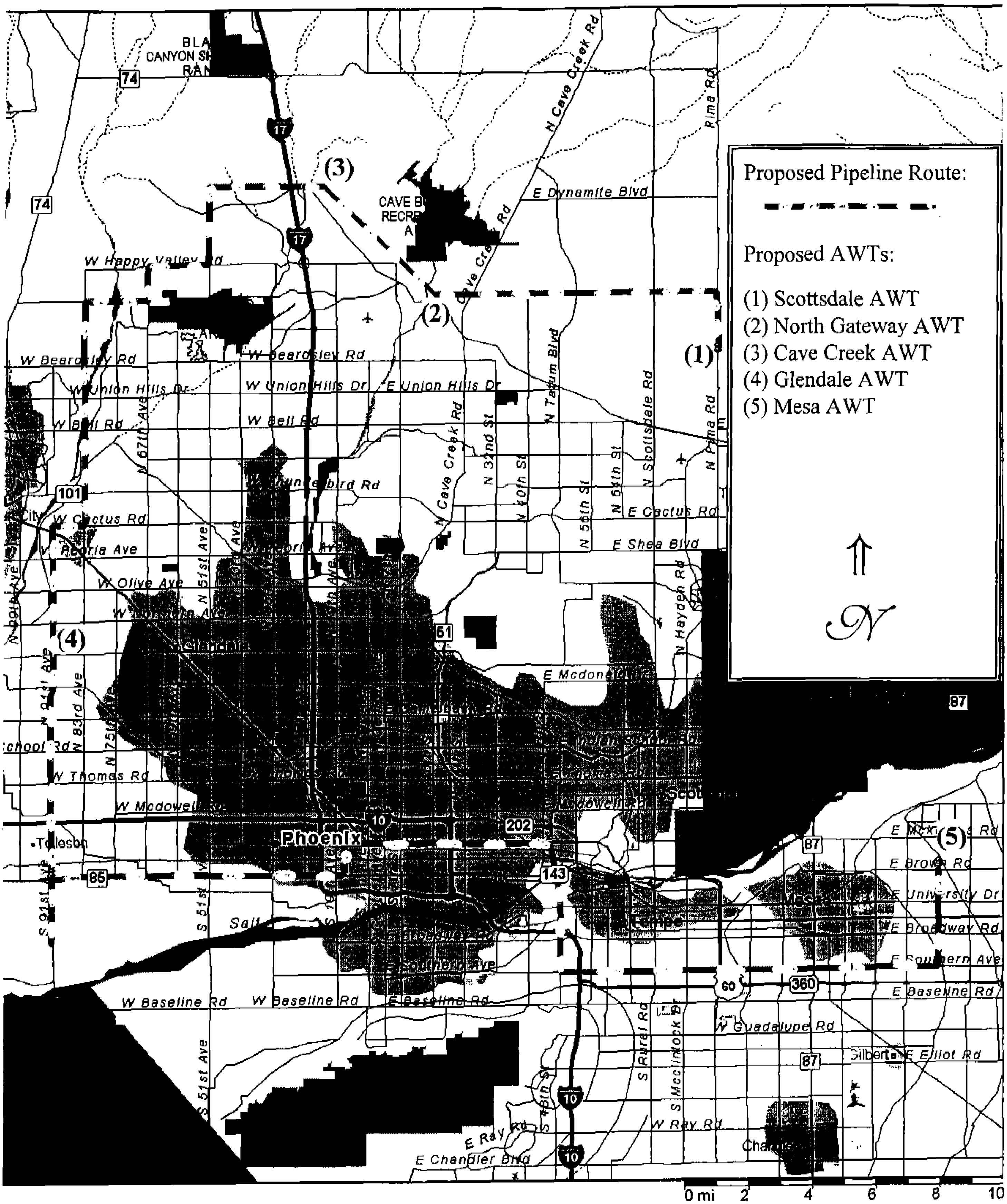


Figure 2-1. Approximate Locations of Proposed Pipeline Routes and AWTs

2.2 Construction of New Membrane Treatment Plant at 91st Ave. WWTP - Option B

If future AWT concentrate flows are discharged to the municipal sewers, then eventually WWTP effluent flows to the Salt River will exceed the maximum allowable TDS concentration of 1200 mg/L. A nanofiltration (NF) treatment plant could be constructed at the 91st Ave. WWTP to remove the excess TDS which would then require disposal of its concentrate flow elsewhere. This sub-appraisal design includes microfiltration (MF) as pretreatment. The cost of the MF pretreatment was estimated from the design parameters for the MF facility at the Scottsdale Water Campus (Sudac, 1999). The nanofiltration design and cost estimate were developed using Reclamation's cost estimating software program for desalination of brackish waters. The design flow volumes, TDS concentrations, and membrane treatment recovery are indicated in the flow schematic in Figure 2-2. A summary of these costs is presented in Tables 2.2 and 2.3. The design assumptions and are attached in Appendix A.

2.3 Comparison of Options A and B

A comparison of the cost summaries (presented in Tables 2.1, 2.2, and 2.3) indicates that construction of an intercity pipeline system to convey concentrate flows (Option A) would be more economical than utilizing the existing sewer pipeline and construction of a nanofiltration treatment plant at the sewer terminus (Option B). As shown, the total annualized cost would be $5.1 million/year for Option A and $21 million/year for Option B. The size and corresponding cost of the nanofiltration treatment plant could be reduced by efficient management of the wastewater and concentrate flows. For example, concentrate flows could be stored in holding ponds during the day and discharged to the sewer during early a.m. hours when wastewater flows are at their lowest level. The required desalination of excess TDS could then be accomplished by treatment of a more concentrated, reduced volume of wastewater as compared to the design flows and salt balance depicted in Figure 2-2. Even under this scenario, however, it is believed that the cost of the nanofiltration treatment plant and the concentrate holding ponds would be substantially greater than the cost of constructing an intercity pipeline system. Therefore, the evaluation of the concentrate disposal alternatives (i.e., evaporation ponds and discharge to the Gulf of California) assumes that concentrate flows from the proposed AWTs will be conveyed to the 91st Ave. WWTP location via a new pipeline system similar to that shown in Figure 2-1.

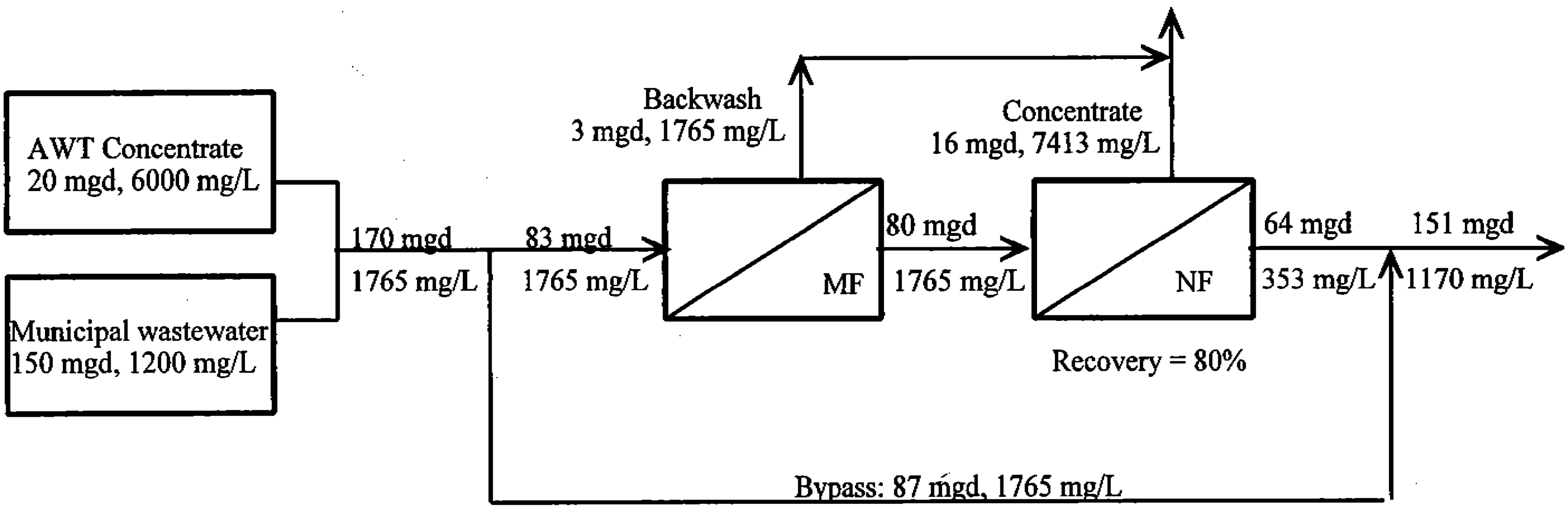


Figure 2-2 Flow Schematic for Proposed RO Treatment at 91st Ave. WWTP

Table 2.2 Summary of Costs for Microfiltration Pretreatment

Direct Capital Costs for MF Treatment Plant					
Microfilters	$	43,522,785	@	340000	$/90M10C
Building	$	4,000,000	@	100	$/ft^2
Plant Interconnecting piping	$	2,176,139		5	% of microfilters
Subtotal	$	49,698,925			
Unlisted Items	$	4,969,892		10	% of subtotal
Contract cost	$	54,668,817			
Engineering	$	4,849,268		10	% of contract cost
Total Direct Capital Costs	**$**	**59,600,000**			

Indirect Capital Costs for MF Treatment Plant				
Interest During Construction	$	3,576,000	6	% of Total direct
Contingencies	$	5,466,882	10	% of contract
Proj. Management		54,668.82	10	% of contract
Working Capital	$	2,384,000	4	% of Total direct
Total Indirect Captial Cost	**$**	**11,500,000**		

Total Construction Cost	**$**	**71,000,000**

Annual Operation & Maintenance Costs		
Electricity	$	944,000
Labor	$	1,110,000
Chemicals (Sodium Hypochlorite)	$	172,000
Membrane Replacement	$	1,843,000
Cleaning Chemicals(NaOCl)	$	34,000
Repairs and Replacement and Misc.	$	1,775,000
Total O & M Cost	**$**	**5,900,000**

Annual Costs		
Capital Recovery	$	5,403,000
Total O&M Cost	$	5,900,000
Total Annual Cost	$	11,000,000
$/1000 gallon	$	0.40

Table 2.3 Summary of Costs for Reverse Osmosis Treatment Plant

Direct Capital Costs for Nanofiltration Treatment Plant					
Membrane Elements	$	3,937,000	@	430	$/(8"x40") element
Pressure Vessel Assemblies	$	7,630,000	@	5000	$/Vessel
Building	$	8,371,000	@	1072	$/m^2 $100/ft2
Electrical	$	1,941,000			
Instrumentation & Controls	$	3,225,000		Operating energy:	
Transfer Pumps	$	525,000		1650	kW
Feed Pumps	$	2,154,000		1889	kW
Interstage Booster Pumps	$	304,000		635	kW
Energy Recovery System	$	155,000		-372	kW
Pilot Plant	$	200,000			
Process Piping	$	2,259,000			
Yard Piping	$	1,240,000			
Chemical Feed Systems					
Acid	$	611,000			
Antiscalant	$	178,000			
Membrane Cleaning Equip	$	194,000			
Sitework	$	3,200,000			
Subtotal	$	36,124,000			
Unlisted items	$	3,612,400		10	% of subtotal
Contract cost	$	39,736,400			
Engineering	$	3,973,640		10	% of Contract cost
Total Direct Capital Costs	**$**	**44,000,000**			

Indirect Capital Costs				
Interest During Construction	$	2,640,000	6	% of Total Direct
Contingencies	$	7,947,000	20	% of contract cost
Proj. Management	$	3,974,000	10	% of contract cost
Working Capital	$	1,760,000	4	% of Total Direct
Total Indirect Capital Cost	**$**	**16,000,000**		

Total Capital Cost	$	60,000,000

Annual Operation & Maintenance Costs		
Electricity	$	2,531,000
Labor	$	832,000
Acid	$	87,000
Antiscalant	$	652,000
Membrane Replacement	$	1,312,000
Cleaning Chemicals	$	17,000
Repairs and Replacement	$	219,000
Insurance	$	87,000
Lab fees	$	50,000
Total Annual O&M Cost	**$**	**5,787,000**

Annual Costs		
Capital Recovery (7.125%, 40 yrs)	$	4,600,000
Total O&M Cost	$	5,800,000
Total Annual Cost	**$**	**10,000,000**
$/1000 gallon	**$**	**0.47**

Total System Cost	$/yr	$/1000 gal
MF	11M	0.40
Nanofiltration	10M	0.47
Total	**$21M/yr**	**$0.87/1000 gal**

3.0 Evaluation of Concentrate Disposal Alternatives

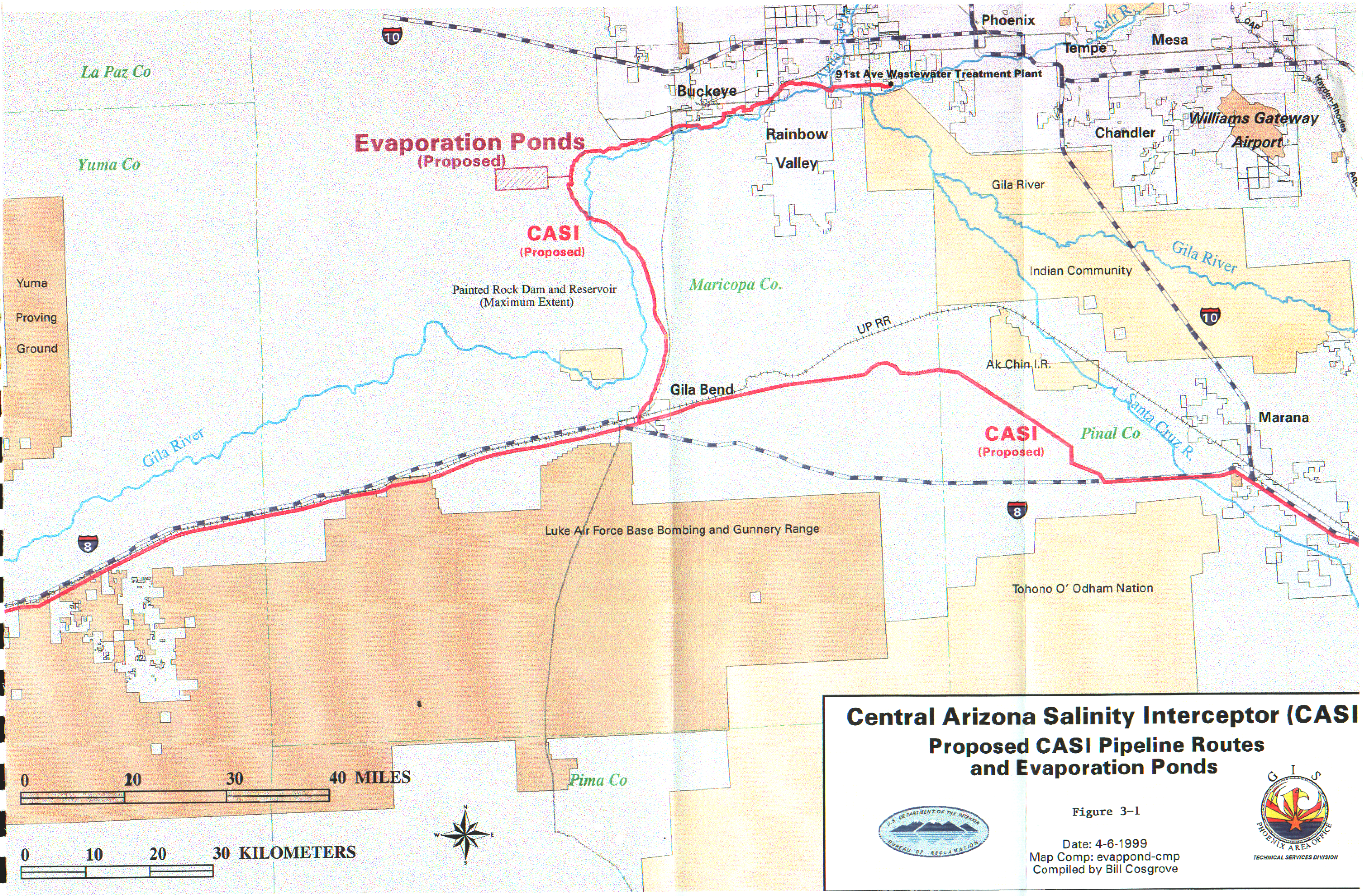
3.1 Concentrate Disposal Using Evaporation Ponds

The sub-appraisal design and cost estimate for construction of evaporation ponds was based on the projected 20-mgd concentrate flows and local evaporation and precipitation rates. The required pond area is about 6,200 acres ($\approx$10 mi^2) based on a net evaporation rate (average annual evaporation - annual average precipitation) of 43 in./year. The substantial land area requirement suggests that the ponds would be constructed outside of the Phoenix metropolitan area. For purposes of this evaluation, a location was selected about 25 miles southwest of Phoenix as shown in Figure 3-1. A hydraulic analysis indicates that concentrate would flow under the force of gravity and that no pumping would be required. Pipe diameters range between 54 and 60 in.

The concentrate water is heavily laden with dissolved salts that are commonly known to induce corrosion and/or scaling of steel or reinforced concrete pipe. A nonconducting thermoplastic coating or liner on the inside of the pipe can prevent scale and corrosion and reduces the cost of maintenance. High density polyethylene (HDPE) pipe costs about the same as steel or concrete pipe, but it is not susceptible to corrosion and does not require additional lining. Current technology limits the manufacture of HDPE pipe to a maximum diameter of 54 in. with a pressure head capacity of 125 feet.

The pipeline design utilizes HDPE where the hydraulic conditions fall within the allowable pressure and diameter. Steel pipe with a 155-mil extruded polymer liner was assumed for all other locations. This is probably the most durable construction for this application, and it is also quite expensive because the thick polymer lining adds about 60 - 80 percent to the cost of standard steel pipe. A more detailed cost study would evaluate the potential for using a thinner (20 - 40 mils), less durable epoxy coating that is sprayed on the pipe surface. A summary of the construction and O&M costs for a 20-mgd pipeline between the 91st Ave. WWTP and the proposed evaporation ponds is provided in Table 3.1.

The evaporation pond design assumes 60-mil HDPE membrane liner placed on grade. Existing grade would be leveled, scarified, and recompacted prior to liner installation. Evaporation ponds would be constructed incrementally as needed to keep pace with the construction of AWTs and the corresponding increase in concentrate flows. This design assumes that evaporation ponds would be constructed as a series of 1-mi^2 pond units each of which is individually contained by a berm around the perimeter. It is assume that two 1-mi^2 ponds would be built at a time.



Phoenix
Tempe
Mesa
Salt R.
Buckeye
91st Ave Wastewater Treatment Plant
Rainbow
Valley
Chandler
Williams Gateway
Airport
La Paz Co
Yuma Co
Evaporation Ponds
(Proposed)
CASI
(Proposed)
Gila River
Indian Community
Yuma
Proving
Ground
Painted Rock Dam and Reservoir
(Maximum Extent)
Maricopa Co.
UP RR
Ak Chin I.R.
Gila Bend
Santa Cruz R.
Marana
CASI
(Proposed)
Pinal Co
Gila River
Luke Air Force Base Bombing and Gunnery Range
Tohono O' Odham Nation
Pima Co
0 20 30 40 MILES
0 10 20 30 KILOMETERS
Central Arizona Salinity Interceptor (CASI
Proposed CASI Pipeline Routes
and Evaporation Ponds
Figure 3-1
Date: 4-6-1999
Map Comp: evappond-cmp
Compiled by Bill Cosgrove
U.S. Department of the Interior
Bureau of Reclamation
GIS
Phoenix Area Office
Technical Services Division

Table 3.1 Summary of Costs for Concentrate Pipeline to Evaporation Ponds

Item	Capital Cost	Annual Cost
HDPE pipe	$14,700,000	
Polymer-lined steel pipe	16,500,000	
Earthwork	2,700,000	
Mobilization	1,700,000	
Unlisted Items (10%)	3,400,000	
Contract Cost	**39,000,000**	
Contingencies (15%)	5,900,000	
Engineering (5%)	2,000,000	
Construction Management (12%)	4,700,000	
Total Capital Cost	**$52,000,000**	
Amortized Capital (7.125%, 40 yrs)		$3,957,000
Pipeline O&M		135,000
Total Annualized Cost		**$4,100,000**

The site plan and cross sections are shown in Figures 3-2 and 3-3, respectively. A summary of the construction and O&M costs for two 1-mi^2 ponds is provided in Table 3.2. The total cost for this alternative is a summation of the costs for: 1) pipeline construction between the proposed AWTs and the 91st Ave. WWTP, 2) pipeline construction between the 91st Ave. WWTP and the evaporation ponds, and 3) construction of ten 1-mi^2 evaporation ponds. The total annualized cost for this alternative is $33 million/year as shown in Table 3.3.

The evaporation ponds have the potential for adverse effects on the environment, including contamination of underlying groundwater due to pond seepage. Concentrated pond contaminants may also be toxic to exposed fauna. Construction and operation of the evaporation ponds would require an *Aquifer Protection Permit* from the Arizona Department of Environmental Quality (ADEQ, 1998). Permit approval requires a pond liner whose permeability does not exceed 1 x 10^{-6} centimeters per second and may also require a groundwater monitoring system for leak detection. Fencing around the pond perimeter should adequately address protection of land species. Waterfowl access would be more difficult to control and would probably require carbide cannons to discourage their occupancy.

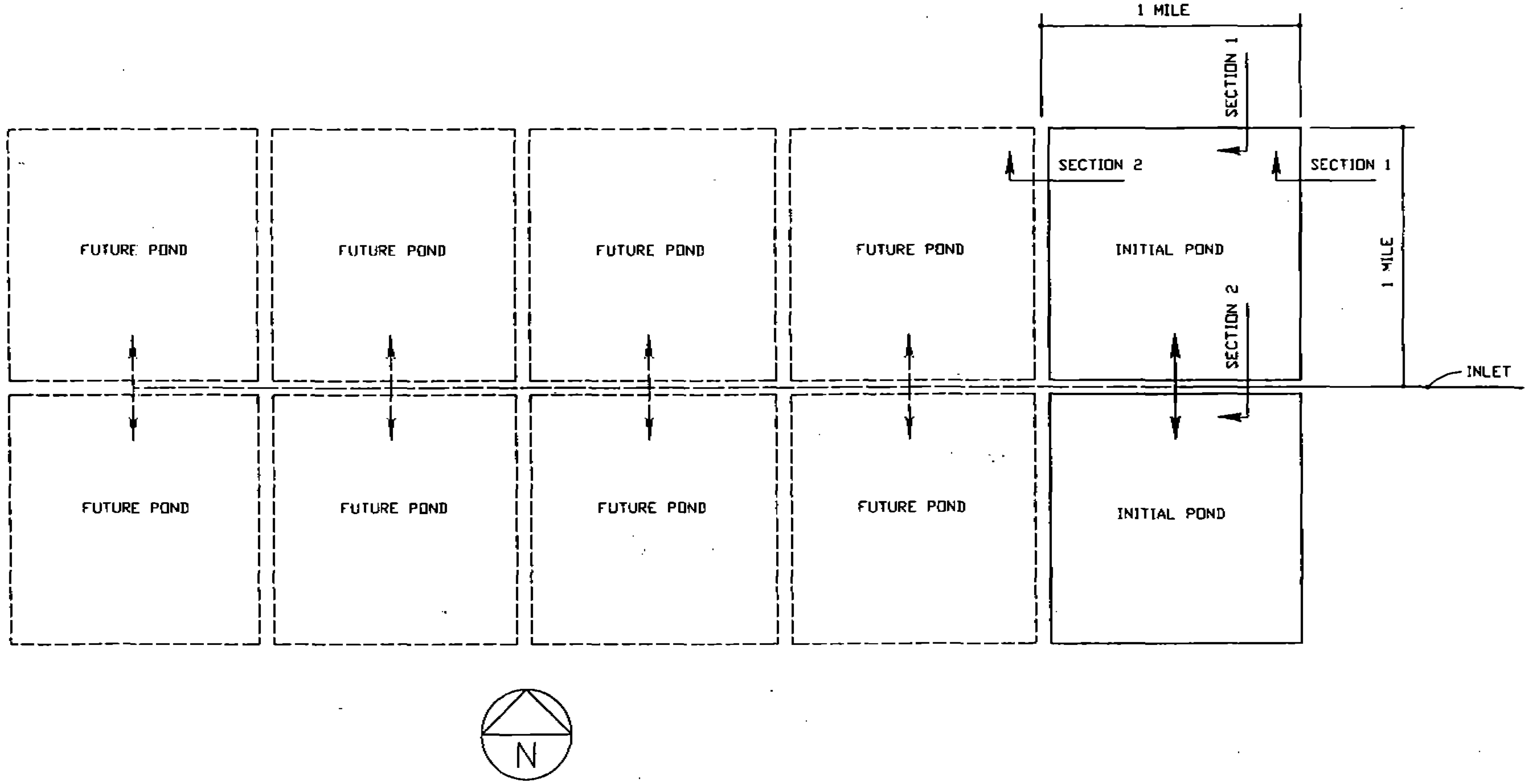
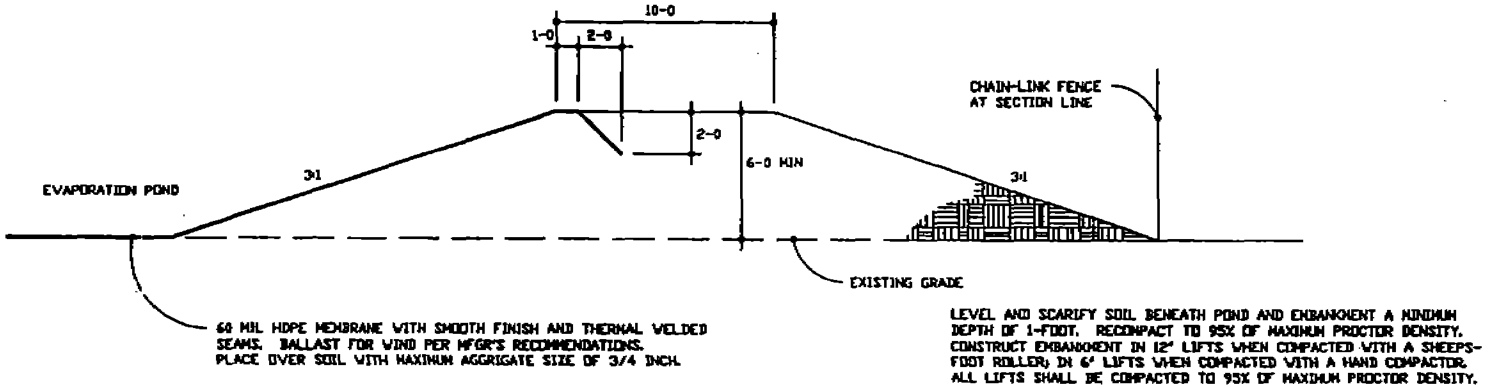
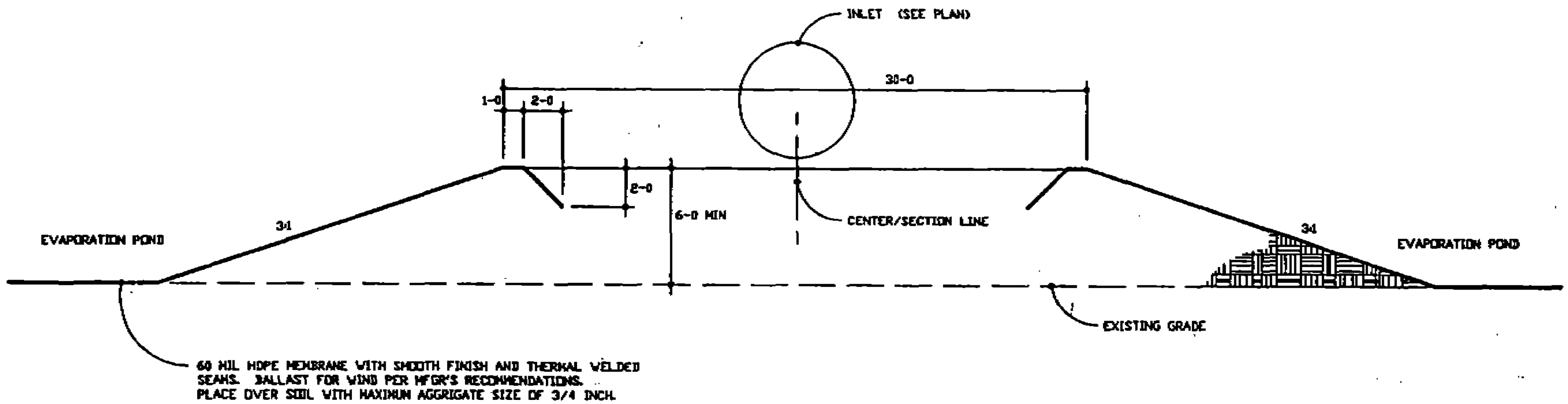


Figure 3-2 Site Plan - Evaporation Ponds



(1) SECTION AT SITE PERIMETER



(2) SECTION BETWEEN PONDS

Figure 3-3 Evaporation Pond Berms

Table 3.2 Summary of Costs for Two 1-mi² Evaporation Ponds

Item	Capital Cost	Annual Cost
Earthwork	$ 7,500,000	
HDPE geomembrane liner, 60-mil	24,600,000	
Pipe	416,000	
Chain-link fence, 6-ft	703,000	
Maintenance building	35,000	
Mobilization	1,660,000	
Unlisted Items (15%)	4,990,000	
Contract Cost	**40,000,000**	
Contingencies (25%)	10,000,000	
Engineering (5%)	2,000,000	
Land Acquisition	1,300,000	
Construction Management (12%)	4,800,000	
Total Capital Cost	**$58,000,000**	
Amortized Capital (7.125%, 40 yrs)		$4,410,000
Annual O&M		250,000
Total Annualized Cost		**$4,700,000**

Table 3.3 Total Costs for Disposal of 20-mgd Concentrate Flow using Evaporation Ponds

Item	Capital Cost	Annual O&M	Annualized Cost[1]
Pipeline to 91st Ave. WWTP	$ 65,000,000	$ 174,000	$ 5,100,000
Pipeline to Evaporation Ponds	52,000,000	135,000	4,100,000
Evaporation Ponds, 10 mi^2	290,000,000	1,250,000	23,500,000
Total Costs	**$410,000,000**	**$1,600,000**	**$33,000,000**

[1]Annualized cost consists of annual O&M costs plus amortized capital costs.

3.2 Concentrate Disposal via Discharge to the Gulf of California

This alternative evaluates the feasibility of a joint, cost-sharing project between SROG communities and the City of Tucson for construction of a pipeline system to convey RO concentrate across the U.S.-Mexico border for discharge to the Gulf of California. The possibility of a joint venture arose from a study currently in progress conducted by Reclamation and the Tucson Water Department entitled, *Reverse Osmosis Treatment of Central Arizona Project Water for the City of Tucson* (Reclamation, 1999). Discharge to the Gulf of California was one of several concentrate disposal alternatives considered for the preappraisal evaluation of 100- and 150-mgd RO plants. The Tucson study evaluated two potential pipeline routes, one of which follows the I-8 interstate highway westward to Yuma and then turns south to the Gulf of California. The proximity of this route to the Phoenix metropolitan area spawned interest in exploring the possibility of a regional pipeline disposal system having multiple cost-sharing partners to dispose of various saline wastewaters. The proposed regional pipeline was dubbed the Central Arizona Salinity Interceptor (CASI) and is shown in Figure 3-1.

The pipeline segment originating in Tucson would follow a northwest alignment for about 133 miles until it reaches the town of Gila Bend. The segment from Phoenix would originate at the 91st Ave. WWTP and follow along the Gila River for about 67 miles until reaching Gila Bend where it would form a junction with the segment from Tucson. From Gila Bend the combined flows follow along I-8 for about 117 miles until reaching the U.S.-Mexico Bypass Drain in Yuma. The U.S.-Mexico Bypass Drain is an existing canal that carries irrigation drainage and RO concentrate flows from the Yuma area to the Santa Clara wetland in Sonora, Mexico. This study assumes that CASI pipeline flows would discharge into the Bypass Drain near the Yuma Desalting Plant. The cost estimate includes a "Bypass Drain Capital Fee" to increase the capacity of the existing canal.

The Santa Clara wetland is a brackish marsh in the Colorado Delta that is separated from the northern Gulf of California by a low, natural land barrier. Seawater from the gulf crosses the barrier only during extremely high tides (Zengel, et al., 1995). Consequently, evaporation tends to increase the salinity and concentration of other solutes of the wetland flows as they migrate southward towards the gulf. Further concentration of CASI waters within the Santa Clara wetland may have adverse impacts on the local environment (Tanner, et al., 1997). On the other hand, additional CASI flows may be sufficient to expand the size of the wetland and reestablish frequent tidal flushing. Numerous government agencies, academic institutions, and environmental groups are actively seeking new sources of water supply to the Santa Clara wetland to preserve and improve the habitat for the migratory waterfowl of the Pacific flyway (Environmental Defense Fund, 1996).

Additional studies are required to determine whether potential CASI flows could be delivered to the Santa Clara wetland in a manner that would be beneficial to its habitat. Alternatively, a pipeline segment could be constructed between Yuma and the Gulf of California (parallel to the Bypass Drain) that would permit direct discharge into the sea. This option would be slightly more expensive due to the additional length of conveyance between the Santa Clara wetland and the gulf coast, but it would have a negligible or very minor impact on the seawater and would be consistent with concentrate disposal practices for most coastal RO plants.

Discharge of CASI flows to the Gulf of California would be feasible only with the approval of the Government of Mexico. A legal precedent to the proposed alternative was established through a bilateral agreement in *Minute No. 242* of the International Boundary and Water Commission (IBWC, 1973). This agreement provides that the U.S. shall discharge to the Santa Clara wetland "... all or a portion of the Wellton-Mohawk drainage waters, the volumes of brine from such desalting operations in the United States as are carried out to implement the Resolution of this Minute, **and any other volumes of brine which Mexico may agree to accept** (emphasis added)."

The proposed alternative for discharging membrane concentrate into the Gulf of California/Santa Clara wetland was presented to the U.S. section of the IBWC in El Paso, Texas, on behalf of SROG and the City of Tucson, to solicit their advice on how to proceed with Mexico. The Commissioner and other IBWC members advise that any perceived environmental benefit would probably not be a sufficient basis for acceptance of this water by Mexico. Based on political considerations regarding international border issues, they recommend against presenting this alternative to Mexico as a valued water resource. The IBWC members believe that Mexico would view the membrane concentrate as undesirable and would accept it only if compensation is provided. The IBWC members suggest a strategy in which Mexico's approval of this alternative is linked to some other border issue/project where Mexico is seeking a material concession by the U.S. (see Appendix B, Notes from Interagency Meeting/Briefing).

One potential opportunity for linking disposal of concentrate waters with another border project is the current negotiations between Mexico and the U.S. to improve the quality of water that crosses the border into Mexico at the "South Boundary" near Yuma, Arizona. South Boundary water is a combination of groundwater that is pumped to lower the water table near Yuma and irrigation drainage water from local agriculture. The pumped groundwater and irrigation drainage water are collected in the Yuma Main Drain canal system and conveyed to the South Boundary at the U.S. border. The South Boundary water is used by Mexican farmers for crop irrigation. South Boundary average and peak flows are about 150 cfs and 220 cfs, respectively, and the TDS content ranges from 1200 - 1600 mg/L. This water is not very suitable for irrigation because of the high salt content. For several years the Mexican government has been requesting that the U.S. provide a remedy to improve the quality of the South Boundary water.

Reclamation staff at the Yuma Desalting Plant are currently evaluating several options for improving the quality of water deliveries at the South Boundary (see Appendix B, YDP Meeting Notes). If the government of Mexico is satisfied with the selected remedy, then further negotiations could explore the possibility to link it with Mexico's acceptance of concentrate waters from Tucson and Phoenix. This particular opportunity for an agreement that would link these projects is available only until a remedy is chosen (perhaps a few years).

For conservatism, the sub-appraisal cost estimate of this report is based on pipe sizing to accommodate average daily concentrate flows of 18-mgd from Tucson from a 100-mgd RO plant having 85% recovery. If Tucson were to build a 150-mgd RO plant to meet its peak-day demand, it would probably build a larger capacity pipeline to handle the additional concentrate flows (as much as 27 mgd) and would assume a greater share of the CASI cost. With the projected 20-mgd flow from the Phoenix area, the combined flows would be 38-mgd between Gila Bend and the Gulf of California. The design and construction of the CASI pipeline would take advantage of the 2400-ft elevation drop between Tucson and Yuma. A hydraulic analysis indicates that pumping facilities would not be required because the concentrate would flow by gravity the entire length of the pipeline. For the purpose of developing this cost estimate, a pipeline plan and profile were generated using U.S. Geological Survey topographical maps. The pipe diameters upstream of the junction at Gila Bend would range from 30 - 45 in. whereas the combined flows downstream of Gila Bend would range from 48 - 60 in. The pipeline cost estimate is based on the pipe material considerations described in the previous section. There may be a potential for supersaturated salts in the RO concentrate to precipitate during pipeline conveyance. The need or cost for stabilization of SROG concentrate was not addressed in this study. A summary of the costs of the proposed CASI pipeline is provided in Table 3.4. Calculations of SROG's cost share were based on the ratio of SROG flow volume to total flow volume in the pipeline segment between Gila Bend and Yuma. As shown, the annualized cost of the SROG share of the CASI pipeline would be about $19 million/year.

Future designs should consider the potential for additional cost-share partners in the CASI pipeline. About 1.9 million tons of salt per year are presently carried into the central Arizona region by the CAP aqueduct and Salt River. This salt is accumulating in the groundwater because there are no water outflows that can carry it out of the region. The need for drainage and return flow facilities was anticipated

Table 3.4 Cost of CASI Pipeline to Gulf of California via Yuma

	1999 Capital and O&M Costs			
Description	**Tucson to Gila Bend (Q= 18 mgd)**	**Phoenix to Gila Bend (Q= 20 mgd)**	**Gila Bend to Yuma (Q= 38 mgd)**	**Total**
HDPE and Lined Steel Pipe	$ 78,900,000	$ 45,775,000	$ 146,800,000	$ 271,475,000
Earthwork	5,900,000	4,314,000	6,900,000	17,114,000
Mobilization	4,240,000	2,504,000	7,685,000	14,429,000
Subtotal	89,040,000	52,593,000	161,385,000	**$ 303,018,000**
Unlisted Items, 10%	8,904,000	5,259,000	16,139,000	30,302,000
Contract Cost	97,944,000	57,852,000	177,524,000	**$ 333,320,000**
Contingencies, 15%	14,692,000	8,678,000	26,629,000	49,999,000
Construction Cost	112,636,000	66,530,000	204,153,000	**$ 383,319,000**
Land and Easements	9,795,000	3,381,000	2,439,000	15,615,000
Bypass Drain Capital Fee				6,600,000
Eng., 5% x Contract Cost	4,897,000	2,893,000	8,876,000	16,666,000
Mgmt. 10% x Contract Cost	9,794,000	5,785,000	17,752,000	33,332,000
Total Capital Cost	**$ 137,100,000**	**$ 78,600,000**	**$ 233,000,000**	**$ 456,000,000**
SROG Share of Capital Cost, 52.6%				**$ 240,000,000**
Bypass Drain Annual O&M				9,900
Pipeline Annual O&M Cost				1,150,000
Subtotal				**$ 1,160,000**
SROG Share of Subtotal, 52.6%				610,000
Amortized Capital Cost, 7.125%, 40 years				18,260,000
Total Annualized Cost for SROG				**$ 18,900,000**

but not included in the original CAP appropriation (U.S. Department of the Interior, 1963). As a result, the quality of groundwater is gradually decreasing and will become nonpotable within 40 years unless the salinity is removed (Bouwer, 1997). The CASI pipeline could provide the means to carry these imported salts out of the region for disposal in the Gulf of California. Potential cost-share partners include municipal, industrial, and agricultural generators of brackish waters.

A similar disposal pipeline system is currently operated by the Santa Ana Watershed Project Authority (SAWPA) in the upper Santa Ana River Basin near Los Angeles, California. SAWPA is a quasi-public, non-profit corporation. The pipeline is known as the Santa Ana Regional Interceptor (SARI) and is designed to convey 30 mgd of non-reclaimable wastewater from various sources to the ocean for disposal. The SARI is constructed of plastic-lined reinforced concrete pipe for most of its 60-mile length. Gravity flow carries municipal and industrial wastewaters to the Fountain Valley Wastewater Treatment Plant in Orange County. Wastewater treatment plant effluent is discharged by a pipeline that extends about 5 miles into the Pacific Ocean. The amortized construction, operation and maintenance, and administration costs of the pipeline are paid by SARI customers in proportion to the flow volume each contributes. SAWPA receives low-interest (currently 3%) construction loans with 20-year repayment terms from the State of California and the U.S. Environmental Protection Agency when additional pipe segments are added (see Appendix B, SAWPA Notes).

Future designs should also consider a combination of pipe and canal conveyance of CASI flows. The cost of concrete-lined canal construction is generally about 70% of the cost of standard (unlined) steel pipe construction but it is limited to locations of fairly constant and gentle grades. There is, however, a greater potential for adverse environmental impact using a canal because of greater seepage and surface exposure of the nonpotable water. Canal leakage can be monitored and repairs made to the concrete lining if required.

The total cost of disposal of SROG concentrate via discharge to the Gulf of California is summarized in Table 3.5.

Table 3.5 Total Costs for Disposal of 20-mgd Concentrate Flow using CASI Pipeline

Item	Capital Cost	Annual O&M	Annualized Cost[1]
Pipeline to 91st Ave. WWTP	$ 65,000,000	$ 170,000	$ 5,100,000
Pipeline to Yuma[2]	240,000,000	610,000	18,900,000
Total Costs	**$310,000,000**	**$ 780,000**	**$24,000,000**

[1]Annualized cost consists of annual O&M costs plus amortized capital costs.
[2]Costs shown are SROG share of costs (52.6%) based on joint venture with City of Tucson. Costs include pipeline from 91st Ave. WWTP to Yuma and U.S.-Mexico Bypass Drain canal from Yuma to Santa Clara wetland.

4.0 Conclusions and Recommendations

This study evaluated two alternatives for the disposal of projected concentrate flows generated by future RO treatment of SROG wastewaters:

1) Evaporation ponds (about 10 mi^2)

2) Discharge to the Gulf of California via cost-shared, CASI regional pipeline (about 320 miles)

Additionally, this study compared the cost of constructing new inner-city pipelines to convey the concentrate to a central location (91st Ave. WWTP) vs. the cost of a new 64-mgd nanofiltration plant to recover the concentrate waters at the central location if they are discharged into existing sewer pipes and mixed with municipal wastewater. The cost analysis determined that construction of new inner-city pipelines would be more economical, and thus this option was used in the evaluation of the two disposal alternatives. If future sources and quantities of concentrate differ significantly from those assumed in this study, then the issue of collector pipelines should be revisited. A summary of the sub-appraisal total cost estimates for the concentrate disposal alternatives is shown in Table 4.1.

Table 4.1 Total Cost Comparison of Evaporation Ponds and CASI Pipeline[1]

Alternative	Capital Cost	Annual O&M	Annualized Cost[2]
Evaporation Ponds	$ 410,000,000	$ 1,600,000	$ 33,000,000
CASI Pipeline to Yuma[3]	$ 310,000,000	$ 780,000	$ 24,000,000

[1]Disposal costs based on projected SROG concentrate flows of 20 mgd.
[2]Annualized cost consists of annual O&M costs plus amortized capital costs.
[3]Costs shown are SROG share of costs (52.6%) based on joint venture with City of Tucson.

This study concludes that the cost to SROG of concentrate disposal using the CASI pipeline is about two thirds of the cost using evaporation ponds. It is emphasized, however, that these are sub-appraisal estimates and that a more detailed study is needed to better ascertain these costs and address factors which influence them. It is recommended that the following issues be addressed in future efforts to study or pursue these alternatives:

- Enhanced evaporation using commercially available evaporation systems. This technology should be evaluated to determine the economic tradeoff between the cost of the enhanced evaporation systems vs. the reduced cost for a smaller evaporation pond area.

- Consultation with ADEQ as to whether special construction, operation, and monitoring requirements would be imposed for evaporation ponds of this magnitude.

- Water quality modeling of the Santa Clara wetland to determine if concentrate waters can be safely discharged from the U.S.-Mexico Bypass Drain or whether construction of additional pipeline would be required for discharge further south into the Gulf of California.

- Detailed assessment of the CASI route to determine land availability and cost, and to evaluate the potential for using less expensive canal segments.

- Consultation with the City of Tucson regarding their interest in participating in the proposed CASI pipeline. As of the date of this report, the Tucson study is still in progress and there is no indication as to the likelihood or schedule of construction of their proposed municipal RO treatment plant nor their preferred method of concentrate disposal.

- Identification of and consultation with other potential users and cost-share partners in the proposed CASI pipeline. Additional CASI users would not only reduce SROG's share of the cost but would also increase the public and political support base that would be necessary to achieve a regional and international project of this magnitude.

- Consultation with the Government of Mexico to determine the feasibility of conveying additional concentrate waters across the border for discharge into their coastal seawater. Approval by Mexico is the single greatest challenge to achieving the proposed CASI pipeline. The precedent of the existing U.S.-Mexico Bypass Drain, Mexico's current interest in negotiating other international water issues, and the environmentally benign method of concentrate disposal by discharge to the sea, suggest that there is potential in achieving this goal. If this alternative is to be pursued, it is recommended that the interested parties enlist the support of the local, state, and federal officials who would be able to assist in the political negotiation process.

- Investigation of two other CASI discharge alternatives: (1) to the Yuma Desalting Plant for additional desalting of the concentrate to augment the local water supply and, (2) to the Salton Sea to reduce its salinity.

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Appendix A

Design Assumptions for RO Treatment Plant at 91st Ave.

Sub-Appraisal Cost Estimate for Nanofiltration Plant with Microfiltration Pretreatment

A sub-appraisal level cost estimate was prepared for the construction and operation of a 64 million gallons per day (mgd) membrane treatment plant at the 91st Avenue wastewater treatment plant (WWTP) to lower the TDS of wastewater effluent. This advanced membrane treatment plant includes microfiltration pretreatment followed by nanofiltration. The total estimated cost of product water is $0.87/1000 gallon.

This sub-appraisal cost estimate provides a relative idea of the magnitude of costs of the 64-mgd membrane treatment plant. These costs are in 1999 dollars and are based on the preliminary information. They are not final design cost estimates nor do they include concentrate disposal, NEPA compliance, or water system storage and distribution cost. Capital cost are the costs for constructing a desalting plant. Annual Operation & Maintenance (O&M) costs are the cost estimates to operate and maintain the plant per year. Total product water cost is defined as the capital cost times the capital recovery factor per year (for amortization of an 7.125% loan over a 40 year period of time) plus the annual operation and maintenance cost per year, all divided by the total product water produced per year (assuming a 95% availability factor to allow 5% of downtime for routine maintenance and repairs). The results are calculated per thousand gallons (kgal). The equation that expresses this relation is:

$$\text{Total product water cost} = \frac{CC \times CRF + OMC}{0.95 \times 365 \times PC}$$

Where

CC = capital cost ($)
OMC = operation and maintenance cost ($/yr)
PC = plant capacity (kgal/day)
CRF = capital recovery factor (7.125%, 40 yr) = 0.0724

The cost estimates were determined by running a computer model that has been developed by the Bureau of Reclamation for calculating costs of desalination from brackish water plants (Wilbert, 1998). The input parameters are based on the information from Water Campus Expansion, City of Scottsdale. The following assumptions were used:

Costs are in 1999 dollars

Plant capacity:	64 million gallons per day (mgd)
Availability:	95%
Recovery ratio:	80%
Power cost:	$0.08/kwh
Capital amortization:	40 year at 7.125% interest
Labor cost:	$40/hr weighted average cost of managers, supervisors, and staff (a total of 17 staff days per day)

Process Flow:
Figure 2-2 in the main report illustrates the process flow diagram of the proposed advanced water treatment plant. The total raw feed water flow is 170-mgd with TDS of 1765 mg/L. The microfiltration plant has a feed flow of 83 mgd with 1756 mg/L of TDS. The 80-mgd microfiltration product then feeds to the nanofiltration plant which has 80% recovery. The 64-mgd nanofiltration permeate with 768 mg/L of TDS is then blended with 87 mgd of raw feed water at 1765 mg/L of TDS to obtain the final product water flow of 151-mgd with 1170 mg/L of TDS. The total concentrate disposal for both microfiltration and reverse osmosis plants is 19 mgd with 6520 mg/L of TDS.

Cost Results:
The following table summarizes the cost estimates for the 80-MGD microfiltration and 64-mgd nanofiltration plants (flow capacity is product flow):

Treatment Process	Capital Cost ($)	O&M Cost ($/yr)	Total Product Water Cost ($/1000 gallon)
Microfiltration	$71,000,000	$5,900,000	$0.40
Nanofiltration	$60,000,000	$5,800,000	$0.47
Total	$130,000,000	$12,000,000	$0.87

SROG 91st Ave. Membrane Treatment Plant Costs:

Nanofiltration Plant Construction Costs:

Direct Capital Costs

Membranes: Estimated cost for membranes is $430 per element (Beardsley, 1998).

This table summarizes number of elements required:

Plant size (mgd)	No. Elements
64	9156

Pressure Vessel Assemblies: The vessel assemblies include the pressure vessels supported by structural support frame, piping connector sets for each vessel, and piping manifolds. $5000 per pressure vessel for painted steel is assumed (Suratt, 1995).

This table summarizes number of pressure vessels required:

Plant size (mgd)	No. Pressure vessels
64	1526

Building: Estimated building area for a 64-mgd nanofiltration plant is summarized in the table below:

	Area	Unit
Process equipment	30000	ft^2
Electrical room	4000	ft^2
Chemical rooms	6600	ft^2
Control room	300	ft^2
Generator	400	ft^2
Transformer vault	500	ft^2
High service pumps	8000	ft^2
Offices and reception	200	ft^2
Bathroom and safety shower space	250	ft^2
Total	**50150**	ft^2

Areas and costs of $100 per square feet are from Suratt (Suratt, 1995).

This table summarizes the building area required.

Plant size (mgd)	Area	Unit
64	83,700	ft^2

Electrical: Cost is estimated by \$130,000 * $Fp^{0.65}$, where "Fp" is the permeate capacity in mgd (Suratt, 1995).

Instrumentation & Controls: Computer control system cost is estimated at \$300,000 plus an additional \$65,000 per control block for instrumentation and control valves(Suratt, 1998).

This table summarizes the number of control blocks and number of computer systerms required:

Plant size (mgd)	No. control blocks	No. computer systems
64	45	1

Transfer pumps: The cost of single speed centrifugal pumps of stainless construction is estimated at $\$35,000*(hp/100)^{0.65}$ for transfer pumps, where hp is the horsepower(Suratt, 1995). There are 5 transfer pumps for the 64-mgd nanofiltration plant, including one spare, at 541 horsepower each. Estimated cost per pump is \$105,000.

This table summarizes number of transfer pumps:

Plant size (mgd)	No. Pumps
64	5

Feed Pumps: Feed pumps consist of single speed, 1272-hp pumps with 1750-hp motors at \$234,000 each and variable speed drive 1272-hp pumps with 1750 hp motors at \$ 484,000 each (Cassidy, 1998: Rogers, 1998). The variable speed drive pumps and motors are used for start up with one as a spare.

This table summarizes number of feed pumps:

Plant size (mgd)	Single speed	Variable speed
64	3	3

Interstage Booster Pumps: The cost of single speed centrifugal pumps of stainless construction is estimated at $\$35,000*(hp/100)^{0.65}$ for interstage booster pumps, where hp is the horsepower (Suratt, 1995). Interstages one and two each have one booster pump per 50 mgd plant size. Booster pump horsepower for interstage one is 406 at \$87,000 per pump. Booster pump horsepower for interstage two is 262 at \$65,000 per pump.

This table summarizes number of interstage pumps required:

Plant size (mgd)	Interstage 1	Interstage 2
64	2	2

Energy Recovery System: Two budgetary prices were obtained for energy recovery systems. For a single energy recovery unit system operating with 6000 gpm at 170 feet of head and 85 percent hydraulic turbine efficiency , the price is $155,300 (Rogers, 1998). For a dual energy recovery unit system with 3063 gpm at 125 feet of head, the turbine efficiency is 82 to 84 percent, and the price is $248,600 (Reau, 1998).

This table summarizes number of energy recovery units required:

Plant size (mgd)	No. Energy recovery units
64	2

Pilot Plant: The estimated cost for a RO pilot plant is $200,000. (Moody, 1998)

Process Piping: Process piping for the RO plant includes feed water, permeate, concentrate, cleaning solution, and miscellaneous small piping. Costs are based on PVC AWWA C900 for all piping less than 100 psi and schedule 10 type 316L for all piping above 100 psi. Costs are estimated at $30,000 * Fp/R, where "Fp" is the plant capacity in mgd and "R" is the water recovery rate (85%) (Suratt, 1995).

Yard Piping: Yard piping includes raw water, permeate, finished water, and concentrate piping. Cost is based on PVC AWWA C900 for all buried piping and FRP for above ground yard piping. Cost is estimated at $\$48{,}500 * (Fp/R)^{0.75}$, where "Fp" is the plant capacity in mgd and "R" is the recovery rate (Suratt, 1995).

Chemical Feed Systems:

Sulfuric acid system includes tanks, piping system to SCRs and production plant, dilution system, and system to serve test plant. The cost is estimated at $610,600 (McAleese, 1998).($430,000 in 1985 dollars adjusted by the ENR cost index to 1998 dollars). The cost is the same for all three plant sizes.

Antiscalant system includes silo, solution mixing system, and injection system. The cost is estimated at $177,600 (McAleese, 1998).($125,000 in 1985 dollars adjusted by the ENR cost index to 1998 dollars). The cost is the same for all three plant sizes.

Membrane Cleaning Equipment: Suratt used $67,000 for a system based on cleaning 14 tubes at one time at a flow rate of 50 gpm per tube. The system includes two 1,000 gallon tanks, a recirculation pump, cartridge filter, mixer, piping, and electrical(Suratt, 1995). The cost for the Tucson plant is estimated at $\$67{,}000*(50/14)^{0.7}$ to clean 50 tubes at one time at a flow rate of 50 gpm per tube. The cost is the same for all three plant sizes.

Contractor Engineering & Training: Estimated cost is $50,000 (Suratt, 1995).

Site Work: Cost is estimated at $50,000 * Fp. Where "Fp" is the plant capacity in mgd (Suratt, 1995). Site work including dewatering, excavation and backfilling, roads, walks, landscaping, fencing, and various yard structures.

Indirect Capital Costs:

Indirect capital costs breakdowns are (Moch, 1996):

- Interest during construction is estimated at 6% for a period over two years of the total construction cost.
- Contingencies are estimated at 20% of contract cost.
- Project management are estimated at 10% of the contract cost.
- Working capital is estimated at 4% of the total construction cost.
- Engineering is estimated at 10% of the contract cost.

RO Plant Operations & Maintenance Costs:

Electricity: Electricity rate is $0.08 per kwh for interruptible(Rawls, 1999).

Labor: a total of 17 staff days per day. Labor rate is $40 per hour (Sudac, 1999).

Acid and Antiscalant Cost: Sulfuric acid cost is calculated at dosage rate of 20 mg/l ,93% purity, and $0.044/kg. Antiscalant cost is calculated at dosage rate of 2 mg/l and $3.30/kg(Belli and Ning, 1998; Sutherland, 1998).

Membrane Replacement: Replacement cost is total membrane cost divided by the membrane life. Expected membrane life is 3 years.

Cleaning Chemicals: Cleaning chemicals are H_2PO_4 and NaOH. H_2PO_4 cost is calculated at solution concentration of 0.05% and $23.7/kg. NaOH cost is calculated at solution concentration of 0.1% and $18/kg. Cleaning frequency is 9 times per year.

Repair and Replacement: Assumed at 0.5% of total capital cost.

Insurance: Assumed at 0.2% of total capital cost.

Lab Fees: Estimated cost is $50,000.

Capital Recovery: Cost is equal total construction cost times the capital recovery factor of 0.0724 at 7.125% of interest rate and a period of 40 years.

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Appendix B

Meeting Notes

Interagency Meeting / Briefing
U. S. International Boundary & Water Commission
U. S. Bureau of Reclamation

Friday Feb 27, 1998

Central Arizona Salinity Interceptor
U S / Mexico Border Alternative

International Boundary & Water Commission

Commissioner John Bernal	832-4101
Secretary Bob Ybarra	832-4100
Principal Engineer Carlos Marin	832-4157
Principal Engineer Debra Little	832-4147
Yusef F. Farran	832-4148
Jim Robinson	832-4152
Ron Kuo	832-4154

Bureau of Reclamation

Scott Irvine	TSC	(303)445-2253
Terri Wilson	PxAO	(602)869-2503
Lorenzo Arriaga	AAO	(915)534-6324

Meeting Synopsis

I. Introductions - L. Arriaga

II. Breifing of proposed Central Arizona Salinity Interceptor (CASI) - Scott Irvine
- Background
- Tucson / Phoenix Project
- Colorado River Delta

III. Discussion

Commissoner Bernal requested a background on the assessment of alternatives, relating the possible Mexican perspective which would require a closer look at alternatives other than disposing the concentrate stream in the Colorado river at Yuma area or thru a pipeline in Mexico. Scott Irvine presented an overview of the screening proces that resulted the selection of 4 preferred alternatives (1.deep well injection into a low quality aquifer, 2.Reuse at private mining operation south of Tucson, 3. Blending with discharge from Pima county Wastewater Treatment Plant into Santa Cruz River, and 4. Conveyance pipeline to Colorado River or Conveyance pipeline thru Sonora Mexico to ocean outfall at Puerto Penasco)

Bob Ybarra stated the political constraints and realities of Mexico's posture regarding the water quality at the Northerly and Southerly International Boundaries. Mexico may accept these low quality waters at Colorado River, only if they are not part of the treaty delivery obligation of 1.5 million acre feet. Mexico may accept these waters only if "linked" to a permanent improvement of waters delivered at the Southerly International Boundary.

The posiibillities of other competing water resource management isues such as the Salton Sea Water Quality Improvement initiative were discussed.

IV. Summary

In future briefings the "concentrate waters" will not be classified as a valued resource. Reclamation will investigate the "linkage" of this proposed project w/ Colorado River Salinity Improvement at SIB and solicite input from Yuma Area Office staff.

MEETING NOTES

Date: September 25 and 26, 1997

Place: Yuma Desalting Plant
7301 Calle Agua Salada
Yuma, Arizona 85364

Attendees: Reclamation: Chuck Moody (303-236-6203, ext. 234), Scott Irvine (303-236-6203, ext. 249), Don Young (520-343-8293), and Ed Lohman (520-343-8331)
International Boundary and Water Commission (IBWC): Al Goff (520-343-9036)

Subject: Feasibility of Concentrate Discharge to Wellton-Mohawk Main Conveyance Channel or Main Outlet Drain Extension (MODE)

1) Mr. Irvine provided a brief overview of the "Tucson CAP Water Treatment Study," the development of membrane concentrate disposal alternatives, and the roles of meeting participants.

2) Mr. Young and Mr. Lohman described the historical operation of the Wellton-Mohawk and MODE canals:

a) The Wellton-Mohawk is a concrete-lined canal that extends about 40 miles east of Yuma and collects irrigation drainage water from local agricultural farms. The initial upstream capacity is about 30 - 40 cfs and gradually increases until its junction with the Main Outlet Drain (MOD) to 333 cfs.

b) Measurements of flow rate and total dissolved solids (TDS) were provided as follows:

Selected Historical Flows of the Wellton-Mohawk (Station 0+00)

Year	Mean Flow (cfs)	Max. Flow (cfs)	Mean TDS (mg/L)
1996	165	237	2716
1995	190	273	2695
1993	161	215	2852
1992	158	200	2880

c) Downstream of the measurement location (Station 0+00) there are a few minor inflows and outflows as the drainage water is conveyed through the MOD, MODE, and U.S. Bypass Drain to Mexico where it is discharged to the Santa Clara Slough. The flow capacity of all downstream canal sections is 333 cfs.

3) Mr. Young explained potential changes to MODE and Bypass Drain flows as a result of current negotiations between the U.S. and Mexico regarding South Boundary water.

South Boundary water consists of groundwater which is pumped to lower the water table in the Yuma area and irrigation drainage water from agriculture. The pumped groundwater and drainage water is collected in the Yuma Main Drain canal system which carries it to the "South Boundary" of the U.S. The South Boundary water is used by Mexican farmers for crop irrigation. South Boundary average and peak flows are about 150 cfs and 220 cfs, respectively, and the TDS content ranges from 1200 - 1600 mg/L. This water is not very suitable for irrigation because of the high salt content. For several years the Mexican government has been requesting that the U.S. provide a remedy to improve the quality of the South Boundary water. Negotiations between the two countries are being conducted by the IBWC and have resulted in the identification of three main options to improve the quality of the South Boundary water:

a) Divert all or a portion of the South Boundary water to the Bypass Drain (discharge to the Santa Clara Slough) and replace with Colorado River water. The net increase in flow to the Bypass Drain would be equal to the flow diverted from the South Boundary. A major difficulty with this option lies in obtaining an allocation of the Colorado River water. Another potential difficulty may be insufficient capacity in the Bypass Drain if all of the South Boundary water is diverted.

b) Divert all or a portion of the South Boundary water to the Bypass Drain (discharge to the Santa Clara Slough) and replace with desalted water from the Wellton-Mohawk canal. Irrigation drainage water from the Wellton-Mohawk would be desalted by reverse osmosis at the Yuma Desalting Plant (YDP) to replace or blend with the current South Boundary water. The concentrate stream from the YDP would be discharged to the Bypass Drain. The net increase in flow to the Bypass Drain would be equal to 30% (concentrate stream) of the flow diverted from the South Boundary. The primary disadvantage of this option is the high cost of desalination. Desalted water would be sent by pipeline to the South Boundary (near San Luis) or the North Boundary (near the YDP).

c) Divert all or a portion of the South Boundary water to the YDP for desalting by reverse osmosis. Clean permeate water would be returned to Mexico by pipeline to either the South or North Boundary locations. The concentrate stream (about 30% of the total water desalted) would be discharged into the Bypass Drain.

The above options are currently being evaluated for presentation to the IBWC in June 1998, after which a selection will be made. Implementation will require agreement between the U.S. and Mexico. Construction is targeted for completion by 2004. In the meantime, Reclamation has budgeted $1 million to begin construction in 1999 of a bypass channel to divert the South Boundary Water to the Bypass Drain.

Depending on the portion of South Boundary water diverted or blended, implementation could result in a significant net increase in the quantity of flow in the Bypass Drain down to the Santa Clara Slough. Option (a) could potentially utilize all of the current available capacity in the Bypass Drain. Existing canal capacity to accommodate potential concentrate flow from Tucson would only be feasible under Options (b) and (c); however, it would probably not be sufficient for concentrate flows from both Phoenix and Tucson.

4) Mr. Lohman and Mr. Young suggested a few alternatives for accepting concentrate flows from the Tucson and Phoenix areas via the proposed Central Arizona Salinity Interceptor (CASI) pipeline:

a) The CASI pipeline would discharge into the MOD at Station 0+00 or into the MODE just downstream of the inlet to the YDP. Discharge upstream of the inlet to the YDP would only be permitted if there are no adverse impacts to YDP desalting operations. Increase the capacity of the canal downstream of this point to accommodate the additional flows by raising the height of the existing canal side slopes.

b) The CASI pipeline would discharge into the upstream reach of the Wellton-Mohawk canal about 40 miles east of Yuma. The existing capacity of this canal may be too small to allow the necessary modification and may require construction of a replacement canal. Once the water reaches the MOD canal, however, additional capacity can be obtained by raising the height of the existing canal side slopes. Again, discharge upstream of the inlet to the YDP would only be permitted if there are no adverse impacts to YDP desalting operations.

c) The CASI pipeline would discharge into the Gila River near Station 0+00. Although the groundwater downstream of this point has a high concentration of TDS and is not used as a source for municipal or irrigation water, it may be difficult to obtain the required permits from the U.S. Environmental Protection Agency and the Arizona Department of Environmental Quality.

d) The CASI pipeline would not connect into the existing infrastructure but instead continue within the right-of-way of the Bypass Drain into Mexico and discharge directly into the Santa Clara Slough.

5) Mr. Moody presented the potential environmental benefits to the Santa Clara Slough and Puerto Peñasco that could be realized by the addition of concentrate flows from Tucson. Specifically, environmental groups have been requesting additional water to maintain the wetland habitat of the Santa Clara Slough. Researchers at the University of Arizona in Tucson are currently evaluating the acceptability of concentrate (about 4,000 mg/L of TDS) to augment existing flows into the wetlands.

6) Mr. Goff commented that the projected TDS levels of the concentrate may be desirable and acceptable to environmental groups and to the Mexican government unless there are other objectionable contaminants present. The next step in determining the administrative feasibility of concentrate discharge into the Santa Clara Slough is to present this alternative for consideration by the Environmental Division of the IBWC in El Paso, Texas.

Action Item: Mr. Irvine will contact Dr. Raymundo Aguirre or Mr. Yusuf Farran of the IBWC in El Paso, Texas at (915) 534-6704 for guidance on how to proceed.

TELEPHONE CONVERSATION NOTES

Date: May 16, 1997
Participants: Dick Smith, Chief Engineer,
Santa Ana Watershed Project Authority (SAWPA)
(909) 785-5411

Scott Irvine, Environmental Engineer
Bureau of Reclamation
(303) 236-6203, ext. 249

The SAWPA constructed and operates the Santa Ana Regional Interceptor (SARI) pipeline. The SARI pipeline is also known as a non-reclaimable waste sewer line. Portions of the pipe are constructed of vitrified clay but most is constructed of plastic-lined reinforced concrete pipe. There are two major collectors within the district each having a diameter of 42 inches and maximum flow capacity of about 20 MGD. Downstream of the collector junction, the pipeline is 48 inches with a capacity of about 30 MGD.

The SARI pipeline was constructed incrementally beginning at the coast in Orange County in the late 1970's. The pipeline was extended to the Northeast about 30 miles in the early 1980's. About one year ago the pipeline reached its current reach into the San Bernardino area. The pipe extends about five miles into the Pacific Ocean where it discharges through diffusers. The total length of the pipeline is about 50 miles.

Within the SAWPA district, the pipeline primarily receives high TDS discharges from the following major contributors:

- Cheese manufacturing plant
- Industrial launderers
- Food processing companies
- Arlington reverse osmosis treatment plant (5 MGD feed rate)

Downstream of the SAWPA district, the pipeline receives municipal sewage which dilutes the high TDS flows from the upstream users. The combined industrial and municipal wastewater flow in the pipeline is treated at the Fountain Valley Wastewater Treatment Plant of the County Sanitation District of Orange County (CSDOC). The wastewater treatment plant effluent is discharged by pipeline into the ocean. CSDOC treatment does not remove TDS, but does treat other contaminants in the influent wastewater. Therefore, CSDOC regulates maximum contaminant loadings on the SARI pipeline users, with the exception of TDS which has no maximum loading criterion. The SARI pipeline does not carry irrigation drainage water. The pipeline and wastewater treatment plant were not designed with sufficient capacity to accept the potentially high flows from irrigation drainage water. Consequently, CSDOC policy is to not accept irrigation drainage water.

SAWPA is a quasi-public, non-profit corporation. The costs of construction, operation and maintenance, and administration are borne entirely by the pipeline users. SAWPA does not have taxation authority. However, SAWPA does receive low-interest construction loans financed by the State of California and the U.S. Environmental Protection Agency which constitute a minor, indirect taxpayer subsidy. The SARI pipeline costs are paid by user fees collected by SAWPA. The pipeline costs are calculated on a per-unit-flow-volume basis and the users are assessed in direct proportion to their flow volume contribution. SAWPA installs a flow meter at each user connection to determine the flow volume contribution. Each user is responsible for financing, constructing and maintaining the lateral pipelines which convey their wastewater to the connection with the SARI pipeline system.

Mr. Smith is available for further consultation as needed, including traveling to Phoenix to participate in our feasibility study of the CASI pipeline to Yuma.