SUMMARY REPORT

for

PARADOX VALLEY
SALINITY CONTROL UNIT

by

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Executive Summary

The Bureau of Reclamation Staff understands the need to plan for the future operation of the Paradox Valley Unit Salinity Control Program. A Request for Proposals was issued in October 2007 to identify and investigate potential methods and combinations of methods for controlling the salt load to the Dolores River at the Paradox Valley.

The Franson Civil Engineers (FCE) Team was awarded the contract and a kick off meeting was held on December 20, 2007. Reclamation Staff provided an extensive project history and the FCE Team prepared a schedule for the deliverables which were:

- Phase 1 Technical Memorandum, Identification of Potential Methods,
- Phase 2 Technical Memorandum, Evaluate Technical Merit of Alternatives, and
- Phases 3 & 4 Technical Memorandum, Evaluate Environmental and Economic.

These documents, which identify and investigate proven alternatives as well as unique alternatives, are included as Appendices to this Summary Report. Reclamation Staff and the FCE Team worked together during the development of these reports.

The alternatives investigated during this study can be divided into three categories. The first category consists of alternatives that would reduce the volume of brine flowing towards the Dolores River, thus reducing the volume of brine to be treated/injected. The second category consists of alternatives that treat/inject the brine removed by the extraction system. The third category is composed of combinations of the various alternatives. The most effective way to limit salt loading to the Dolores River is a combination of alternatives. These are described in further detail in this Summary Report.

The FCE Team Concludes that the existing system should continue operating in its current manner and that some of the identified alternatives possess sufficient merit for further consideration. Studies to verify concepts and gain a greater understanding of the hydrogeology of the area may also be justified.

Project Purpose

The purpose of this project was to identify supplemental and alternative approaches to managing the brine extracted by the wells adjacent to the Dolores River. Since deep well injection was identified as the preferred alternative in 1982 the Bureau of Reclamation (BOR) was interested in knowing whether any technological advances, had become feasible options of brine disposal/treatment. FCE was contracted to identify brine disposal alternatives. In investigating options for brine disposal/treatment, it became apparent that there were also alternatives available that may reduce the amount of brine to be disposed of or treated. Although outside of the initially identified project purpose, these alternatives have been included in the study because they offer the potential to improve the salt removal and cost effectiveness of the existing and future system. These brine volume reduction alternatives are presented as a supplement to a brine disposal/treatment system, not a replacement.

The FCE Team has evaluated the alternatives based on technical, environmental and financial feasibility but not political or social feasibility. Thus, an alternative that is identified as technically, environmentally, and financially feasible may not be politically or socially feasible. For example, Alternative 11, Agricultural Land Management, is likely politically infeasible but has been included in the alternatives carried forward through the various phases because it has met the evaluation criteria identified in the Approach to Work. BOR will choose what alternatives to study further, based on the information presented here and other factors, such as political feasibility, that were not evaluated as part of this project.

Introduction

Over 30 years ago, the Paradox Valley was identified to be a major contributor of salt loading to the Colorado River Basin. Operational since 1996, the Paradox Valley Salinity Control Unit (Unit) of the Colorado River Basin Salinity Control Project (CRBSCP) was designed to control natural brine inflow to the Dolores River by intercepting it, thereby preventing substantial salt loads from entering the river and degrading the water quality of the Colorado River's main stem. The brine is intercepted by pumping a series of nine shallow brine extraction wells adjacent to the river and disposing of it by injection into a 16,000 foot deep well to a brine reservoir. When the system is operating, 230 gpm of brine is injected.

Well testing began in 1991 and over the history of the project more than one million tons of salt have been intercepted and disposed of. Since the Unit's inception, many and various changes have occurred to the deep well brine injection process with the process continuing to evolve. Over the years, studies and tests have been conducted to determine the life of the injection well. Current projections are that the injection well can be used for 10 to 20 more years. The Bureau of Reclamation (Reclamation) determined that alternatives needed to be evaluated in order to select the best options to continue brine removal into the future. It is hoped that new technologies for salt removal will be more cost effective than deep well injection.

Three Technical Memoranda (TM) were prepared to identify potential methods, evaluate alternatives based on technical merit, and based on environmental and economic feasibility. Phase 1 Technical Memorandum identified 16 potential methods. Phase 2 Technical Memorandum evaluated the 14 alternatives based on technical merit with emphasis on volume of brine to be removed and identified major structural components, their operational characteristics and relative cost and cost effectiveness. The Phase 3 and 4 Technical Memorandum discussed the environmental and economic feasibility of the remaining alternatives.

This Summary Report is a compilation of the memoranda's to provide the Bureau with one reference report. The three technical memoranda are included as the Appendices.

Alternatives Investigated

Key team members made a site visit on January 9 and 10, 2008, which is documented in a Trip Report to Reclamation. The Trip Report can be seen in Attachment D. As a result of this visit, team members collaborated to identify sixteen plausible alternatives, including an initial technical screening of the technical adaptability and effectiveness of each potential method, as described in the Phase 1 TM. Additionally, potential methods can be combined to create other alternatives, these are identified in the Combined Alternatives Section, which identifies what alternatives can replace the current system and can be used to improve the efficiency of the current or proposed system. Table 1 summarizes the alternatives with their respective advantages and constraints, originally identified in the Phase 1 TM. The type of alternative is also indicated in the description column of Table 1. Type 1 corresponds to an alternative that reduces the volume of brine flowing towards the river. Type 2 corresponds to an alternative that treats or injects extracted brine. Type 3 is a combination of Types 2 and 3.

Table 1: Summary of Preliminary Candidate Alternatives

Alternative		Advantages	Constraints
No.	Description		
1	Enhance existing injection system (type 2)	Optimize existing facilities	Limited opportunities
2	Additional injection well (type 2)	Recent technological improvements Increased system flexibility Maintain reduced seismic activity	Siting challenge – drill through salt dome Relatively expensive Technical constraints
3	Divert West Paradox Creek (West Valley, last 5 miles) (type 1)	Reduces infiltration to West Valley; potentially reduces brine volume to extraction wells, Relatively economical	Environmental Political (water rights)
4	Zero-liquid-discharge (ZLD) (type 2)	Crystallizer technology demonstrated Suitable for application Optimize extraction schedule	Expensive, High power required Solar power not suitable in peak periods
5	Dewvaporation (DV) (type 2)	Favorable innovative technology Recent technological improvements	Not demonstrated at project salinity levels
6	Other innovative treatment (SAL-PROC, Vibratory Shear Enhanced Process, Product Recovery from Brine, burning salt water) (type 2 and)	Promising technologies (research level) Potential end product benefits (magnesium)	Not demonstrated extensively Single-vendor patent costs
7	Enhanced Leakage Pit (type 2)	Eliminates surface storage	Application limited to Australia
8	Salt bricks (type 2)	New opportunity Potential end product benefits	Technical rationale questionable Technique not demonstrated Single vendor
9	Conventional evaporation basins (1,400 acres) (type 2)	Positive elimination of brine Relatively economical construction	Environmental waterfowl injury Land costs May require bird netting
10	Diversion Tunnel (Dolores River Siphon Crossing of Paradox Valley)	Eliminates brine inflow to river Technique demonstrated in Combined Sewer Overflow applications	Technical challenges Residual seepage at other areas Expensive, Environmental Issues
11	Agricultural Land Management (convert irrigated farmland to wildlife habitat) (type 1)	Eliminate / reduce return flow 5-year demonstration Options (near river – Paradox Basin)	Institutional issues Environmental issues Adverse social impacts
12	Add liner to West Paradox Creek Wetlands (100 ± acres) (type 1)	Reduce brine outflow Maintain environmental benefits Bentonite available locally Relatively economical	Requires cooperation of private owners,Wildlife damage to liner Approval of Division of Wildlife Critical construction scheduling
13	Increase consumptive use by phreatophyte growing (type 1)	Salt uptake Wildlife attractions (SW Flycatcher)	Loss of agricultural lands
14	Integrated evaporation pond and treatment (type 3)	Optimize existing facility Process heat source for ZLD	Limited existing installations
15	Line bed and banks of Dolores to prevent upwelling of brine (type 1)	Stop upwelling of brine Technically demonstrated (amphibious barge)	Residual seepage at other areas Construction impacts High cost
16	Fresh Water Cutoff Wells (type 1)	Reduce or eliminate the circulation of groundwater through the salt dome thus eliminating the brine.	Understanding groundwater system well enough to locate wells Adversely impacting current wells and water rights, drying up wetlands

Alternative type: (1) Brine volume reduction, (2) Treat/inject extracted brine, (3) combination of types 1 and 2

Findings

The Phase 1 Technical Memorandum, Identification of Potential Methods, identified 16 alternatives, with 4 options as part of Alternative 6, for reducing salt loading to the Dolores River. Of the 16 identified alternatives, 10 were evaluated for technical merit in the Phase 2 Technical Memorandum, Evaluation of Salinity Control Alternatives Technical Merit. The Phase 2 TM justified the elimination of Alternatives 7, 8, 10, 13, 15 and 16 and options 6C and 6D of Alternative 6. During the evaluation of technical merit, Alternative 6A, SAL-PROC and Alternative 12, line West Paradox Creek Wetlands were eliminated from further evaluation.

The Phase 3 and 4 Technical Memorandum, Evaluate Environmental and Economic Feasibility justified the elimination of Alternative 12 and option 6A of Alternative 6 based on the environmental and economic feasibility. Utilizing the numbering system used in the Phase 1 Technical Memorandum, the following alternatives have been eliminated from further consideration:

- Alternative 6A, SAL-PROC;
- Alternative 6C, Product recovery from brine;
- Alternative 6D, Burning salt water;
- Alternative 7, Enhanced leakage pits;
- Alternative 8, Salt bricks;
- Alternative 10, Diversion tunnel;
- Alternative 12, Line West Paradox Creek wetlands;
- Alternative 13, Increase consumptive use by phreatophytes;
- Alternative 15, Line bed and banks of Dolores River; and
- Alternative 16, Fresh water cutoff wells.

The alternatives further evaluated in Phases 3 and 4 Technical Memorandum included:

- Alternative 1, Enhance existing injection system;
- Alternative 2, Additional injection well;
- Alternative 3, Divert West Paradox Creek;
- Alternative 4, Zero Liquid Discharge;
- Alternative 5, Dewvaporation;
- Alternative 6B, Vibratory Shear Enhanced Process;
- Alternative 9, Conventional evaporation basins;
- Alternative 11, Agricultural land management; and
- Alternative 14, Integrated evaporation pond and treatment approaches.

A summary of the results for the alternatives further evaluated in the Phases 3 and 4 Technical Memorandum is in the following sections.

Result of Investigations

Table 2 summarizes the relative technical, economic and environmental merits of the alternatives evaluated in the Phase 3 and 4 Technical Memorandum.

Table 2: Summary of Alternatives Technical, Economic and Environmental Merits

Alter-native No.	Alternative Name	Relative Technical Merit	Environ-mental Feasibility	Capital Cost ($ Millions)	Annual O&M Cost ($ Millions)	Tons of Salt Removed per Year	Expected Relative Cost Effectiveness ($/Ton)
1	Existing Collection and Injection System	Good	Excellent	66.3	2.9	109,000	66
2A	Replacement Injection Well Only	Good	Excellent	84.4	2.9	109,000	76
2B	Additional Injection Well operated with Current Well	Good	Excellent	84.4	3.0	109,000	68
3(A)	Divert Lower West Paradox Creek	Good	Poor	1.3	<0.005	4,000	19
3(B)	West Paradox Pressurized Irrigation	Good	Excellent	6.0	0	48,700	7
3(C)	Divert West Paradox Creek	Excellent	Poor	14.0	0	8,000	94
3(D)	Divert West Paradox Creek with Pressurized Irrigation	Excellent	Poor	18.0	0	56,700	17
4A	ZLD – 8 months only during daylight	Good	Excellent	40.2	0.55	35,000	110
4B	ZLD – 8 months, 24 hrs per day	Good	Excellent	72.7	2.33	70,000	120
4C	ZLD – 8 mo. Daylight only, 4 mo. 24 hrs/day	Good	Excellent	40.2	0.85	41,000	104
4D	ZLD 12 mo, 24 hrs/day	Good	Excellent	72.7	2.63	76,000	116
5	Dewvaporation	Unproven	Excellent	12.0	3.5	109,000	46
6(B)	Vibratory Shear Enhanced Process (VSEP)	Questionable	Good	unknown	unknown	109,000	unknown
9(A)	Conventional Evaporation Basin – Radium Site	Good	Fair	103.0	3.6	109,000	79
9(B1)	Conventional Evaporation Basin – East Paradox Valley Without Nets	Good	Fair	129.0	0.075	109,000	66
9(B2)	Conventional Evaporation Basin – East Paradox Valley With Nets	Good	Good	220.0	0.075	109,000	148
11	Agricultural Land Management	Good	Good	$71,500/yr.	<0.05	26,800	3
14	Integrated Evaporation Pond and Treatment Approaches	Fair	Good	12.9	1.1	159,000	86

Conclusion

The FCE Team has had the opportunity to study in detail the current operations of the Paradox Valley Salinity Control Unit. Over a period of three decades, Reclamation has fine-tuned and adjusted the management of the Unit facilities to meet evolving challenges. Those actions have resulted in a stable and reliable operation to effectively prevent about 109,000 tons of salt from entering the Dolores River and causing damages in downstream water use areas. The FCE Team concludes that the current management of the Paradox Unit is being accomplished in a professional and effective manner and the involved Reclamation staff deserves to be recognized for their good work.

Given the fact that the current injection well will not operate indefinitely options for its successor have been identified. The FCE Team has identified alternatives that have the potential to replace or supplement the existing injection well, that may be more cost-effective than the current operations. This project has identified viable alternatives for consideration. BOR may want to further explore the viability of these alternatives by utilizing a “concept verification" approach similar to that used on the Meeker Dome Salinity Control Unit in the early 1980s. Concept verification would involve conducting pilot scale tests of alternatives such as ZLD and Dewvaporation.

Given that the alternatives to reduce the volume of brine are based on a limited hydrogeologic understanding of the Paradox Valley, BOR may choose to conduct further studies to better understand the fresh water/brine interaction. In recent years, remote sensing technology has radically improved the ability of scientists to understand how underground fresh water and saline water systems interact. In a recent investigation of sources of saline water entering the Rio Grande in southern New Mexico, scientists with the US Geological Survey (USGS) have used helicopter electromagnetic data (HEM) to physically identify how sources of saline and fresh water interact as they approach the Rio Grande. The FCE Team believes that this technology could possibly assist with developing a better understanding of how deep percolation from irrigated agriculture interacts with other ground water sources and the saturated brine that reaches the Dolores River area. If BOR is interested in pursuing HEM the person to contact at the USGS is:

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APPENDIX A

Phase 1 Technical Memorandum – Identification of Potential Methods

APPENDIX B

Phase 2 Technical Memorandum – Evaluation of Salinity Control Alternatives Technical Merit

APPENDIX C

Phases 3 and 4 Technical Memorandum – Evaluate Environmental and Economic Feasibility

APPENDIX D

TRIP REPORT

On January 9, 2008, members of the FCE Engineers Team (the Team) visited the Paradox Valley Salinity Control Unit (Unit) in the area of Bedrock, Colorado. Team members included Layne Jensen, Bill Everest, Walt Fite and Michael Clinton. The purposes of the site visit were to (1) familiarize the Team with the current physical layout and condition of Unit facilities, (2) obtain copies of available operational data and documentation, and (3) observe areas adjacent to the Unit collection system to identify possible alternative methods of achieving the Unit's salinity control objective.

The Team stayed in Moab, Utah, on the evening of January 9 and traveled through La Sal to Bedrock on the morning of January 9th. A heavy snow storm began as the Team traveled to Bedrock. The Team arrived in Bedrock about 10:00 AM and met with Reclamation's Facility Operations Specialist, Andy Nicholas. Mr. Nicholas introduced the Team to members of his staff, as well as on-site employees of the contractor operating the Unit's facilities.

The Team spent the morning with Mr. Nicholas, who provided a number of file reports describing the planning and construction of the Unit. The Team also discussed the current operational strategies, including the current injection strategy, which includes twice yearly shutdowns to rest the well. Mr. Nicholas indicated his feeling that the current injection strategy has minimized both seismic and injection well back-pressure concerns, although the long-term operational viability of the injection well is still a concern.

Significant time has been spent discussing how the saline aquifer is being recharged. Mr. Nicholas indicated that he has seen little evidence of Dolores River water entering the collection well system. In reviewing a graph showing daily Dolores River flow and daily salt loading, the Team observed that there have been short-term occurrences when changes in river flow (stage) result in inverse changes in daily salt loading – this suggests that there may be a "bank storage" process operating within the banks of the Dolores River. Mr. Nicholas also told the Team that he has observed saline rivulets along the West Bank of the Dolores River when an adjacent wildlife pond (Pond No. 3) is filled. There may be a possibility that when the pond was excavated, the excavation cut into the gravel formation that connects the halite beds and the Dolores River. The option to line Pond 3 was discussed.

In addition, the Team discussed the Unit's operational results. The Unit has been injecting about 110,000 tons of salt per year, while salt loading to the Dolores River has been reduced by about 150,000 tons per year. We discussed possible reasons for this anomaly, including the influence of recent drought conditions on West Paradox Creek, as well as improved irrigation methods (side roll and center pivot sprinklers) on irrigated farmland in West Paradox Valley. The irrigated farmland supports a population of about 200 people living in the West Paradox Creek Basin.

The Team discussed the availability of groundwater monitoring data. Mr. Nicholas told the Team that they have 40 groundwater monitoring wells – water levels are read at the beginning and end of each operational shutdown period. It appears that those data could be used to

calibrate a model of the groundwater flow network. Mr. Nicholas indicated that Reclamation owns 340 acres in the area.

Following lunch, Mr. Nicholas drove the Team on a tour of the area. Sites visited included most of the collection wells, two of the EC Meter sites on the Dolores River, the abandoned Union Carbide evaporation pond site, the facility where the flow from the collection wells is monitored and filtered before being transmitted by pipeline to the injection facility, the Conoco Well location (possible site for an additional injection well), farmland on the west side of the Dolores River, the wildlife ponds (including Pond 3) and the injection well location. Because power to the facility was shut off for maintenance reasons, the Team did not enter the injection facility. Team members took many photographs during the field tour.

Following the field tour, the Team returned to Moab via Grand Junction because of the ongoing snow storm.

On January 10, the Team met in Moab and developed a list of additional information that would be requested from Reclamation. The Team also developed a preliminary list of alternatives before returning to their respective offices.