TECHNICAL REPORT

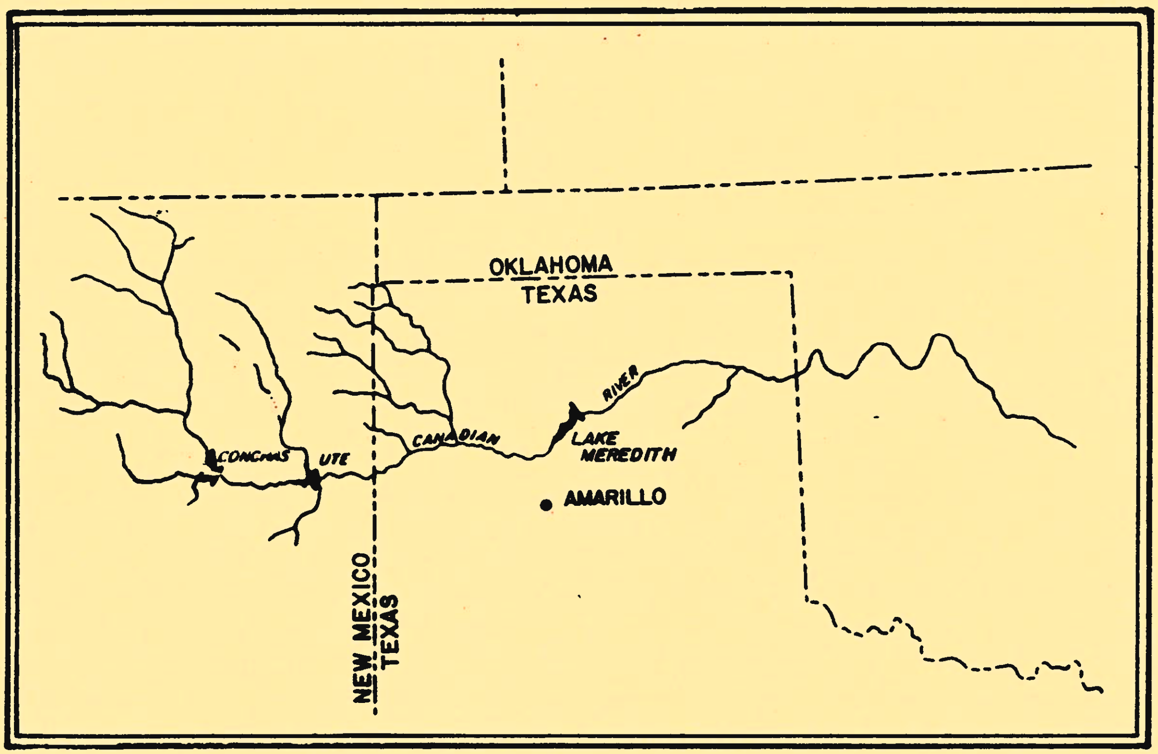
on the

LAKE MEREDITH

SALINITY CONTROL PROJECT

Canadian River

Texas—New Mexico



UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

JUNE 1985

TECHNICAL REPORT ON THE LAKE MEREDITH SALINITY CONTROL PROJECT

CANADIAN RIVER
NEW MEXICO-TEXAS

THIS REPORT WAS PREPARED PURSUANT TO PUBLIC LAW 96-375, OCTOBER 3, 1980. PUBLICATION OF THE FINDINGS AND CONCLUSIONS HEREIN SHOULD NOT BE CONSTRUED AS REPRESENTING EITHER THE APPROVAL OR DISAPPROVAL OF THE SECRETARY OF THE INTERIOR. THE PURPOSE OF THIS REPORT IS TO PROVIDE TECHNICAL INFORMATION FOR CONSIDERATION BY THE BUREAU OF RECLAMATION, OTHER FEDERAL AND STATE AGENCIES, THE CANADIAN RIVER MUNICIPAL WATER AUTHORITY, AND INTERESTED PUBLICS.

Prepared by

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SOUTHWEST REGION
AMARILLO, TEXAS

JUNE 1985

SUMMARY

Purpose and Scope

The purpose of the investigation was to provide sufficient information to the project sponsor, the Canadian River Municipal Water Authority (CRMWA), for deciding upon a future course of action to alleviate or control the salinity problem occurring in Lake Meredith. The scope of the investigation was to (1) identify the source(s) of saline contamination into the Canadian River between Ute Reservoir near Logan, New Mexico, and Lake Meredith, Texas; (2) determine the magnitude and extent of saline-water inflow to this reach of the Canadian River; (3) evaluate alternatives for reducing and/or controlling salinity inflow to Lake Meredith; and (4) evaluate the effectiveness of implementing a plan for reducing and/or controlling the salinity level of Lake Meredith.

Problem

Since impoundment began in 1965, Lake Meredith has experienced a gradual decline in water quality associated with reduced reservoir levels. Available data suggest that the quality of water in Lake Meredith will continue to decline, especially during periods of low flow and low volume accompanied by high evaporation. The mean value of concentration for sodium (Na), chlorides (Cl), and sulfates (SO_4) can be expected to remain in excess of the recommended secondary standards for drinking water supplies.

Need

Corrective action should be taken to maintain the concentration of salts in Lake Meredith water within desirable limits, preferably those limits recommended by the secondary drinking water regulations.

Location

The area of investigation included the region of major brine inflow, which occurs naturally, to the Canadian River around Logan, New Mexico, and encompassed the 150-mile river reach between Ute Dam and Lake Meredith (see Location Map, drawing No. 1253-500-17, following page I-4).

Public Involvement

Several meetings were held with and presentations made to CRMWA and other entities having an interest in the study. The purpose of these activities was to provide information and receive input to the study. A discussion of the main activities is included in chapter I of this report.

Findings

1. The hydrogeologic investigations conducted by Hydro Geo Chem, Incorporated, (HGC 1984A and 1984B) and the Bureau of Reclamation (Reclamation) determined that a sodium-chloride brine of natural origin produced by dissolution of Permian halite beds flows into the Canadian River near Logan, New Mexico. The

brine flows upward from the Permian deposits into a geologic unit in the upper Permian or lower Triassic Formations (refer to figure II-1 following page II-1), then upward into the river alluvium. The exact route of movement is not known but is probably through a complex fracture system. The movement of this brine through the alluvial system is not very well understood. Brine appears to discharge into the river at several discrete points; but because of influences from freshwater springs and floodflows, these sites have not been adequately defined. It is possible that brine seepage may be relatively continuous downriver from Ute Dam.

2. The HGC analysis of the regional and site geology (New Mexico and Texas) relating to the sources of brine contamination in the Canadian River concludes that about 70 percent of the sodium chloride entering Lake Meredith comes from New Mexico and that most of this contamination enters the river channel near Logan, New Mexico. The report also states that an additional 10 to 15 percent of the total salt load enters the river channel between the Tascosa and Amarillo gauges. Reclamation investigations indicate that this brine appears to flow continuously to the river system. Floodflows do not appear to affect concentration levels within the alluvium.

3. Results of a water and salt budget analysis show that if no action is taken, the CRMWA and other local interests would likely face continuing deterioration of the quality of Lake Meredith's water supply in addition to that which would normally occur because of evaporation.

4. After an evaluation of several alternative plans for reducing salinity in Lake Meredith, the most acceptable plan to CRMWA is well pumping and brine dispoal by deep-well injection. Based on October 1984 prices, construction costs for the basic plan are estimated to be $3,270,000 and $7,760,000 for the expanded plan.

5. The CRMWA has indicated a willingness and financial capability to pay the costs of brine removal at the source and disposal by deep-well injection. This plan has a benefit/cost ratio of 1:1, based on the cost of the most likely salinity reduction method in lieu of Reclamation action. Engineering and economic feasibility of the project is based on the success of two concepts: (a) interception of the brine without significant dilution, and (b) injection of the brine using acceptable pressures and without serious plugging of the injection zone.

6. The results of a preliminary study completed by Reclamation (USBR 1984) indicate that the Logan, New Mexico, area has adequate average wind speed for considering windpower systems as a source of project power.

7. There would be minimal environmental or cultural resources impacts for either the basic or expanded plan for reducing the salinity of Lake Meredith.

8. Results of a HGC salinity control model, simulating low-flow characteristics, for the Canadian River between Ute Dam and Lake Meredith provide estimates of the effect after 10 years of 100-percent reduction in brine inflow

near Logan. The reduction is calculated to be about 24 percent (in milligrams per liter) of total dissolved solids (TDS) in the river water reaching Lake Meredith. If the brine inflow was only reduced by 50 percent, the time for the system to respond was nearly the same; but the amount of salinity reduction was about half of that calculated for the 100-percent reduction in brine inflow. The response to the inflow salinity reduction in Lake Meredith would be direct but at a slightly reduced rate.

9. Based on existing information on deep formations in the Logan, New Mexico, area, a suitable disposal zone probably exists for deep-well injection.

Conclusions

1. Based on the above findings, the plan that is most acceptable to the project sponsor, CRMWA, for improving the water quality of Lake Meredith is brine interception at the source by well pumping and disposal by deep-well injection.

2. Additional fieldwork to include exploratory drilling and long-term pump testing is needed to verify the findings presented in this report and the effectiveness of the plan.

PREFACE

The content and format of this report are structured to reflect the sequence of events that occurred during the investigation. Field testing conducted in March 1978 of the riverbed sands and subsurface water conditions of the Canadian River, accompanied by exploratory drilling, resulted in the identification of a brine artesian aquifer contributing saline pollution to the natural flow of the river. The leaky aquifer was located in the general area of Logan, New Mexico, downstream from Ute Reservoir. Based on the field test data, an appraisal report was completed by the Bureau of Reclamation in 1979 which presented a potential plan to control the brine flow from the aquifer. It was felt that an improvement in Lake Meredith water quality could be achieved by isolating the brine artesian aquifer. The plan as envisioned at the time was to continuously pump the aquifer at a rate of about 1 cubic foot per second to lower the potentiometric surface or head pressure, thereby reducing the upward flow of brine from the aquifer to the Canadian River.

Reclamation's 1979 appraisal report recommended that feasibility investigations be conducted to further evaluate potential plans for controlling saline inflow to the Canadian River from the leaky aquifer. In fiscal year 1983, funds were appropriated to conduct further studies to verify the findings presented in the 1979 appraisal report.

The present report focuses on a plan for reducing salinity inflow to Lake Meredith, complete with cost estimates to accomplish this objective. Data for the report are based on water quality sampling, streamflow readings, analysis of regional geology in the Logan area, and seismic work needed to identify a probable location for brine injection. Additional fieldwork such as exploratory drilling or further pump testing was not done because of program constraints.

The contents of this report together with the supporting data should provide sufficient information to the project sponsor, the Canadian River Municipal Water Authority, for deciding upon a future course of action.

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SUPPORTING DOCUMENTS

Available on request to: Bureau of Reclamation
Southwest Region
Commerce Building
714 South Tyler Street, Suite 201
Amarillo, Texas 79101

1. Bureau of Reclamation--Hydrology/Hydrogeology Appendix, December 1984.

2. Hydro Geo Chem, Inc.--Analysis of Geophysical Data to Examine the Feasibility of Deep-Well Injection of Brine Near Logan, New Mexico, December 19, 1984.

2. Hydro Geo Cehm, Inc.--Study and Analysis of Regional and Site Geology Related to Subsurface Salt Dissolution Source of Brine Contamination in Canadian River and Lake Meredith, New Mexico-Texas, and Feasibility of Alleviation or Control, May 1, 1984.

CHAPTER I - INTRODUCTION

Purpose and Scope

In response to local concerns and those of its own, the Canadian River Municipal Water Authority (CRMWA) requested Federal assistance in seeking means to alleviate, or at least control, the salinity problem occurring in Lake Meredith. Lake Meredith is the storage reservoir for the Canadian River Project (CRP), Texas, which supplies municipal and industrial (M&I) water to member cities on the Texas High Plains. In March 1983, the Bureau of Reclamation (Reclamation) initiated the Lake Meredith Salinity Control Project to provide sufficient information to the project sponsor, CRMWA, for deciding upon a future course of action. The scope of the investigation was to:

1. Identify the source(s) of saline contamination into the Canadian River between Ute Reservoir near Logan, New Mexico, and Lake Meredith, Texas.

2. Determine the magnitude and extent of saline-water inflow to this reach of the Canadian River.

3. Evaluate alternatives for reducing and/or controlling salinity inflow to Lake Meredith.

4. Evaluate the effectiveness of implementing a plan for reducing and/or controlling the salinity level of Lake Meredith.

Problem and Need

Problem

Since impoundment began in 1965, Lake Meredith has experienced a gradual decline in water quality associated with reduced reservoir levels. This trend was interrupted by large inflows of relatively freshwater in June 1981. Over the long term, the gradual increase in concentration for sodium (Na), chlorides (Cl), sulfates (SO_4), and total dissolved solids (TDS) is expected to continue. The extent of increase is such that contaminant levels often exceed the recommended secondary standards for domestic water supplies. For example, the maximum concentration measured for Cl is 600 milligrams per liter (mg/L) and for TDS is 1,880 mg/L. These values are excessively high when compared to the recommended level of 250 mg/L for Cl and 500 mg/L for TDS.

Table I-1 provides a summary of water quality data recorded at Lake Meredith from November 1965 through January 1984. It also includes the percent of samples exceeding the Environmental Protection Agency (EPA) 1983 secondary drinking water standards, the Texas drinking water standards, and the State stream standards.

The Safe Drinking Water Act of 1974 requires the EPA to establish primary and secondary drinking water regulations to assure safe drinking water supplies for the public. Primary regulations are aimed at protecting public health. They establish maximum allowable contaminant levels in drinking water and are

Table I-1
Water Quality
Lake Meredith Near Sanford, Texas 07227900
General Constituents - USGS Data
(1965-1984)

						Standards or Criteria					
Constituents	Number of Samples	Mean Level	Median Level	Maximum Level	Minimum Level	EPA Domestic Water Supply	Percent Exceeding Standard	State Domestic Water Supply	Percent Exceeding Standard	Streambed Standard	Percent Exceeding Standard
Temperature Water (centigrade)	37	14.5	15.0	28.0	3.0	--	0.00	--	0.00	--	0.00
Transparency Secchi (meters)	3	2.9	2.8	3.7	2.1	--	0.00	--	0.00	--	0.00
Color (PT CO units)	2	0	0	0	0	75.0	0.00	--	0.00	--	0.00
Specific Conductance (UMHOS/CM)	41	1,740	1,680	3,010	1,090	--	0.00	--	0.00	--	0.00
Dissolved Oxygen (mg/L)	5	9.7	9.9	11.6	7.3	**	0.00	--	0.00	--	0.00
Dissolved Oxygen (SAT)	5	92	92	97	85	--	0.00	--	0.00	--	0.00
pH (units)	33	7.9	7.8	8.7	7.2	**	3.03	--	3.03	--	3.03
Alkalinity (mg/L $CaCO_3$)	40	170	170	200	140	**	0.00	--	0.00	--	0.00
Hardness TOT (mg/L $CaCO_3$)	40	250	260	340	190	--	0.00	--	0.00	--	0.00
Hardness Noncarb (mg/L $CaCO_3$)	40	80	83	200	32	--	0.00	--	0.00	--	0.00
Calcium Dissolved (mg/L Ca)	40	58	59	70	44	--	0.00	--	0.00	--	0.00
Magnesium Dissolved (mg/L MG)	40	26	26	42	17	--	0.00	--	0.00	--	0.00
Sodium Dissolved (mg/L NA)	35	270	260	550	150	--	0.00	--	0.00	--	0.00
Sodium Adsorption Ratio	41	7.6	7.3	13	5.0	--	0.00	--	0.00	--	0.00
Sodium (Percent)	35	68	69	78	60	--	0.00	--	0.00	--	0.00
Potassium Dissolved (mg/L K)	33	6.7	6.6	8.8	4.3	--	0.00	--	0.00	--	0.00
Chloride Dissolved (mg/L Cl)	42	300	280	600	160	250	80.95	300	30.95	350	9.52
Sulfate Dissolved (Mg/L SO_4)	40	260	260	520	150	250	55.00	300	5.00	350	2.50
Flouride Dissolved (mg/L F)	37	.80	.80	1.0	.50	**	0.00	--	0.00	--	0.00
Silica Dissolved (mg/L SIO_2)	40	3.8	2.9	18	.40	--	0.00	--	0.00	--	0.00
Dissolved Solids (180C Mg/L)	4	748	764	842	621	500	100.00	1,000	0.00	1,250	0.00
Sum of Constituents (mg/L)	41	1,020	1,000	1,880	620	500	100.00	1,000	39.02	1,250	7.32
Dissolved Solids (tons/acre-ft)	41	1.4	1.4	2.6	.84	--	0.00	--	0.00	--	0.00

** Standard or Criteria variable but calculated.
-- Standard or Criteria variable or not established.

enforceable under both State and Federal law. Secondary regulations are designed to protect public welfare and deal with taste, odor, and appearance of drinking water. Constituents controlled by secondary standards are considered to be nuisances rather than direct threats to health. At this time, secondary regulations are not enforceable. The State of Texas has chosen to have recommended secondary constituent levels which are higher than those recommended by EPA for several of the constituents. For example, the State TDS standard is 1,000 mg/L versus 500 mg/L recommended by EPA, and the State Cl and SO_4 standards are 300 mg/L versus 250 mg/L recommended by EPA.

The effects of poor water quality on the water user are varied. When Cl concentrations exceed 250 mg/L, water begins to taste salty and the corrosion of steel and aluminum begins to increase. Sulfates may cause problems for some industrial users when concentrations exceed 100 mg/L; and when over 250 mg/L, the water will begin to taste bitter.

Available data suggest that the quality of water in Lake Meredith will continue to decline, especially during periods of low inflow and low volume accompanied by high evaporation. The mean concentration for Na, Cl, and SO_4 can be expected to remain in excess of the standards recommended by the secondary drinking water regulations.

Need

The CRMWA and its water users are concerned about the degrading water quality of Lake Meredith. Inasmuch as Lake Meredith is the principal source of water for the 11 member cities, its value, both in quantity and quality, is extremely important to its users. They believe that corrective action should be taken to maintain the concentration of salts in Lake Meredith water within desirable limits, preferably those limits recommended by the secondary drinking water regulations.

Authority for Study

The Lake Meredith Salinity Control Project, New Mexico-Texas, was authorized by Public Law 96-375, October 3, 1980. Funding to begin the study was provided in fiscal year 1983.

Location and Description

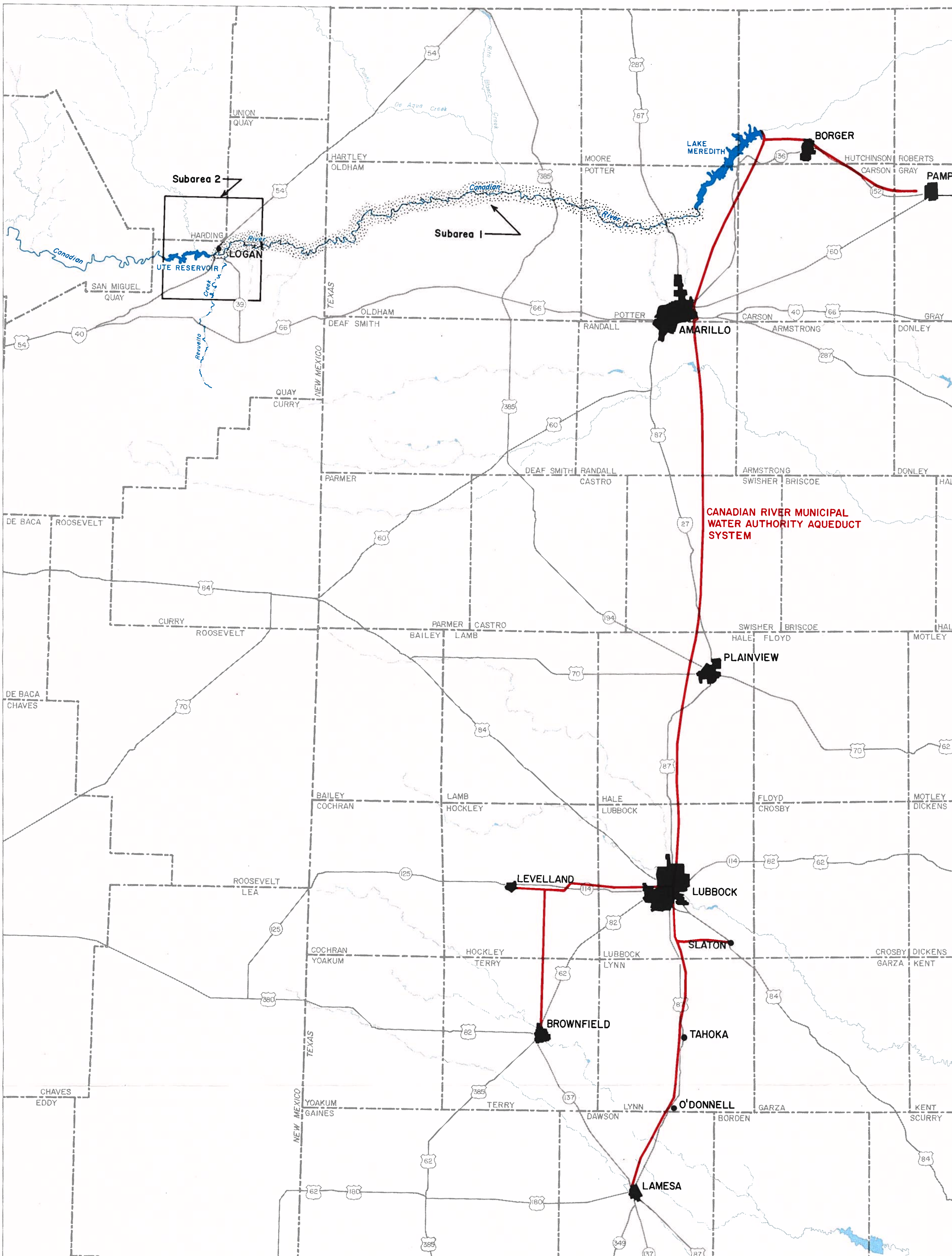
The location of the study area, as shown on the Location Map (Drawing No. 1253-500-17), corresponds to the general boundaries of the CRP which is located in eastern New Mexico and the Texas Panhandle. It includes a 150-mile reach of the Canadian River in eastern New Mexico and Texas; Lake Meredith, the storage reservoir for the CRP; and the CRP water delivery area consisting of 11 service communities including Borger, Pampa, Amarillo, Plainview, Lubbock, Slaton, Tahoka, O'Donnell, Lamesa, Levelland, and Brownfield. Population of the 11 cities in 1980 was approximately 430,000 (about 168,000 household units).

For purposes of the present investigation, the study area has been divided into subareas 1 and 2. Subarea 1 encompasses the river reach between Ute Dam and Lake Meredith; subarea 2 is a detailed area centering around Logan, New Mexico, and includes the region of major brine inflow to the Canadian River.

The CRP is an M&I water supply project built by Reclamation in the mid-1960's. Major features of the project include Sanford Dam/Lake Meredith, 323 miles of pipeline, 10 pumping plants, and 3 regulating reservoirs. Management, including operation and maintenance (O&M), of project facilities was assumed by the CRMWA in 1968. Since that time, delivery of project water has been made to the service area on a continuous basis. The project is designed to deliver up to 103,000 acre-feet per year (acre-ft/yr) which was the estimated firm annual reservoir yield.

Lake Meredith, located on the Canadian River about 37 miles northeast of Amarillo, Texas, supplies M&I water to the 11 member cities of the CRP water delivery area. In addition, it provides flood control, recreation, and fish and wildlife benefits. Annual visitation to the reservoir often exceeds the million mark.

The reservoir at top of conservation has a total capacity of about 840,000 acre-feet with a corresponding surface area of about 16,000 acres. In 1973, the reservoir achieved its largest volume to date, consisting of 522,700 acre-feet. Beginning in 1973, however, the reservoir experienced a gradual decline in



SUBAREA I -- INCLUDES THE CANADIAN RIVER REACH BETWEEN UTE DAM AND LAKE MEREDITH

SUBAREA 2 -- INCLUDES THE REGION OF MAJOR BRINE INFLOW TO THE CANADIAN RIVER

N

10 0 10 20 30 40
SCALE of MILES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTROL PROJECT

LOCATION MAP

DECEMBER 1984

AMARILLO, TEXAS

1253-500-17

volume, reaching a low point of about 108,000 acre-feet in 1981. The volume of water rose to over 460,000 acre-feet in the spring of 1983 and has since fallen to 320,000 acre-feet in the fall of 1984.

The 150-mile reach of the Canadian River being investigated extends from Lake Meredith upstream to Ute Dam and Reservoir, New Mexico, which is located about 35 miles west of the State line. In the study area, the river is entrenched 200 to 700 feet below the general land surface and is flanked on both sides by the Canadian River "breaks," consisting of a strip of land 15 to 30 miles wide which is extensively dissected by tributaries of the river. The resulting topography is one which varies from generally rolling to rough and broken. Flows in the river below Ute Dam are normally seasonal, varying from almost none to high-flushing flows associated with intense rainfall over a large area.

Public Involvement

Prior to the initiation of and throughout the investigation, Reclamation coordinated with Federal, State, and local entities in order to provide information and receive input to the study. A discussion of the main activities follows.

July 21, 1982 - Reclamation personnel, Division of Planning, met with representatives from the CRMWA to discuss past Reclamation/CRMWA involvement, results, and the proposed future program for the Lake Meredith Salinity Control Investigation. The CRMWA has contributed to the appraisal investigations and has, along with other concerned local interests, recommended future studies be conducted in an effort to resolve the salinity problem of Lake Meredith.

August 24-27, 1982 - Southwest Region Division of Planning staff members and a representative from the CRMWA toured several ongoing salinity control projects in the Colorado River Basin. Staff members from Reclamation's Upper Colorado River Region gave the visiting group briefings on the Paradox Valley Unit, Glenwood-Dotsero Unit, Big Sandy Unit, and Meeker Dome Unit. Some of these briefings were followed up with an onsite field tour of the project area and facilities.

November 17, 1982 - Reclamation personnel met with several entities that have a direct interest in this study. Attendance included representatives from the CRMWA, technical and elected officials from CRMWA member cities, Panhandle Regional Planning Commission, Canadian River Compact Commission, Texas Department of Water Resources (TDWR), and New Mexico Interstate Stream Commission (NMISC). Informational material including the draft Plan of Study (POS) concerning this study was submitted to some of these entities prior to the meeting. The purpose of the meeting was to discuss the overall study and Reclamation's proposed approach and to define objectives.

March 1983 - The Notice of Initiation of Investigation was sent out to interested agencies, organizations, and individuals.

April 1983 - Reclamation representatives met with the city of Amarillo Water Reclamation Superintendent and his staff members to discuss the field monitoring and water quality sampling program. The city of Amarillo volunteered to conduct laboratory analysis on water samples to be provided by Reclamation and CRMWA.

August 1983 - The POS was approved. Copies of the POS were provided to selected agencies and organizations and made available to requesting entities.

August 31, 1983 - Reclamation met with the New Mexico Department of Game and Fish (NMDGF) and the U.S. Fish and Wildlife Service (FWS) to discuss the Lake Meredith Salinity Control Study and to develop a plan of study addressing New Mexico's environmental concerns on the project alternatives. It was agreed that data gaps exist in the biological knowledge of the area and that a study plan was needed. The NMDGF agreed to provide materials to Reclamation so that New Mexico collecting permits could be obtained. In addition, Reclamation and FWS agreed to work closely with NMDGF and provide up-to-date information as the study progressed.

September 19, 1983 - Reclamation met with a representative from CRMWA to discuss the status of the investigation and contents of the Preliminary Findings Report (PFR). It was decided that Reclamation would provide copies of the PFR to the CRMWA board members and member cities, and the CRMWA representatives would then discuss the contents of the PFR with the members of the board and cities.

July 1984 - The PFR was prepared. Copies were provided to selected agencies and organizations and made available to requesting entities. Some entities, including the CRMWA, provided comments on the PFR which were used in determining the acceptability of the various alternatives.

November 5, 1984 - Reclamation met in Santa Fe, New Mexico, with representatives from FWS and several New Mexico State agencies including NMISC, State Engineer's office, Environmental Improvement Division, and NMDGF. The purpose of the meeting was to brief the agencies on the results and status of the Lake Meredith Salinity Control Project and to discuss the permit process for brine production and disposal wells.

December 11, 1984 - The Regional Planning Officer and other Reclamation representatives met in Amarillo, Texas, with the project manager and a board member of CRMWA and the chairman of CRMWA's Water Quality Committee. The purpose of the meeting was to brief the CRMWA representatives on the study findings.

December 18, 1984 - A public information meeting was held in Logan, New Mexico, to brief the local interests on the status and findings of the study. The meeting also gave the public an opportunity to express their views and concerns relating to the potential project. No major issues or concerns were raised.

Previous Investigations

Several reports have been prepared which deal with the water quality of the Canadian River and Lake Meredith. Presented below is a synopsis of each report and its findings.

Definite Plan Report--Canadian River Project, 1960

The Definite Plan Report was Reclamation's final report prior to construction and development of the CRP. In this report, existing and future water quality conditions were analyzed based on data available at that time. Reservoir operation studies indicated that during critical reservoir drawdown periods the maximum concentrations of Cl and TDS of water stored in the reservoir could reach levels of about 400 mg/L and 1,800 mg/L, respectively. It was recognized that the quality of water in the Canadian River was marginal and that during critical periods of low reservoir inflow combined with reservoir evaporation, the level of salinity in the reservoir could be expected to increase. The report further noted that mixing of surface water with available ground water supplies would normally result in an acceptable quality of water.

Texas Water Quality Board Study, 1970

In 1970, the Texas Water Quality Board (TWQB) completed a streamflow-water quality study between Ute Dam in New Mexico and Boy's Ranch, Oldham County, Texas. The results of the study suggest that most salts were entering the river between Ute Dam and the New Mexico-Texas State line, with the most significant amounts appearing near Ute Dam. The TWQB recommended that a complete study be made of the river from Logan, New Mexico (Ute Dam), to Lake Meredith during periods of base flow and for periods of runoff from the watershed.

Mason-Johnston and Associates, Inc., 1972

The CRMWA commissioned the firm Mason-Johnston and Associates, Inc., to conduct a study of data reduction and interpretation relative to water quality of base flow of the Canadian River between Conchas Dam, New Mexico, and Lake Meredith.

Conchas Dam is located on the Canadian River about 50 miles upstream from Ute Dam. In 1972, findings of the study were presented in report form to the CRMWA. The results and recommendations of the report are summarized as follows:

1. Primary contribution of Cl, SO_4, and TDS to Canadian River base flow is of natural origin.

2. Industrial, commercial, and agricultural sources of pollution are only minor contributors of contaminants to the overall base flow water quality of the river.

3. A detailed surface reconnaissance and a water sampling survey should be made of main stem base flow between Ute Dam and Boy's Ranch, Texas. Particular attention should be given to the reach from Ute Dam to immediately downstream from the confluence of Revuelto Creek and the Canadian River; to areas immediately downstream from the confluence of the major tributaries; and to any other ground water sources including springs, seeps, and municipal and private wells.

4. A detailed study should be made of geologic and ground water conditions in the Ute Dam-Revuelto Creek area.

<u>Lake Meredith Salinity Study, USBR 1979</u>

In response to local concerns and those of its own, the CRMWA requested Federal assistance in seeking means to alleviate or at least control the salinity problem. In 1973, Reclamation began an appraisal investigation aimed at locating point sources of river water contributing to the salinity problem in Lake Meredith. The investigation was completed in 1979.

Testing of the riverbed sands and subsurface water conditions of the Canadian River accompanied by exploratory drilling resulted in the identification of a brine artesian aquifer contributing saline pollution to the natural flow of the river. The leaky aquifer was located in the general area of Logan, New Mexico, about 2 river miles downstream from Ute Reservoir. A potential plan that would control the brine flow from the aquifer had been formulated. The plan, as envisioned, was to continuously pump the aquifer at a sufficient rate to lower the potentiometric surface or head pressure, thereby reducing the upward flow of brine from the aquifer to the Canadian River. Based on an assumed aggregate flow from the brine aquifer of about 0.6 cubic foot per second (ft^3/s), it was estimated that the contribution of Na, Cl, and SO_4 from the brine aquifer averages about 26,900 tons per year or about 32 percent of these constituents entering Lake Meredith. It was concluded that if the effects of the brine aquifer could be eliminated, the average concentration of Na, Cl, and SO_4 combined flowing into Lake Meredith should be reduced from about 500 to about 350 mg/L. Hypothetical operation studies, covering the period 1965 through 1977, indicated that elimination of the brine inflow would have resulted in a 1977 average TDS concentration in the reservoir of about 800-900 mg/L instead of the measured TDS concentration of 1,150 mg/L.

Consideration was given to the possibility of constructing a diversion dam or low-flow storage dam on the Canadian River immediately downstream from the aquifer seep area. Brine flows would be contained and then pumped into an evaporation pond. Although upstream Conchas and Ute Dams would control some minor floods, any floods of large magnitude could flush salts from a low-flow storage dam. Also, the steep canyon walls, rugged terrain, and absence of a nearly natural evaporation site did not make a diversion dam appear practical.

The possibility of using the brine water for powerplant cooling was considered but eliminated from further consideration because of the distance to nearby powerplants and low volumes of brine water that would be available.

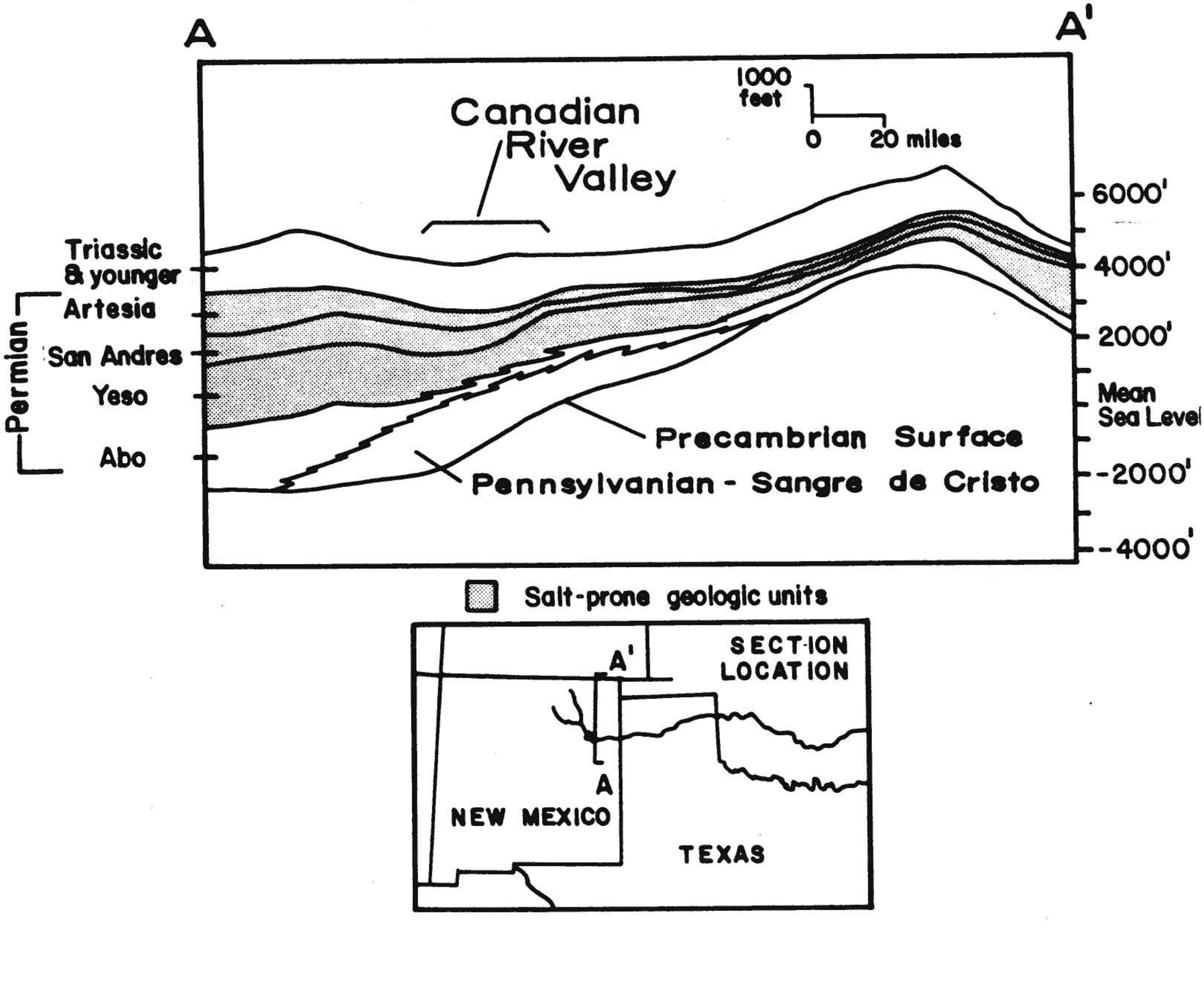
The appraisal report, completed in 1979, recommended that feasibility investigations be conducted to further evaluate potential plans for controlling saline inflow to the Canadian River from the leaky aquifer.

CHAPTER II - GENERAL GEOLOGIC AND HYDROLOGIC CONDITIONS

General Geology

This section examines the geology of the region centering around Logan, New Mexico. Information used in this section comes from two reports prepared by Hydro Geo Chem, Incorporated (HGC), Tucson, Arizona, for Reclamation, Southwest Region, under Contract No. 3-CS-50-01580 (HGC 1984A and 1984B). Information on the general geologic conditions encompassing the river reach between Ute Dam and Lake Meredith is included in a 1979 Reclamation report entitled "Lake Meredith Salinity Study, Appraisal-Level Investigation, Canadian River, Texas-New Mexico (USBR 1979)."

The area around Logan, New Mexico, lies near the edge of the Tucumcari Basin, which can be considered to be an extension of the Palo Duro Basin of Texas. The sedimentary units dip gently southward toward the depositional axis of the basin. Prior to the formation of the basin in mid-Pennsylvanian time, the Panhandle region was the site of shallow water carbonate deposition. As the basin developed, arkosic sandstones and shales originating from uplifted granitic highlands north and west of Logan were deposited initially as irregular clastic units that became more developed and continuous as the basin filled. These sediments are represented by the Pennsylvanian/Permian Age, Sangre de Cristo, and Abo Formations. Conformably overlying the sandstones are the Permian Yeso, San Andres, and Artesian Formations. Figure II-1 shows the subsurface geologic formations in the Logan, New Mexico, area. All three Permian Age formations contain fine-grained siltstone, dolomite, anhydrite, gypsum, and



SUBSURFACE GEOLOGIC FORMATIONS
Logan, New Mexico Area

Source : Hydro Geo Chem, Inc., January, 1984

Figure II-1

halite and represent shelf and shelf-margin depositional systems that existed in an arid environment. In the upper section, the units generally grade from fine-grained sandstones and interbedded mudstone and salt to bedded halite, gypsum, anhydrite, and carbonate. A lithographic analysis of the available well logs shows that 20 to 40 percent of the three Permian units may contain salt (HGC 1984A). Unconformably overlying the evaporitic sediments are the fluvio-deltaic Dockum Group sediments which are Triassic in age and crop out throughout the region. A veneer of alluvial sands and gravels and irregularly exposed caliche deposits cap the highlands and terraces above the river channel.

The structure of the Precambrian basement rock defines the structure of the Tucumcari Basin and the geometry of the deep sediments. The dominant structural features are northwesterly trending, high-angle normal faults deep in the subsurface and a structural high in the Precambrian basement, both of which have apparently influenced all of the Paleozoic sedimentary systems. No surface trace of the faulting has been observed. Analysis of the well logs available for the area indicates that the updip limits of the salt-bearing Permian units have undergone thinning in the vicinity of Ute Reservoir. The area of thinning lies just north of a northwest trending fault zone that has been active since at least Pennsylvanian time. Thinning of the rock units is believed due to both salt dissolution and the normal variation in stratigraphic thickness over a structural high.

In addition to the deep subsurface structure, there is a system of weakly developed northeast trending flexures which can be observed at the surface. The flexures rarely exhibit dips greater than 5 to 10 degrees. An east-west trending anticline was mapped along the Canadian River in the area of

Ute Reservoir that runs subparallel to the dissolution fronts mapped in the subsurface. A regional fracture pattern exists in the area. The northeast trending flexures, variations in the fracture pattern, and the group of depressions along the Canadian River are believed to have formed in response to dissolution. The structure observable at the surface is believed to be primarily controlled by the dissolution of salt units in the subsurface.

A more detailed description of the regional geology and the possible stratigraphic and structural controls upon brine movement is included in the report prepared by HGC (1984A).

Hydrologic Conditions

This section is divided into discussions of the hydraulics of flow in the Permian-Triassic ground water system and the hydrology of the channel deposits and the Canadian River flow. A detailed description of the region's hydrologic conditions is included in the report prepared by HGC (1984A).

Ground water conditions

Permian Formation. Ground water within the Permian Formation flows eastwardly at a fairly uniform gradient between 15 to 20 feet per mile from the Sangre de Cristo uplift in New Mexico to the eastern escarpment of the caprock in the Panhandle of Texas. Hydraulic heads are above land surface in the New Mexico portion of the study area; but because the hydraulic gradient is much steeper than the land surface gradient, heads are far below land surface in Texas. The permeability of the Permian rocks is generally low but may locally be very high due to fractures and dissolution.

Triassic Formation. The Triassic system is divided into the Santa Rosa Sandstone, Chinle, and Redonda Formations. It is separated from the salt-prone Permian geologic units by the shales and mudstones of the Permian Artesia Group. Most water flow within the Triassic Formation in the Logan area is toward the Canadian River. The topography and surface drainages of this area strongly influence water levels, especially south of the Canadian River. The Canadian River, Revuelto Creek, and Rana Canyon are apparent discharge areas for the water in the Triassic. The shape of the water table surface shows that much of the recharge to the Triassic is derived locally.

Transmissivity of the Triassic Formation has not been measured between Ute Dam and Lake Meredith. Hydraulic conductivity is estimated to range from about 0.25 to 2.5 feet per day. Available data indicate that this aquifer has typically low water yields. Estimates of specific capacity range from about 0.01 to 0.5 gallon per minute per foot of drawdown. The saturated thickness of the aquifer is unknown.

The average hydraulic gradient north of the Canadian River is about 40 feet per mile; south of the river, it is extremely variable but is estimated to average about 20 feet per mile. The estimated ground water discharge from the Triassic Formation into the Canadian River is about 5 ft^3/s between Ute Dam and the State line. The heterogeneity of the rocks, thickness variations, and changes in hydraulic gradient probably cause this inflow to occur unevenly along the channel. In Texas, as the Triassic thins through erosion, much less water is conducted to the river. In addition, the water-level gradient appears to decrease eastwardly toward the State line. Therefore, most ground water inflow from the Triassic probably occurs within the New Mexico portion of the study area.

Shallow brine aquifer. Drilling records and geophysical logs of wells drilled by Reclamation indicate that the top of the brine aquifer is a shale layer in the lower Triassic. It is probably bounded on the bottom by shale near the top of the Artesia Group, with a saturated thickness of about 100 to 150 feet. The hydraulic head varies with location but appears to be about 10 feet above river level or about elevation 3,674 feet at well TW-1. The shallow brine aquifer might be connected directly to the deeper Permian ground water system by fractures or dissolution channels.

Surface water conditions

Channel deposits. The Canadian River below Ute Dam has cut a channel through nearly 1,000 feet of Triassic rocks. Between 50 and 75 feet of fine-grained clastic sediments have been deposited in the channel. The channel is 400 to 600 feet wide for most of the reach between Ute Dam and the New Mexico-Texas State line with a uniform stream gradient averaging 5.3 feet per mile.

The CRMWA and Reclamation have each installed numerous piezometers [1/] into the channel deposits. Water levels in the piezometers are generally within a foot or two of the land surface, and there are minor water-level variations between piezometers open at different depths at the same sites. Permeability has not been measured in any of the channel piezometers. Given the predominance of poorly sorted, medium- to fine-grained sands and the uncertain continuity of ground layers, the channel's hydraulic conductivity is estimated to be 30 feet per day. The actual fluid velocity within the channel sediments is assumed to be less than 0.1 foot per day with an assumed effective porosity of 20 percent. Based on this information, the largest amount of brine within the river system is assumed to be transported by surface water.

Surface water flow. Based on information provided to Reclamation by HGC, the average surface water flow in the Canadian River between Ute Reservoir and Lake Meredith is shown in the following tabulation. The figures reflect flows since the closure of Ute Dam in December 1963. The locations of the gauging stations are shown on drawing No. 1253-500-18.

1/ A piezometer is a small-diameter well with a short section of screen through which water can enter. It is used to measure water elevations and to obtain water samples from discrete points within an aquifer.

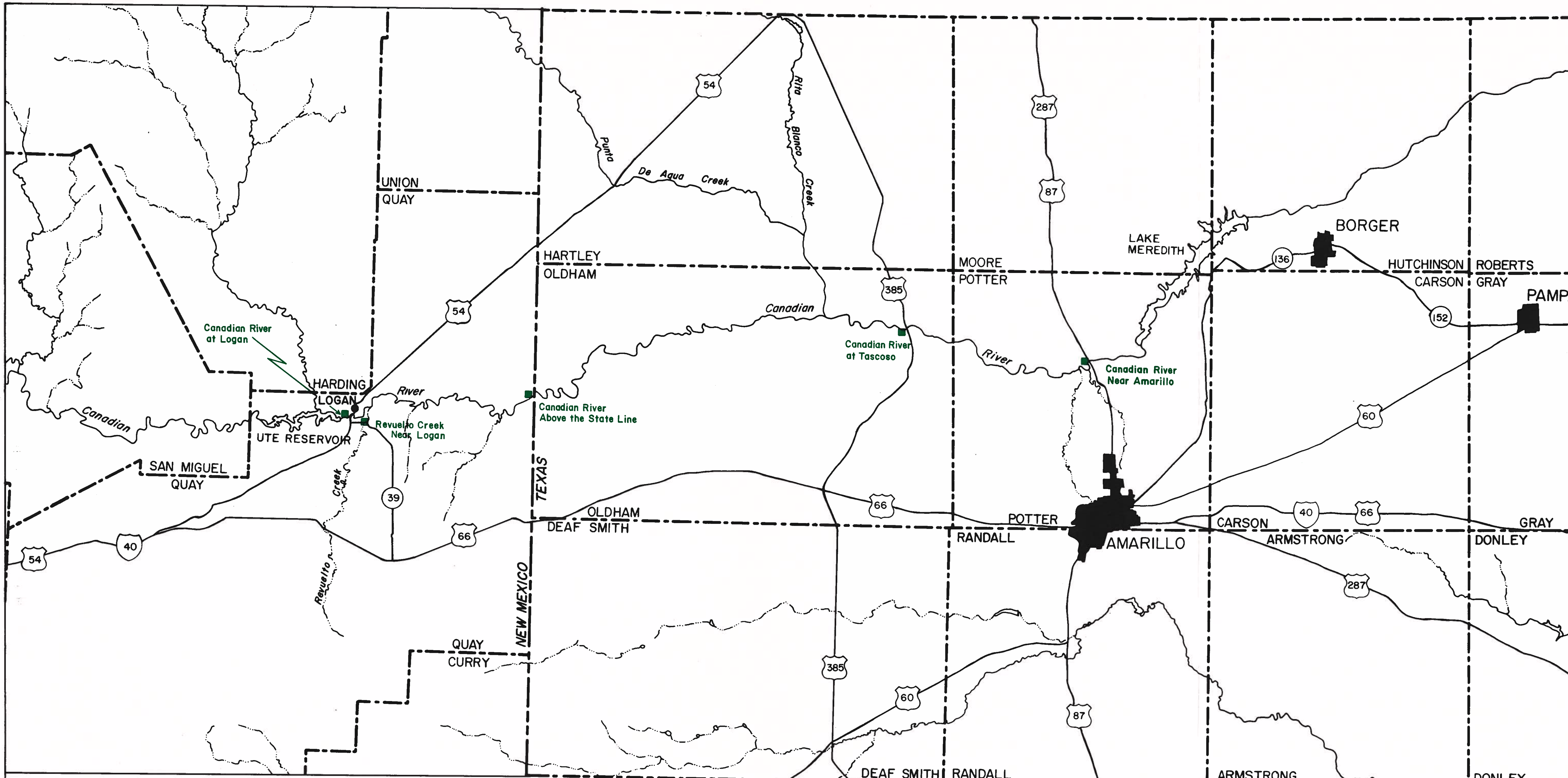
Average Surface Water Flow

Gauging Stations	Average Flow (ft^3/s)	Median Flow (ft^3/s)	Period of Record (water years)
Canadian River at Logan	30	2	1963-Spring 1984
Revuelto Creek near Logan	45	8	1963-Spring 1984
Canadian River above the New Mexico-Texas State line	81	13	1969-Spring 1984 (periodic measurements taken only)
Canadian River at Tascosa, Texas	168	30	1968-1977
Canadian River near Amarillo	190	50	1963-Spring 1984

As shown in the above tabulation, on the average, the Canadian River gains in flow between Ute Dam and the gauge near Amarillo. The present-day gains are shown in the following tabulation.

Summary of Gains in Canadian River Flow Between Ute Dam and Lake Meredith

	Flow Gain (ft^3/s)	Percent	From
	30	16	Below Ute Dam, of which about 2 ft^3/s is from seepage and ground water inflow, the rest from the few occasions of flow over the spillway. This may vary because of modifications made to the spillway in spring 1984.
	45	24	Revuelto Creek, primarily from irrigation return (about 8 ft^3/s) and floodflows.
	5	2	Between Revuelto Creek and State line, primarily from ground water inflow.
	87	46	Between State line and Tascosa, primarily from floodflows, probably from the Punta de Aqua drainage.
	22	12	Between Tascosa and Amarillo, mostly from ground water, ground water inflow, some from irrigation return, and little from floodflows.
Total -	190	100	At Amarillo gauge.



EXPLANATION

■ GAUGING STATIONS

SCALE of MILES (10, 0, 10, 20, 30, 40)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTROL PROJECT

GAUGING STATIONS

DECEMBER 1984

AMARILLO, TEXAS

1253-500-18

CHAPTER III - FIELD INVESTIGATIONS

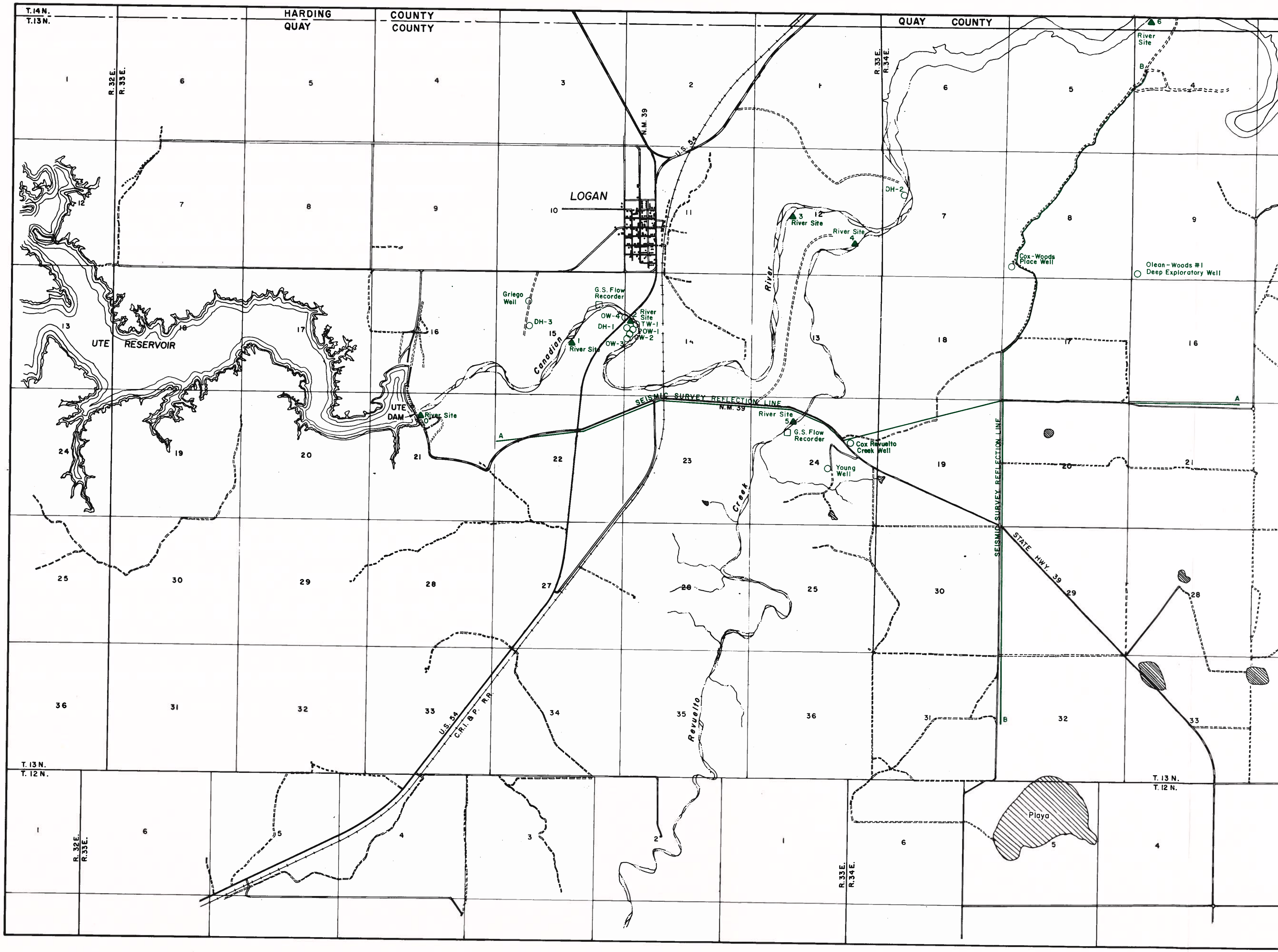
Fieldwork completed by Reclamation began in May 1983 and ended in September 1984. The purpose of the work was to collect hydrologic and hydrogeologic information along and near the Canadian River from Ute Dam to about 10 miles downstream. Additional reconnaissance work was completed downstream to Lake Meredith. Numerous piezometers were placed in the river bottom sands and sampled periodically. The Canadian River, Revuelto Creek, and wells in the Logan area were also sampled periodically. In addition, an exploratory hole was drilled and cored, then completed as an observation well.

A 4-day brine aquifer pump test conducted by Reclamation in March 1979 indicated that pumping the aquifer at 1 ft^3/s for a continuous 12-month period would lower the artesian head below the river elevation. Based on this testing, Reclamation's 1979 appraisal report recommended feasibility investigations be conducted (refer to page I-11). Upon appropriation of funds in fiscal year 1983, Reclamation outlined work items required to conduct further studies to verify previous findings. It was with this in mind that an early network of piezometers was installed. The best location for test production wells was to be determined upon completion of site-specific geology. Because of program constraints, adjustments were necessary after the study was initiated. This resulted in limiting additional fieldwork to periodic water level monitoring; water quality sampling; streamflow readings; analysis of regional geology in the Logan, New Mexico, area; completing a geologic coring for stratigraphic correlation; and seismic work to identify a probable location for a deep-well brine injection system. Long-term pump tests were not conducted. The data gathered was sufficient to confirm that a major portion of the brine inflow entering Lake Meredith comes from a reach of the Canadian River from Ute Dam to about 10 miles downstream.

Surface Water and Alluvium

The Canadian River meanders within a steep-walled canyon in New Mexico where most of the detailed fieldwork was completed. This canyon bottom is filled to a depth of about 60 feet with silt, sand, and gravel. Leakage of brine up through the bedrock must first pass through this thick sequence of sediment where it mixes and is diluted with fresher water as it moves upward to the river channel. In order to determine the actual thickness of these sands and the spatial and temporal variations of saline water within the river alluvium, sampling sites were established and piezometers were installed at several points on the river downstream of Ute Dam. Seven sites located along the Canadian River and Revuelto Creek from Ute Dam to about 10 miles downstream were selected for water quality and flow monitoring. The locations of these seven sites are shown on drawing No. 1253-500-19. A description of the sites and sampling procedures used in the investigation follows.

Site 0 was located at the toe of Ute Dam. No drilling was done at this site since a piezometer was already in place in the river sands for monitoring hydraulic head below the dam. Several water quality samples were collected from the toe drains at this site and one sample from the piezometer. After pumping



EXPLANATION

▲ WATER QUALITY and FLOW MONIT

○ OBSERVATION or EXPLORATORY

UNITED STATES
DEPARTMENT OF THE INTER
BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTRO

DATA SITES

DECEMBER 1984

AMARILLO, TEXAS

Site 3 was located 5.4 miles below Ute Dam on the south side of the river. Two piezometers were installed in sand containing lenses of clay and gravel at this point. The total depth of piezometer 3A was 34 feet and piezometer 3B was 20 feet. Bedrock was encountered at 34 feet; this may not have been the deepest point of the channel.

Site 4 was located in the middle of Revuelto Creek about 0.2 mile above the confluence with the Canadian River at 6.3 miles below Ute Dam. Two piezometers were installed in sand containing lenses of pea-sized gravel. Piezometer 4A was set at 20.5 feet total depth, and piezometer 4B was set at 15 feet total depth. Bedrock was encountered at about 18 to 20 feet. Soft sandstone, which forms the canyon bottom, made determination of the bedrock top very difficult. However, this depth was probably near the lowest point of the bedrock channel. No staff gauge was installed at this site.

Site 5 was planned for Revuelto Creek about 2.1 miles above the Canadian River confluence, just downstream of the U.S. Geological Survey (USGS) gauge. It was not possible to physically enter the creek with the drill rig at this point because of steep banks, so the piezometer installation was not completed. Flow and water quality data were obtained from USGS.

Site 6 was located 9.9 miles below Ute Dam on the south side of the river. Three piezometers were completed in sand containing clay and gravel lenses. Piezometer 6A was completed to 50 feet total depth, piezometer 6B was completed to 31 feet total depth, and piezometer 6C was completed to 21 feet total depth.

Drill bits were left in all three holes, but their presence should not have affected the concentration of major ions in the water quality samples. Bedrock was encountered at 52 feet. This depth should have been close to the maximum depth of the bedrock channel. A staff gauge was placed just upstream of the site.

Water quality samples were collected from all the piezometers of sites 1 through 4 and 6 on a regular schedule. Samples were obtained by injecting air at the bottom of the piezometer via a small-diameter tube to lift the water to the surface where it could be collected. Piezometers were pumped from the shallowest to the deepest. Water was discharged away from the site.

Stream samples were collected upstream of the piezometers and a discharge measurement made. Additionally, supplemental data were acquired by HGC and from USGS.

Several samples were collected from the surface and the outlet works of Ute Reservoir, and several stream water quality surveys were completed to determine the changes in quality of the surface waters at different locations.

Ground Water

Several observation and exploratory wells have been drilled in the Logan vicinity to (1) locate areas of brine pollution into the Canadian River system and (2) determine the depth and thickness of the Permian-Triassic Formations in the area of suspected brine contamination. The locations of these wells are shown on drawing No. 1253-500-19 following page III-2. The following is a description of the procedures used in this evaluation.

Water level recorders were installed on two wells which were drilled during a previous Reclamation investigation (USBR 1979). A recorder installed on the DH-2 hole was in operation for 2 months before it was discontinued because water levels were responding to fluctuations in the riverflow. A second recorder was installed on well TW-1 near the New Mexico State Highway 54 bridge. The recorder was in operation from May 1983 until August 1984. The major fluctuations in water levels observed were small and reflected atmospheric pressure changes and earth tides. Limited water level data were also collected from observation wells OW-4, OW-3, and DH-3.

Water surface elevation data for Ute Reservoir were acquired from USGS for the period August 1982 through September 1984. These data were used to determine the relationship, if any, of the lake surface elevation and the water levels in the brine artesian aquifer as depicted by observation wells TW-1, OW-3, OW-4, and DH-3.

Several water samples were collected from wells DH-2, DH-3, and OW-3 for analyses and correlation. Limited isotope data were also collected for age dating, recharge area, and water-mixing determinations.

Core Drilling

Information obtained from bore holes completed near Logan during a 1979 Reclamation investigation had raised questions about the local stratigraphy which could not be adequately resolved due to problems encountered with obtaining reliable samples of the Triassic rocks. It was determined that a core was needed from the Triassic and Upper Permian rocks for proper correlation. This coring operation (DH-3) was started in August 1983 and completed about 1 month later. Problems with hole caving slowed the drilling in the shales of the Triassic Formation which continued until 362 feet of casing was set. The coring then continued to 569.5 feet. Core recovery was about 100 percent, which allowed a very reliable stratigraphic column to be compiled. A natural gamma log was also obtained from the drill hole.

A 147-foot section of grayish-white to bluish-gray sandstone was cored from about 350 feet to 497 feet. It was determined that this sandstone was the brine artesian aquifer identified by earlier drilling. Permian Age rock was first encountered at 514 feet. The hole was completed as an observation well with screen set between 418 and 361 feet within the blue-gray sandstone unit. The water level measured just after the well completion was 84.9 feet below land surface, a water level considerably above the top of the aquifer. This information, combined with the thick shale sequences, indicated a confined condition.

One significant observation was made during drilling which sheds some light on the questionable stratigraphic log produced for the DH-2 hole. The shales in the Triassic section caved continuously and were recored periodically. This caving and reworking may account for the approximately 350 feet of reddish-brown shale and the 150 feet of white-gray shale logged during DH-2 drilling. Because of this, correlation of other well logs to the DH-2 log should be done with caution.

Seismic Survey

In order to evaluate the subsurface for disposal of brine, a seismic reflection survey was completed during July 20-23, 1984. Approximately 7 miles of full 24-fold subsurface coverage was obtained for two survey lines oriented north-south and east-west and located just south and east of the Canadian River near Logan. The two seismic survey reflection lines are shown on drawing No. 1253-500-19 following page III-2. An analysis of the survey shows that the fault-bounded Tucumcari Basin extends further north than originally expected from previous studies. A thick accumulation of Abo and Sangre de Cristo Formations sediments can be found near Logan. The Abo Formation sandstones are the most laterally extensive and the least structurally disrupted of the arkosic sandstones. The Abo is located 3,800 to 4,400 feet below land surface in the vicinity of the seismic lines. The acquired data are sufficient to speculate that there is a high probability that a successful injection well can be completed in the area. Details of the survey and interpretation are contained in a report entitled "Analysis of Geophysical Data to Examine the Feasibility of Deep-Well Injection of Brine near Logan, New Mexico," prepared by HGC (1984B).

CHAPTER IV - ANALYSIS OF DATA

Data for this investigation have been received from several sources including Reclamation, CRMWA, the city of Amarillo, HGC, and other State, Federal, and private agencies. The city of Amarillo contributed to this study by conducting extensive laboratory water quality analyses on field samples provided by Reclamation and CRMWA. The HGC provided, through a contract agreement, summaries of a substantial amount of these data (HGC 1984A and 1984B). A summary of all the hydrogeologic data collected during this investigation is provided in this section.

Water Quality

Surface water and alluvium

Water quality data were collected on surface flows and from the alluvium of the Canadian River between Ute Dam and a point about 10 miles downstream from the dam and the lower 2-1/2 miles of Revuelto Creek. The purpose of the data collection was to establish a good basic understanding of the spatial and temporal variation in the chemical makeup of these waters. The data also provided a baseline to which future water quality information could be compared if a salinity control project was implemented.

All the water collected from the Canadian River, Revuelto Creek, and the alluvium (from Ute Dam and below to site 6) was characteristically the same type.

The Na and Cl ions generally dominate. The other ions are much less significant, especially as the total concentrations increase. A description of water samples collected at each site and statistical procedures used in the analysis are included in the Hydrology Appendix.

The statistical analyses show that there is a good correlation between Cl, TDS, and field-specific conductance for the piezometer and surface water data. They also show that there is a poor linear correlation between streamflow and these same parameters.

An analysis of the surface water data shows that Cl and TDS concentrations are the same from sites 1 to 2 on the average, increase sharply to site 3, and then decrease steadily to site 6. The decrease below site 3 is directly related to the dilution by Revuelto Creek water. If the average Cl and TDS concentrations for site 6 are plotted when Revuelto Creek is dry or nearly dry, there is very little change in these concentrations from site 3 to site 6. It is possible that if the Revuelto Creek flows were not available, the concentrations would remain constant or continue to rise downstream from site 3. Continuous data collected during long periods of very low Revuelto Creek flows would help test this.

The chemical concentrations recorded for the deep piezometers at each site rise from site 1 to site 2 to site 3, then drop toward site 6. Shallow piezometers at each site indicate a steady decrease in concentration from site 1 to site 6.

It is hard to determine where the brine enters the surface water system due to the uncertainties regarding movement into the bedrock channel, then up and through the thick sand, gravel, and clay deposits. The 12 piezometers discussed previously were installed at 5 locations and 2 or 3 depths to evaluate this very large, complex system. The data points and sampling frequency were not great enough to answer the questions about the distribution of brine in the alluvium. A piezometer installed deeper into the alluvium at site 1 could greatly alter the trend of brine concentrations for the deep piezometers. The deep piezometers at the other sites also may not be at the deepest point in the alluvial material. Also, total mixing of brine in the surface water and the alluvium may not occur for miles or not at all, causing problems with collecting representative samples at specific river cross sections. Freshwater springs, which occur many places along the first 10 miles below Ute Dam, may alter the brine movement or change its concentration intermittently along the stream course. Brine and freshwater pools occur along the drainage. This has been well documented by various sources--most recently by HGC in 1984 and by Reclamation in 1983.

The surface and alluvial sampling program was designed to help explain the mechanisms controlling movement of salt in the streambed and the interchange between the stream and the alluvium. The HGC presents annual data indicating that transport of salt in the river varies with flow rate. They also concluded that the salt concentrations in the shallow piezometers resulted from periodic flushing. As stated previously, statistical analysis of the water quality data collected from the piezometers did not correlate with surface flows directly, indirectly, or with various transformations of data including log, natural log, and lagging of the data. Most variations in a single piezometer or grouped piezometers appeared statistically insignificant. However, the data set is also small. The data to support either large storage of salt in the channel alluvium or the flushing of salts from the alluvium by high flows is not available.

A recurring question that was not answered by this investigation is the impact Ute Reservoir has made on the concentration of brine in the river. Water quality data available prior to Ute Reservoir are very limited. A high Cl concentration of 6,410 mg/L was reported by the USGS in 1957 for the Canadian River at the Logan gauge. The recorded flow was 0.05 ft^3/s (Berkstresser and Mourat 1966). From 1957 to 1962, prior to Ute Dam construction, Cl and TDS concentrations ranging from 1,000-3,000 mg/L and 2,000-5,000 mg/L, respectively, were reported when flows were in the 1- to 2-ft^3/s range. This is the same range recorded for most of the present sampling period. Higher concentrations were recorded by USGS during higher flows, indicating some possible antecedent flushing of the surface channel.

Ground water

Chemistry of the Triassic water. Chemical determinations for wells completed in the Triassic Formation were made by Reclamation to supplement those collected by HGC (1984A) and are included in the Hydrology Appendix. The TDS and Cl concentrations observed ranged from about 700 mg/L to 3,300 mg/L and 100 mg/L to 300 mg/L, respectively.

Higher SO_4 and magnesium were detected in wells completed in the Triassic near Revuelto Creek near the Canadian River than from most other sampled wells in the Triassic, which may be unusual for the area. An upward leakage of Permian water could be causing this anomaly; but Cl and Na concentrations are not significantly greater than other water samples from the Triassic. This observation may be significant and should be investigated further. Water from the Permian may be moving upward through gypsum beds at these locations instead of salt beds.

Chemistry of the brine artesian aquifer. Water samples collected for wells OW-3 and OW-4 show concentrations of chemical constituents, indicating a Na-Cl brine. This is similar to results reported by previous investigations (HGC 1984A and USBR 1979).

Water samples were also collected from two wells not previously sampled. Holes DH-2 and DH-3 were sampled to determine if brine could be detected in other deep wells. It was found that Na-Cl ions were the primary constituents of these samples. Hole DH-2 water is probably a less concentrated mixture of water from the Triassic and the same brine from the Permian found at other deep wells.

Water from all four wells contains carbon dioxide (CO_2), which escapes from the solution rapidly after the sample leaves the well. Field pH and alkalinity were collected for OW-3 when sampled by HGC, but not for any of the samples collected by Reclamation. There was a rapid change in pH shortly after sampling due to outgassing of CO_2, with a resultant change in the carbonate distribution. If more representative samples are required, then field determinations for these constituents should be made.

Two concerns need to be noted about DH-2 and DH-3 samples. First, the samples from DH-2 were collected from the flowing well at a valve installed in the top of the casing. The well was only cased a short way into bedrock; so when it was reentered for geophysical logging in September 1983, the logging tool could only be lowered 160 feet. Since the well was not cased and only partially open, it was not possible to determine where the sample water was coming from or how much mixing with fresher water was occurring. The depth of 160 feet is at elevation 3,496 feet, which correlates with the top of the brine artesian aquifer at well OW-3.

Second, DH-3 was pumped by air injection for about 1 hour. The specific conductance had not stabilized when the sample was collected. However, the sample was considered to be a reasonable reflection of the water from the Brine Artesian Aquifer at this location. It would be desirable to pump the well two to three times longer, then sample again to confirm this.

A single sample was collected from well OW-3 by HGC for a tritium activity determination. The conclusion drawn from the reported 0 tritium activity was that the brine artesian aquifer at well OW-3 does not contain any modern water; i.e., Ute Reservoir water.

Hydrogeology

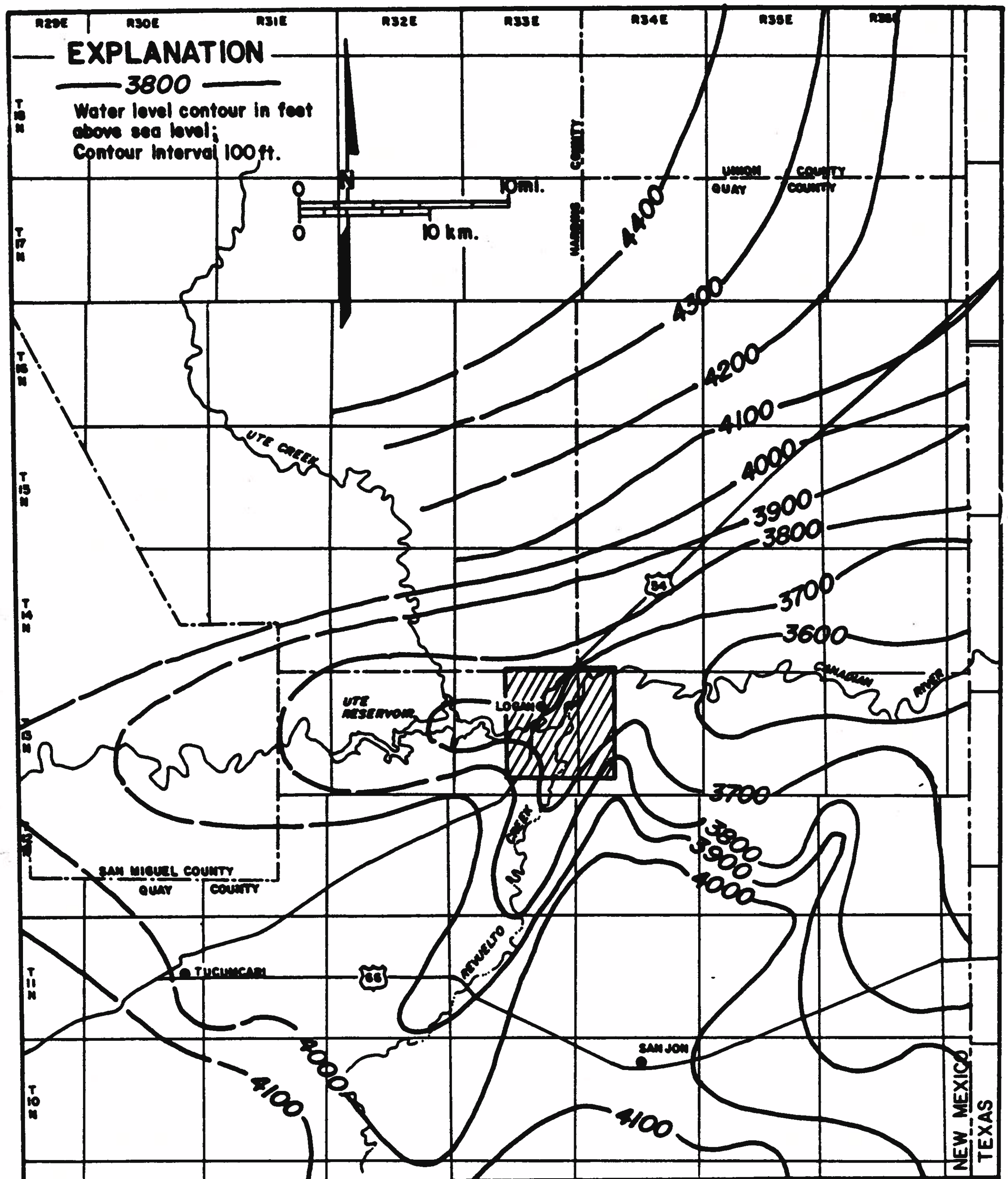
For a detailed description of the geologic and hydrologic environment in the Logan, New Mexico, study area, refer to the report by HGC (1984A). A natural Na-Cl brine derived from solutioning of halite beds within the Permian Formations moves up into the overlying Triassic Age Formations (probably through fractures) at a rate of about 0.6 ft^3/s. This brine mixes with and is diluted by the Triassic water. The diluted brine then moves upward (also probably along fractures) through the Triassic rocks into the Canadian River alluvium. This leakage is estimated to be about 0.9 ft^3/s in the Logan area. The brine is then further diluted by fresher water within the alluvium as it moves downstream, emerging at numerous points along the river. These points may be directly associated with the brine pools noticed at many points along the river from Ute Dam to 10 miles downstream at site 6.

The subsurface data available in the Logan area are very limited. A detailed and accurate description of the hydrologic flow system within the Permian, Triassic, and Alluvial geologic units immediately adjacent to the river and their interrelationships is not possible without additional data and analysis.

A recorder was installed on well TW-1 for continuous water level measurements in order to try to determine if there was any physical relationship between the hydraulic head of Ute Reservoir and the brine artesian aquifer. In addition, monthly water level measurements were collected from Ute Reservoir and wells OW-3 and DH-3. The Ute Reservoir water level elevation had been lowered for construction of a new spillway during about half of the measurement period and was slowly rising toward the end of the data collection period. During the approximate 4 feet of rise in the reservoir water level elevation late in the summer of 1984, no change in well TW-1 water level occurred (other than barometric or earth tide). These observations neither prove nor disprove that there is a relationship, only that one was not observed. There may be a considerable time lag in any pressure response of the brine artesian aquifer to water level changes in Ute Reservoir, or the ratio of response may be very small and not measurable at 4 feet of change. Very limited data collected during the summer of 1982 showed a higher water level elevation in well TW-1 when the Ute Reservoir water level elevation was 16 feet higher; however, this observation was not verified during the present investigation.

In order to evaluate the assumptions and preliminary conclusions made about the hydrologic and geologic systems within the study area and to determine if brine leakage to the river alluvium could be controlled, a three-layered, quasi-three-dimensional, finite-element, ground water flow model was constructed. The model code used was provided to Reclamation by Golder Associates, Incorporated, a consulting engineering firm in Seattle, Washington. The model covered a 4.5- by 5-mile area near Logan, New Mexico, which included the Canadian River from Ute Dam to about 9 miles downstream and the lower 5 miles of Revuelto Creek (refer to figure IV-1).

Calibration runs of the model showed the importance of the many input parameters on the final output. Basically, the upper layer responded as a water table



Triassic water-level surface centering around Logan, New Mexico

Area included in ground water flow model

Source : Hydro Geo Chem, Inc., May, 1984

Figure IV-1

aquifer conforming to topographic changes, especially along the river canyon. The water table was high in the topographically high areas and low in the topographically low areas, and water movement was toward the Canadian River and Revuelto Creek. The simulation output generally reflected the water table maps shown in figure IV-1. The potentiometric surface of the lower confined layer generally sloped from west to east and toward the river and creek canyons. A "cone of depression" formed along the river as a result of upward leakage of water (brine) toward the river. Vertical upward leakage was highest where the upper layer was thinnest; i.e., along the canyons, and leakage was lowest and sometimes downward where the upper layer was thickest. The rate and direction of ground-water leakage was controlled by the head difference between these two layers since the vertical hydraulic conductivity coefficient of the middle confining unit was held constant.

After a satisfactory steady-state calibration was achieved, a lower layer node representing a well near the TW-1 well site was pumped at 450 gallons per minute (gal/min) for 1 month, 1 year, 5 years, and 10 years.

When this lower layer was stressed (pumped), the response was minimal. Within 1 month of pumping, the brine aquifer was drawn down about 23 feet at the pumping well. The longer pumping times had no affect on the drawdown, and the "cone of depression" decreased to a negligible amount within about 1 mile to the west of the pumping well and about 2 miles to the northeast. The steeper cone to the west may have reflected the closeness of the constant head boundary.

The drawdown computed for this discharge node is only about one-half that observed at well OW-3 during Reclamation's aquifer test in 1977. The reason for the difference in computed versus observed drawdown may be due to the lack of certainty in the input data to the model. The calibration coefficients and the physical geometry of the multiaquifer system are not known in any detail. The model was constructed as a general test of the known parameters. Any unknowns were based on professional judgment. During calibration of the model, it became apparent that it was very sensitive to minor changes in the input data. Since the input data were only generally known, an accurate output was not expected. However, the model was very helpful by providing a means to conceptualize the hydrogeologic system and for indicating how little is really known about the hydrogeology of the area.

The model also helped raise the question of whether a single 450-gal/min pumping well would be adequate for controlling the brine inflows to the river. The necessary "cone of depression" needed to control the brine leakage may not form along the river as desired. Also, because of vertical downward leakage of fresher water, it may be necessary to increase the amount of water pumped. The model had a vertical component of flow which reversed direction within the "cone of depression." Some of the water removed at the pumping node was from the upper layer. This is what was expected during Reclamation's aquifer test but did not show up in the drawdown plots. It may be that the 1977 aquifer test was much too short to reverse the vertical gradient. It is possible that with a longer period of pumping, the drawdown in the observation wells would have reflected this leakage.

Seismic Survey - Disposal Well Site Determination

In July 1984, Reclamation contracted with Grant Geophysical of Midland, Texas, to perform a deep Seismic Reflection Survey southeast of Logan. The HGC was asked to interpret these data and comment on the potential for deep well disposal of brine in this area (HGC 1984B). In summary, the analyses of the geophysical data led to the conclusion that the potential for deep well disposal of brine was high in an area about 5 miles southeast of Logan. The injection depth selected was the middle Abo Formation of Permian Age or possibly a large zone through the entire Abo and into the Sangre De Cristo Formation of Pennsylvanian Age. It was also determined that the injection zones were capped by a thick continuous anhydride bed, which should provide an adequate barrier to any potential upward leakage of injected brine.

Seismic Hazard

The Logan area is situated in zone 1 (minor damage) on the Seismic Risk Map of the Conterminous United States. The largest event ever recorded near Logan occurred in 1970 about 40 miles to the north-northeast and registered VI intensity on the Modified Mercalli Intensity Scale of 1931. [1/]

Based on the seismic history of the area, the project is in an area subject to minor seismic events, producing horizontal accelerations of less than

1/ Modified Mercalli Intensity Scale of 1931. This is an earthquake rating scale that evaluates actual physical sensations and damage or intensity. The scale ranges from I to XII, with intensity I being barely perceptible to people. An intensity VI earthquake would be noticeable to all people in the area and cause slight damage.

0.04 gravity with a 90-percent probability of not being exceeded in a 50-year period. It is not anticipated that the injection of brine into the subsurface will significantly change the seismicity of the area. The injection of water and brines in the nearby Panhandle of Texas has occurred for many years without inducing any known earthquakes. The potential project site is an area of low seismic activity and low seismic hazard.

CHAPTER V -

WELL PUMPING AND BRINE DISPOSAL BY DEEP-WELL INJECTION

Exploration and Development

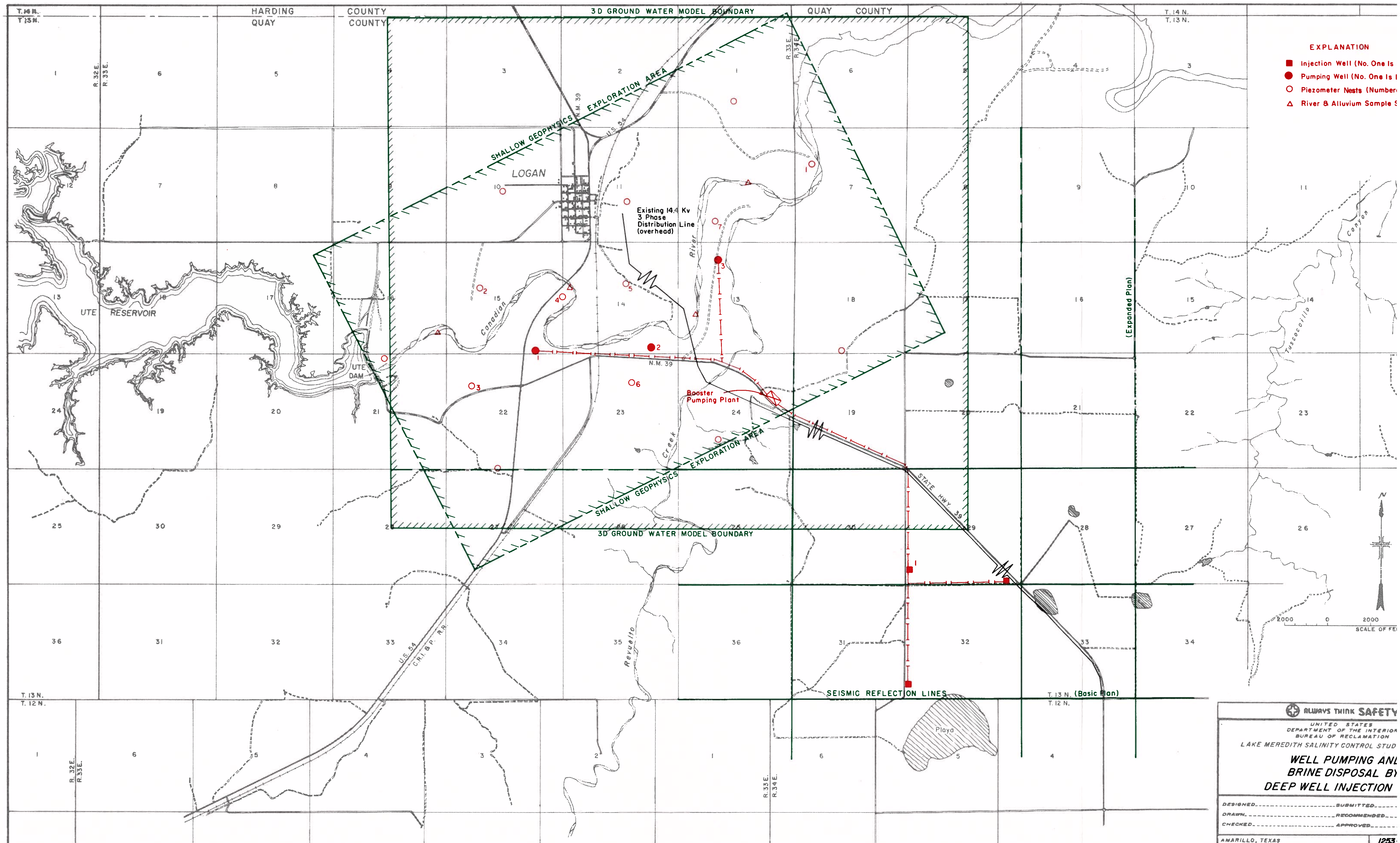
Interpretation of the hydrologic and geologic data available has led to the conclusion that natural Na-Cl brine seeps into the Canadian River near Logan, New Mexico. The source of this brine, which makes up a major portion of the Na-Cl entering Lake Meredith, is from upward leakage of water from the Permian through a complex network of fractures. Interception and control of this brine may be possible before it reaches and mixes with the surface water of the Canadian River.

In order to properly design, monitor, and operate a saline water interception and disposal program, certain key questions concerning the hydrology and geology of the project area have to be answered. The feasibility of the project is based on the success of two concepts: (1) interception of the brine without significant dilution and (2) injection of the brine using acceptable pressures and without serious plugging of the injection zone. Data are not available to adequately support these concepts, especially the latter where permeability and other properties of the injection zone, which are crucial, are not known. Until the concepts can be tested under operational conditions, the success of the project cannot be verified. A proposed project plan layout and details for collection of project design and operational data are presented in this chapter. The project plan is proposed at a basic and expanded level. The basic plan is for a pilot project with the minimum features required to operate the project and is designed to test some basic concepts of the feasibility for controlling the brine leakage. The expanded plan includes the cost of the basic plan plus additional costs for two production wells, two injection wells, seven piezometer nests, and related features--all or part of which may be required to adequately control brine leakage to the river should the basic plan not achieve the desired results.

After an evaluation of several alternative methods for brine removal and disposal, the plan that is judged most viable and acceptable to the sponsor for controlling brine leakage to the river is to pump the brine aquifer to lower the hydraulic head, thus reducing or eliminating the driving force controlling brine movement. The brine removed from the aquifer would then be transported by pipeline to a disposal area. Disposal is proposed to be by injection into a deep well completed in an acceptable receiving formation. The plan would require locating an appropriate site or sites for production wells, disposal wells, monitoring wells (piezometers), and stream sampling sites. The data requirements and project layout will be discussed for three interrelated hydrologic and geologic areas--the brine artesian aquifer, the shallow ground water system, and the injection zone.

Brine artesian aquifer

Three tentative sites have been selected for pumping the brine artesian aquifer (see drawing No. 1253-500-20). These sites were selected based on existing



HARDING
QUAY
COUNTY
COUNTY
QUAY COUNTY
3D GROUND WATER MODEL BOUNDARY
SHALLOW GEOPHYSICS EXPLORATION AREA
LOGAN
UTE RESERVOIR
UTE DAM
Canadian River
Revuelto Creek
Tuscocoillo Canyon
N.M. 39
U.S. 54
U.S. 54 C.R.I. & P. R.R.
STATE HWY 39
Existing 14.4 Kv 3 Phase Distribution Line (overhead)
Booster Pumping Plant
SEISMIC REFLECTION LINES
(Expanded Plan)
T. 13 N. (Basic Plan)
T. 12 N.
T. 14 N.
T. 13 N.
R. 32 E.
R. 33 E.
R. 34 E.
Playa
SCALE OF FEET
2000 0 2000
EXPLANATION
Injection Well (No. One Is
Pumping Well (No. One Is
Piezometer Nests (Number
River & Alluvium Sample S
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAKE MEREDITH SALINITY CONTROL STUD
WELL PUMPING AN
BRINE DISPOSAL B
DEEP WELL INJECTION
DESIGNED
SUBMITTED
DRAWN
RECOMMENDED
CHECKED
APPROVED
AMARILLO, TEXAS
1253

5. If the current Federal tax credits are renewed before they expire at the end of 1985, it may be desirable to enter into a power purchase agreement with a private company similar to that being negotiated by Pacific Gas and Electric and Southern California Edison for the large number of wind turbine projects currently operating in California. All construction and financing costs plus the performance risks are assumed by the developer and the private investors. The disadvantage would be that the operating entity would never own the wind turbine project and would not realize any savings after the project is paid off in 6 to 7 years.

6. The results displayed in tables V-3 and V-4 show that there are several other considerations in making the final decision beyond just the current cost of electricity charged by the local utility. The internal rate of return, using a life-cycle cost analysis, is usually the method used by private industry in making such decisions.

7. It would appear that the results of this preliminary study would warrant further consideration of windpower systems as a source of project power for the Lake Meredith Salinity Control Project.

Environmental Aspects

Riparian habitat

No significant impacts will result from the installation of the basic or expanded plan's physical facilities. Production and disposal wells and pipelines will be located on the upland, well out of the riparian habitats.

Terrestrial habitat

Terrestrial habitats and their associated wildlife will not be affected by either the basic or expanded plan. Edaphic conditions will not change sufficiently to affect the growth or distribution of vegetation, because neither the basic nor expanded plan will reduce the river's salt load by more than 70 percent and because of the salt already stored in the alluvium.

Aquatic habitat

In 1983, fishery and water quality studies were begun in the portion of the Canadian River between Ute Dam and Lake Meredith to determine the significance of lowering the salinity level of the Canadian River on aquatic habitat. In August 1983, conductivity readings (method of measuring salinity levels) and fish collections were made for the Texas portion of the Canadian River. Representatives from Reclamation, FWS, and the Texas Parks and Wildlife Department participated in the investigations. For this reach of the river, no statistically significant relationships were found between the abundance of any species and conductivity. The red shiner (*Notropis lutrensis*) showed a slight positive association with more saline water ($r = 0.40$).

Similar field studies were conducted by Reclamation, FWS, and NMDGF during November 1983 and July 1984 in the portion of the Canadian River between Ute Dam and the New Mexico-Texas border. Specimens were kept for analysis by NMDGF; however, the analyses are not yet available.

Threatened or endangered species

No threatened or endangered (T or E) species are expected to be affected by implementing either the basic or expanded plan for brine removal and disposal. The NMDGF has expressed concern over two species of fish--the Arkansas River shiner (*Notropis girardi*) and the speckled chub (*Hybopsis aestivalis tetranemus*), which are considered endangered in New Mexico. These species are of particular interest because of their continuing disappearance from many southwestern streams. They were examined for possible dependence on more saline water, either because of preference or because of competitive advantage over other species with lower salinity tolerances. Based on the Texas collections that included 29 collections of the Arkansas River shiner and 17 collections of the speckled chub, there was no relationship between conductivity and the abundance of these species ($r = 0.01$ and -0.10, respectively). Therefore, lowering the salinity level is not expected to affect these species.

Discharge considerations

As previously discussed, the saline inflow to the Canadian River contributes slightly less than 1 ft^3/s. Seepage from Ute Reservoir has averaged about 2 ft^3/s prior to the dam and spillway modification. This seepage rate is expected to be greater after the reservoir fills to its new conservation level. If the brine removal and disposal plan successfully removes all of the saline inflow to the river, the loss will probably be replaced by increased seepage from Ute Reservoir. If not, the plan could cause a small reduction in the size and number of pools present in the river during drought conditions.

None of the impacts discussed above are expected to significantly affect any fish species in the Canadian River.

<u>Remote sensing</u>

In 1983, Reclamation requested the EPA to obtain natural color aerial photography and multispectral scanner imagery for a 10-mile reach of the Canadian River channel below Ute Dam and Reservoir. The purpose of the aerial photography and imagery was to obtain information to inventory the area for possible sources of saline seeps and springs intruding into the Canadian River freshwater system. The EPA identified 35 possible saline seeps or springs. The actual presence of seeps or springs has not been determined at this time but should be verified before additional downstream remote-sensing evaluations are made.

It can be noted that there appears to be a greater number of potential saline seeps downstream of the Revuelto Creek confluence with the Canadian River. Actual volumes from these potential seeps have not been determined. Other studies conducted have shown that the major incoming brine flows are originating above the Revuelto Creek-Canadian River confluence. If the potential saline seeps are verified, additional analyses should be done to identify and locate other anomalies downstream of the 10-mile reach.

Cultural Aspects

No sites currently listed or eligible to be listed on the National Register of Historic Places are located within the potential project area. However, a 1983 record search of the Museum of New Mexico Laboratory of Anthropology files revealed that many prehistoric archeological sites are known along the terraces of the Canadian River. Two new sites (one historic and one prehistoric) were defined in 1983 by Reclamation staff who conducted a cultural resource survey over a portion of the area, and two previously defined sites were reassessed.

A cultural resource survey of the entire impact area of the project design should occur before any additional ground-disturbing activities are performed. Significant cultural resources impacts are not anticipated for either the basic or expanded plan. However, should surveys reveal that impacts to cultural resources could occur, appropriate procedures should be defined and implemented in coordination with the New Mexico State Historic Preservation Officer.

Suggested Procedural Steps for Plan Implementation

1. The CRMWA must obtain authority and funding for plan implementation;

2. File with appropriate State of New Mexico offices for drilling, pump testing, and injection permits;

3. Obtain/negotiate rights-of-way entry permits with landowners;

4. Reclamation to complete an environmental assessment;

5. Before any additional ground-disturbing activities are performed, a cultural resource survey of the site-specific impact area(s) should be completed;

6. Conduct additional seismic reflection work;

7. Drill and test disposal formations;

8. Complete disposal well (critical decision point--viability of brine disposal);

9. Analyze surface geophysics to define extent of brine aquifer (during this time, a ground water flow model should be programed);

10. Drill and complete piezometers in brine and Triassic aquifers--sample and monitor;

11. Drill and complete production well--sample and test;

12. Complete pipeline between production well and disposal well;

13. Drill and complete river alluvial piezometers and inventory saline seeps--sample;

14. Conduct long-term pump test;

15. Monitor water quality in river and piezometers;

16. Implement expanded plan, if needed; and

17. Monitor expanded plan.

CHAPTER VI - OTHER ALTERNATIVES CONSIDERED

The following alternative plans were evaluated and presented in Reclamation's April 1984 PFR. Copies of the PFR were provided to various interested entities for review and comment including the CRMWA and its member cities. For purposes of comparison, these alternative plans were based on the assumption that they would reduce the salinity level of Lake Meredith water, either in the reservoir or at the point of use, from 1,200 mg/L to about 800-900 mg/L for TDS. None of these alternatives were found acceptable for the reasons cited under each.

Well Pumping and Brine Disposal Pond

This plan could reduce brine seepage into the river by lowering the potentiometric surface of the aquifer through pumping. The discharge from the well would be transported by pipeline to a playa lake for storage and evaporation.

The production well would be located in Quay County, New Mexico, downstream of Ute Dam and south of the Canadian River. The well would be sited to accomplish the lowering of the artesian head of the saline aquifer at the point of discharge into the Canadian River.

A potential brine storage and evaporation site selected for this study is within a playa located southeast of the production well site. A 230-acre area, lined with a 20-mil polyvinyl-chloride membrane liner and enclosed with a dike, was used for estimating purposes. A system of drainpipes with risers under the liner material and eight observation wells around the perimeter are provided to monitor any seepage. Rights-of-way required for the disposal site are estimated at 350 acres. Some 2.7 miles of fencing would also be required to enclose the area.

The annual amount of salts that would accumulate through evaporation is estimated to be about 34,500 tons. It is estimated that the storage site has the capacity to contain 100 years of salt and sediment deposits in addition to the brine water.

Delivery of the brine from the production well to the surface disposal site would be accomplished by a pipeline and two pumping plants. The pipeline would have a diameter of 12 inches and a length of about 36,750 feet (7 miles). The pipeline route from the production well would be easterly across open rangeland to State Highway 39, southeast along Highway 39, and then south to the playa.

Approximately 42 acres of easement right-of-way would be required using a width of 50 feet. The first pumping plant would be located at the production well; the second plant would be about at the midpoint or mile station 3.4 on the pipeline. Each plant would have electrically operated pumps rated at a capacity of 450 gal/min. The pumping plant at the well would have a total dynamic head of 178 feet, and the second pumping plant would have a total dynamic head of 182 feet.

The October 1984 construction cost was estimated to be $13,900,000. This includes 15 percent for unlisted items, 30 percent for contingencies, and 25 percent for indirect costs. Annual OMR&E costs for this surface discharge-surface evaporation disposal plan would be $43,000.

The CRMWA and its member cities support the concept of eliminating the salinity problem at its source (near the Logan area) before the brines flow into Lake Meredith. However, the construction cost for this alternative if it were to include evaporation ponds as a means of salt disposal is considered to be too costly. The cost of evaporation ponds represents about 53 percent of the construction cost for this alternative. Indications were that Reclamation should evaluate cheaper brine disposal alternatives to reduce the project cost.

Hydrostatic Control Pool

A diversion dam-type structure located on the Canadian River below the confluence of the Revuelto Creek could be constructed to provide a hydrostatic control pool over the brine seepage areas. It is assumed that 10 feet of head in the vicinity of test well (TW-1) 1/ would suppress the seepage areas, that seepage would not recur downstream from the structure, and that the brine seepage area is confined upstream from the confluence of the Canadian River and Revuelto Creek.

To produce a hydrostatic head of 10 feet at TW-1, the crest of the uncontrolled structure would be at elevation 3,685. The riverbed at the proposed structure site was assumed to be at elevation 3,655. Bedrock is probably 50 feet below the riverbed.

1/ Test well No. 1 was drilled during previous appraisal investigations; its location is just downstream from the intersection of the Canadian River and U.S. Highway 54 near Logan, New Mexico.

A pool with a normal water-surface elevation of 3,685 would require about 10,800 acre-feet of water with a surface area of 660 acres.

The dam structure cost was estimated using a sheet piling cutoff protected with riprap and an outlet works. The sheet piling and upstream-downstream embankment buttresses would extend 30 feet above the streambed and down about 50 feet to bedrock. A concrete cap would protect the crest of the sheet piling, and an outlet works structure would be provided to drain the reservoir.

Approximately 990 acres of rights-of-way would need to be purchased. The only known improvements are high-level railroad and highway bridges, and it was assumed that relocation would not be required. The October 1984 construction cost was estimated to be $7,700,000. This includes 15 percent for unlisted items, 30 percent for contingencies, and 25 percent for indirect costs. Annual OMR&E costs would be about $770,000.

In order to provide sufficient head to suppress brine flows effectively, the crest of the proposed overflow dam would have to be set at elevation 3,685 feet mean sea level. The backwater effects would adversely affect the existing Ute Dam functions during normal operations and at flood (during spills) stage. It is not known whether the suppressed brine would eventually start seeping out in other adjacent areas or further downstream. The cost, overall effectiveness, and reliability questions are also of concern.

Alluvial Pumping

The plan for an infiltration gallery pumping system consists of an excavated infiltration trench with perforated pipe installed as the collection element, a water collection sump, and a sump pumping plant. The perforated pipe would be laid in the river alluvium to intercept the rising brine as it enters the channel alluvium. The brine would flow into the sump and be pumped to an evaporation pond or injected in a deep well.

The main disadvantage of this concept is that most of the "freshwater" in the alluvium would be lost through the collection and disposal process.

This brine control plan was abandoned for several reasons. First, water pumped from the alluvium may contain a high total suspended solids content, which would require a filtering plant to prevent clogging of the injection well. This would increase the cost of pumping substantially. Second, this pumping program would probably remove the base flow of the Canadian River, leaving a dry streambed for several miles. The associated environmental problems such as wildlife habitat destruction and legal problems with disruption of existing water rights were also considered unacceptable.

Blending Ground Water With Lake Meredith Water

This plan considers blending available Texas High Plains ground water supplies with Lake Meredith water to achieve the desired quality. The availability of ground water for M&I purposes varies considerably in the study area; some cities do not have locally available ground water of good quality for use as a blending supply.

The TDS concentration in ground water varies from 300 mg/L north of Amarillo to about 500 mg/L at the southern end of the study area. Some CRMWA user cities are already blending to improve quality and to meet peaking requirements.

To fully evaluate the blending concept, it is necessary to examine the long-term water demands of the member cities and how these demands will be met. Local projections for growth in the CRMWA area indicate that M&I water needs will increase from 107,600 acre-ft/yr in 1980 to about 213,700 acre-ft/yr by the year 2040. The estimated yield of Lake Meredith, as predicted in the Canadian River DPR (1960), is 103,000 acre-ft/yr. However, for the period 1977-1981, deliveries averaged only 72,100 acre-ft/yr. Based on the 103,000 acre-foot yield, a deficit supply occurs in 1980 and increases to a deficit of about 110,000 acre-feet by the year 2040. Since surface water supplies are extremely limited, ground water appears to be the most likely alternative source for some CRMWA member cities; i.e., Amarillo. However, the city of Lubbock has indicated that they do not have ground water locally available for blending. Importation of water from outside the study area is also a possibility.

Table VI-1 (columns 1, 2, and 3) provides a summary of the water demands versus supply capabilities for the CRMWA area.

To estimate the quantities of ground water needed for blending to achieve better quality, it is assumed that well water of 300 mg/L TDS would be available to blend with 1,200 mg/L of Meredith water. Therefore, to achieve blended water

Table VI-1

Canadian River Project Long-Range Water Needs and Ground Water Blending with Lake Meredith Water

(acre-feet/year)

Year	Total Demand 11 Cities 1/	Lake Meredith Supply 2/	Ground Water Needed to Meet Demand 3/	Ground Water Needed for Blending 4/	Net Ground Water Needed for Blending 5/
1980	107,600	103,000	4,600	47,800	43,200
1990	120,400	103,000	17,400	53,800	36,400
2000	135,300	103,000	32,300	60,100	27,800
2010	156,300	103,000	53,300	69,500	16,200
2020	180,600	103,000	77,600	80,300	2,700
2030	197,300	103,000	94,300	87,700	-6,600
2040	213,700	103,000	110,700	95,000	-15,700

1/ Based on actual projections by five major cities plus 8 percent for other cities.
2/ Firm yield of Lake Meredith - DPR.
3/ Column 1 minus column 2.
4/ Based on a ratio of four parts well water to five parts lake water to achieve 800 mg/L TDS.
5/ Column 4 minus column 3.

of about 800 mg/L TDS, four parts (44 percent) of well water must be mixed with five parts (56 percent) of Lake Meredith water. More ground water, however, would be required to achieve an average level of 350 mg/L for Na, Cl, and SO_4.

Based on a total water use by the 11 member cities in 1980 of 107,600 acre-feet, 59,800 acre-feet of Lake Meredith water would be needed for mixing with 47,800 acre-feet of ground water to achieve a quality of about 800 mg/L TDS.

The 47,800 acre-feet of ground water used for blending in 1980 would be the maximum amount needed since demand requirements are beginning to become the dominant purpose. By the year 2020, 77,600 acre-feet of additional ground water would be needed to meet demand while only 2,700 acre-feet is needed for blending. At a point in time, somewhere between the years 2020 and 2030, the need to use ground water for meeting demand overcomes the need to blend for a quality purpose only.

Table VI-1 (columns 3, 4, and 5) shows the relationship between demand and blending needs for supplemental ground water.

The following criteria were used to estimate the cost of a plan to supply ground water for blending purposes:

1. New wells and appurtenances, collection systems, and transmission lines would have a base cost of $488,000 per million gallons per day (Mgal/d) (October 1984). This cost is based on a plan that Amarillo has for obtaining

water from Carson County and does not take into account any existing capability to supply ground water.

2. Water rights would be leased for $0.20 (October 1984) per 1,000 gallons. This cost includes 10 percent for administration.

3. Annual OMR&E cost is $0.35 per 1,000 gallons.

4. Unlisted items (10 percent), contingencies (25 percent), and administrative (15 percent) costs were added to the base cost of new wells and appurtenances, collection system, and transmission lines.

Constructions Cost	October 1984 Cost
38.5 Mgal/d 1/ x $488,000/Mgal/d =	$18,790,000
Unlisted items (10%±)	1,890,000
	$20,680,000
Contingencies (25%±)	5,120,000
	$25,800,000
Administrative cost (15%±)	4,200,000
Construction cost (October 1984)	$30,000,000
Annual water rights cost	
14,074,000 (1,000 gal/yr) x $0.20/1,000 gal)	$2,930,000
Annual OMR&E	
14,074,000 (1,000 gal/yr) x $0.35/1,000 gal)	$5,300,000

1/ Amount of ground water needed to meet 1980 net blending needs, see table VI-1.

This concept is not acceptable. When legislation was sought by CRMWA to seek a solution to the salinity problem, it was never intended to blend existing supplies with ground water as a solution to the problem. The CRMWA is restricted to the delivery of Lake Meredith waters, with acquisition or use of ground water being specifically prohibited. As stated previously, some cities in the Texas Panhandle do not have locally available ground water supplies of good reliable quantity and quality. For example, the city of Lubbock does not have local ground water available for blending. Lubbock is presently in the process of developing another surface water source with similar characteristics to the water from Lake Meredith.

Desalination

This alternative provides for desalting Lake Meredith water along the Main Aqueduct. The most desirable place to do this appears to be at the bifurcation of the Main Aqueduct and the East Aqueduct, near Pumping Plant No. 2. The aqueduct has a capacity to deliver a steady rate of 92 Mgal/d which equals the firm yield of the reservoir.

Disposal of the desalting plant effluent could be accomplished by a surface evaporation pond or deep-well injection. Approximately 6,100 acre-feet of brine effluent would be discharged annually from one Reverse Osmosis (RO) plant.

Approximately 2,240 acres of private land would be needed for the plant and disposal pond.

A cost estimate (indexed to October 1984 price level) was prepared for an RO plant using the computer program based on "Desalting Handbook for Planners" by the Office of Saline Water and Reclamation, May 1972. The estimating data limits the capacity of the plant to 50 Mgal/d. The product water from a RO plant can range from 100 to 500 mg/L TDS. Blending product water from one RO plant with 1,200 mg/L TDS lake water would result in about 800-900 mg/L TDS.

The following tabulation presents the costs of one 50 Mgal/d RO plant:

Construction costs (October 1984)		Annual OMR&E (October 1984)	
Desalting plant	$66,200,000	Operation and Maintenance	$ 2,470,000
Evaporation ponds	32,000,000	Chemicals	2,380,000
Site development	3,900,000	Replacement	2,600,000
Owner's expenses	7,500,000	Energy (electricity @ $0.045/kWh)	19,750,000
Land	1,200,000		
Cost--one RO plant	$110,800,000	Cost--one RO plant	$27,200,000

The cost of the desalination process exceeds the ability and willingness of the project sponsor to pay.

Table VI-2 provides a cost and benefit summary for the well pumping and brine disposal pond, desalination, blending, and hydrostatic control alternatives. The net beneficial effects for these alternatives would be negative since the B/C ratio is less than unity.

Table VI-2
Cost and Benefit Summary for Unacceptable Alternatives
(October 1984 Prices)

	Well Pumping and Brine Disposal Pond	Desalination	Blending Ground Water with Lake Meredith Water	Hydrostatic Control Pool
Construction Cost	$13,900,000	$110,800,000	$19,080,000 1/	$7,700,000
Interest during construction 2/ (8.375%)	582,063	14,550,737	798,975	322,438
Total Investment	$14,482,063	$125,350,737	$19,878,975	$8,022,438
Average Annual Investment 3/	$ 1,213,262			$ 672,094
Average annual investment formulated to coincide with the time (by the 12th year) when benefits of the most likely alternative are expected to occur. The 12 years is an established point within a range of 6 to 18 years.		$ 3,998,293	$ 7,415,706	
OMR&E	$ 43,000	$ 27,300,000 (includes chemicals)	$ 2,562,614 4/ (includes water rights)	$ 770,000
Total Average Annual Costs	$ 1,256,262			$1,442,094
Total average annual cost formulated to coincide with the time (by the 12th year) when benefits of the most likely alternative are expected to occur.		$31,298,293	$ 9,978,320	
Total Average Annual Benefits	$1,256,262			$1,442,094
Total average annual benefits formulated to coincide with the time (by the 12th year) when benefits of the most likely alternative are expected to occur.		$31,298,293	$9,978,320	
Benefit/Cost Ratio (benefits based on the cost of the most likely alternative				
Basic Plan: $426,704	.34:1	.01:1	.04:1	.30:1
Expanded Plan: $997,968	.79:1	.03:1	.10:1	.69:1

1/ Amount to construct a source of supply to reach a quality level of 800 to 900 mg/L; about $11,000,000 is the current cost for blending ground water to meet current demands.
2/ One-year construction period except for the desalination method which has a 3-year construction period.
3/ Amortized for 100 years at 8.375 percent.
4/ Annual water rights of $2,930,000 plus annual OMR&E of $5,300,000 divided by 30,400 acre-feet of water required for blending for quality during years 1997-2023 times total acre-feet 11,339 = $2,562,614 for annual OMR&E plus cost for water rights.

CHAPTER VII - NO ACTION

If no action is taken, the quality of the water supply in the stream system in New Mexico-Texas will continue to decline; and the saline taste will persist for domestic users. In addition, about 200 acres of water-right land east of Logan, New Mexico, and adjacent to the Canadian River will be left under present status (not irrigated) due to high salt concentrations in the river water. Limited use of the Canadian River for livestock watering will also continue.

If no action is taken beyond this point, some provision will be required to properly clean up the study area. The alluvial piezometers and staff gauges can be removed by pulling them out of the sand with a winch and cable. The deep wells would have to be redrilled to remove the casing, then cemented to the surface. It is also important to properly reseal the deeper drill holes. Holes DH-1 and DH-2 were only cased to bedrock so they may presently be providing a route for brine leakage to the alluvium (other wells may be leaking now or in the near future). The roads leading to the drill and sampling sites may have to be reseeded, depending upon the wishes of the landowner.

BIBLIOGRAPHY

(Algermissen 1969) - Algermissen, S. T., "Seismic Risk Studies in the United States," Proceedings, Fourth World Conference on Earthquake Engineering, Santiago, Chili, 1969.

(Algermissen and Perkins 1976) - (Algermissen, S. T., and D. M. Perkins, "A Probablistic Estimate of Maximum Acceleration in Rock in the Contiguous United States," Open File Report 76-416, U. S. Geological Survey, 1976.

(Andersen and Kleinman 1978) - Andersen, Jay C., and Alan P. Kleinman, "Salinity Management Options for the Colorado River," Utah State University, Logan, Utah, 1978.

(Arrow 1966) - Arrow, K. J., "Discounting and Public Investment Criteria," Water Resources Research, volume 6, No. 3, April 1966.

(Arrow and Lind 1970) - Arrow, K. J., and R. C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," American Economic Review, June 1970.

(Austin 1980) - Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Water Supply Systems, Austin, Texas, 1980.

(Austin 1981) - "Texas Surface Water Quality Standards," LP-71, Austin, Texas 1981.

(Bassett and Bentley 1983) - Bassett and M. E. Bently, "Deep Brine Aquifers in the Palo Duro Basin: Regional Flow and Geochemical Constraints," Bureau of Economic Geology, University of Texas, 1983.

(Berkstresser and Mourant 1966) - Berkstresser, C. F., and W. A. Mourant, "Ground-Water Resources and Geology of Quay County, New Mexico," New Mexico Bureau of Mines and Mineral Resources, Ground Water Report 9, 1966.

(Bower and Allen 1968) - Bower, Blair T. and Allen V. Kneese, Managing Water Quality: Economics, Technology, Institutions, The Johns Hopkins Press, Baltimore, Maryland, 1968.

(Dorfman 1965) - Dorfman, R. ed., "Measuring Benefits of Government Investments," Brookings Institute, Washington, D.C., 1965.

(Eckstein 1958) - Eckstein, O., Water Resources Development: The Economics of Project Evaluation, Harvard University Press, Cambridge, Massachusetts, 1958.

(EHA 1982) - "Long-Term Chlorides Accumulation in Lake Meredith," Espey, Huston and Associates, Inc., Austin, Texas, 1982.

(EPA 1975) - Interim Primary Drinking Water Regulations, Environmental Protection Agency, 1975.

(EPA 1976) - "Quality Criteria for Water," U.S. Environmental Protection Agency, Washington, D.C., 1976.

(Hanke and Walker 1974) - Hanke, Steve H. and Richard A. Walker, "Benefit-Cost Analysis Reconsidered: An Evaluation of the Mid-State Project," Water Resources Research, volume 10, No. 5, October 1974.

(Howe 1976) - Howe, Charles W., Benefit-Cost Analysis for Water System Planning, American Geophysical Union, Washington D.C., 1976.

(HGC 1984A) - "Study and Analysis of Regional and Site Geology Related to Subsurface Salt Dissolution Source of Brine Contamination in Canadian River and Lake Meredith, New Mexico-Texas, and Feasibility of Alleviation or Control," Hydro Geo Chem, Inc., Tucson, Arizona, May 1984.

(HGC 1984B) - "Analyses of Geophysical Data to Examine the Feasibility of Deep-Well Injection of Brine Near Logan, New Mexico, Draft Report," Hydro Geo Chem, Inc., Tucson, Arizona, December 1984.

(HGC 1984C) - "Geologic Study Related to Salt Pollution, Lake Meredith Salinity Study, Texas-New Mexico," Hydro Geo Chem, Inc., Tucson, Arizona, January 1984.

(Koenig 1958) - Koenig, L., "Disposal of Saline Water Conversion Brines--An Orientation Study," U.S. Department of the Interior, Office of Saline Water, Research and Development, Washington, D.C., 1958.

(Krutilla 1961) - Krutilla, J. V., "Welfare Aspects of Benefit-Cost Analysis," Resources for the Future, Inc., Reprint No. 29, 1961.

(Maass 1966) - Maass, A., "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions," Quarterly Journal of Economics, No. 80, May 1966.

(Margolis 1959) - Margolis, J., "The Economic Evaluation of Federal Water Resource Development," American Economic Review, No. 49, 1959.

(McBean and Rovers 1984) - McBean, E. A., and F. A. Rovers, "Alternatives for Assessing Significance of Changes in Concentration Levels," NWWA Ground Water Monitoring Review, vol. 64, No. 3, 1984.

(Mishan 1976) - Mishan, E. J., Cost-Benefit Analysis, Praeger, New York, 1976.

(MJA 1972) - Consulting Report to the Canadian River Municipal Water Authority, Mason-Johnston and Associates, Inc., 1972.

(MJA 1972) - "Interpretation of Data Relative to Water Quality in the Base Flow of the Canadian River Upstream of Lake Meredith and Extending Westward to Conchas Dam, New Mexico," Mason-Johnson and Associates, Incorporated, Dallas, Texas, April 1972.

(MNMLA) - Museum of New Mexico Laboratory of Anthropology, Archeological Site Files.

(Sassone and Schaffer 1978) - Sassone, Peter G. and William A. Schaffer, Cost-Benefit Analysis, A Handbook, Academic Press, New York, New York, 1978.

(TDH 1978) - Rules and Regulations for Public Water Systems, Texas Department of Health, Water Hygiene Division, Austin, Texas, 1978.

(TDH 1980) - Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Water Supply Systems, Texas Department of Health, Water Hygiene Division, Austin, Texas, 1980.

(TDH 1983) - "Water Chemistry," Texas Department of Health, Water Hygiene Division, Austin, Texas, 1983.

(TDWR 1980) - "The State of Texas Water Quality Inventory," Pursuant to Section 305(b) Federal Water Pollution Control Act (as amended) LP-50, Texas Department of Water Resources, Austin, Texas, 1980.

(TDWR 1981) - "Texas Surface Water Quality Standards," LP. 71, Texas Department of Water Resources, Austin, Texas, 1981.

(Tresch 1981) - Tresch, Richard W., Public Finance: A Normative Theory, Business Publications, Incorporated, Plano, Texas, 1981.

(TWQB 1970) - "Preliminary Report, Canadian River Project No. 527, Canadian River Water Quality Survey, Logan, New Mexico, to Tascosa, Texas," Texas Water Quality Board, 1970.

(TWQB 1970) - "Canadian River Water Quality Survey - Logan, New Mexico, to Tascosa, Texas," Texas Water Quality Board, Austin, Texas, 1970.

(USBR 1960) - "Definite Plan Report, Canadian River Project, Texas," U.S. Department of the Interior, Bureau of Reclamation, Amarillo, Texas, 1960.

(USBR 1960) - "Appendixes to Definite Plan Report, Canadian River Project, Texas," volume I, appendix B, U.S. Bureau of Reclamation, Amarillo, Texas, 1960.

(USBR 1976) - "Report on Electrical Resistivity and Seismic Refraction Surveys, Canadian River, Lake Meredith Salinity Study," U.S. Bureau of Reclamation, Engineering and Research Center, Denver, Colorado, 1976.

(USBR 1979) - "Lake Meredith Salinity Study, Appraisal-Level Investigation, Canadian River Texas-New Mexico," U. S. Bureau of Reclamation, Amarillo, Texas, 1979.

(USBR 1981) - "Colorado River Water Quality Improvement Program, Saline Water Use and Disposal Opportunities," Special Report, U.S. Department of the Interior, Bureau of Reclamation, Amarillo, Texas, September 1981.

(USBR 1984) - "Preliminary Study of Windpower and Solarpower Systems for Project Power, Lake Meredith Salinity Control Project," U.S. Bureau of Reclamation, Engineering and Research Center, Division of Research and Laboratory Services, Denver, Colorado, November 1984.

(USBR 1984) - "Preliminary Findings Report, Lake Meredith Salinity Control Project, Texas-New Mexico," U.S. Department of the Interior, Bureau of Reclamation, Amarillo, Texas, April 1984.

(USDI 1972) - Federal Reclamation and Related Laws Annotated, volume II, U.S. Department of the Interior, U.S. Government Printing Office, Washington, D.C., 1972.

(USDI 1972) - Desalting Handbook for Planners, U.S. Department of the Interior, Bureau of Reclamation and Office of Saline Water, U.S. Government Printing Office, Washington, D.C., 1972.

(USDI 1980) - "Colorado River Salinity: Economic Impacts on Agricultural, Municipal, and Industrial Users," U.S. Department of the Interior, Water and Power Resources Service, Colorado River Water Quality Office, Engineering and Research Center, Denver, Colorado, December 1980.

(USDI 1983) - Reclamation Instructions, Series 110, Parts 112 and 116, U.S. Department of the Interior, Bureau of Reclamation, U.S. Government Printing Office, Washington, D.C., 1983.

(USGS 1961-1968) - Quality of Surface Waters of the U.S., Water Supply Papers 1573, 1644, 1744, 1884, 1944, and 1950, parts 7 and 8 (Water Years 1958-1963), U. S. Geological Survey, 1961-1968.

(USPHS 1962) - Drinking Water Standards, U.S. Public Health Service Publication No. 956, U.S. Public Health Service, 1962.

(USWRC 1983) - Principles and Guidelines for Water and Related Land Resource Planning, U.S. Water Resources Council, U.S. Government Printing Office, Washington, D.C., 1983.

ATTACHMENTS

ATTACHMENT A - CONSTRUCTION COST ESTIMATES

TABLE A-1 - BASIC PLAN
TABLE A-2 - EXPANDED PLAN

7-1482 (5-78)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

BASIC PLAN

CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-1
Project Cost Estimate
(Basic Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04				DEEP WELLS										
				Lake Meredity Salinity Study is located in New Mexico about 1/2 mile south of the city of Logan and about 1 mile east of Ute Dam in Quay County. The basic plan would consist of 1 production well (500 ft. Total Depth [TD]), 1 injection well (5,000 ft. TD), 7 observation wells (500 ft. each TD), and about 4 miles of 12-inch pressure pipe.										
	01			DESIGN DATA INVESTIGATIONS								219,000	55,000	274,000
		092		Investigations							219,000			
			1	Seismic Reflection Survey	20	miles	7,500	150,000						
			2	Resistivity/Electromagnetic Survey	25	days	1,000	25,000						
				Subtotal				175,000						
				Contingencies (25 percent±)				44,000						
				Field Cost 04.01.092				219,000						
				Other Costs (25 percent±)				--					(55,000)	
	02			DEEP WELLS								30,000	8,000	38,000
		120		Clearing Lands - Archeology							30,000			
			1	Archeology survey and mitigation	Lump sum	l.s	l.s	30,000						
				Field Cost 04.02.120				30,000						
				Other Costs (25 percent±)									(8,000)	

GPO 836-819

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

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BASIC PLAN CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-1 (Con.)
Project Cost Estimate
(Basic Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
	1			2	3		4		5		6	7	8	9
04				DEEP WELLS (continued)										
	03			PRODUCTION WELL (1 WELL)								329,000	82,000	411,000
		100		Land and Rights							5,000			
			1	Acquiring land and rights				5,000						
				Field Cost 04.03.100				5,000						
				Other Costs (25 percent±)									(1,000)	
		130		Structures and Improvements							269,000			
			1	Mobilization and demobilization	Lump sum	ls	ls	50,000						
			2	Drill rig operation (1-500 ft. T.D.)	5	day	4,500	22,500						
			3	Water	Lump sum	ls	ls	1,000						
			4	Drill bits	Lump sum	ls	ls	5,000						
			5	Rental equipment	Lump sum	ls	ls	3,000						
			6	Mud and chemicals	Lump sum	ls	ls	5,000						
			7	Consultant	Lump sum	ls	ls	3,000						
			8	Furnishing and setting 20-inch conductor casing in 26-inch hole and cementing to surface	35	lin ft	170.00	5,950						
			9	Furnishing and setting 12-inch casing in 15-inch hole and cementing to surface	400	lin ft	70.00	28,000						
			10	Furnishing and setting 12-inch slotted casing in 16-inch hole	100	lin ft	60.00	6,000						
			11	Core drilling	400	lin ft	60.00	24,000						
			12	Gravel pack	Lump sum	ls	ls	5,000						
			13	Acid	Lump sum	ls	ls	5,000						
			14	Completion unit	Lump sum	ls	ls	3,000						
			15	Wellhead equipment	Lump sum	ls	ls	20,000						
			16	Borehole geophysical logging	Lump sum	ls	ls	5,000						
			17	Packer	Lump sum	ls	ls	2,500						
			18	Miscellaneous control valves	Lump sum	ls	ls	10,000						
			19	Allowance for unlisted items	Lump sum	ls	ls	20,050						
				Subtotal				224,000						
				Contingencies (20 percent±)				45,000						
				Field Cost 04.03.130				269,000						
				Other Costs (25 percent±)									(67,000)	

GPO 838-812

7-1488 (5-78)
Bureau of Reclamation
Formerly Basic Estimate DO-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

BASIC PLAN CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-1 (Con.)
Project Cost Estimate
(Basic Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

Property Class	Identified Property	Plant Account	Pay Item	Description	Quantity	Unit	Labor and Materials by Contractor: Unit Price	Labor and Materials by Contractor: Amount	Labor and Materials by Government: Unit Price	Labor and Materials by Government: Amount	Field Cost: Plant Account	Total Field Cost: Identified Property	Other Costs: Identified Property	Total Cost: Identified Property
1				2	3		4		5		6	7	8	9
04	03			PRODUCTION WELL (continued)										
		140		Roads and Road Structures							18,000			
			1	Access road and site preparation	Lump sum	ls	ls	15,000						
				Subtotal				15,000						
				Contingencies (20 percent±)				3,000						
				Field Cost 04.03.140				18,000						
				Other Costs (25 percent±)									(5,000)	
		160		Pumps and Prime Movers							16,000			
			1	Pump - 450 gpm and 40 hp motor	Lump sum	ls	ls	8,000						
			2	Manifolds and valves	Lump sum	ls	ls	4,000						
			3	Allowance for unlisted items	Lump sum	ls	ls	1,000						
				Subtotal				13,000						
				Contingencies (20 percent±)				3,000						
				Field Cost .04.03.160				16,000						
				Other Costs (25 percent±)									(4,000)	
		170		Accessory Electrical Equipment							16,000			
			1	Control panel	Lump sum	ls	ls	12,000						
			2	Allowance for unlisted items	Lump sum	ls	ls	1,000						
				Subtotal				13,000						
				Contingencies (20 percent±)				3,000						
				Field Cost 04.03.170				16,000						
				Other Costs (25 percent±)									(4,000)	

GPO 838-513

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

BASIC PLAN

CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-1 (Con.)
Project Cost Estimate
(Basic Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04	03			PRODUCTION WELL (continued)										
		199		Miscellaneous Installed Equipment							5,000			
			1	Miscellaneous electrical equipment	Lump sum	ls	ls	4,000						
				Subtotal				4,000						
				Contingencies (20 percent±)				1,000						
				Field Cost 04.03.199				5,000						
				Other Costs (25 percent±)									(1,000)	

7-1488 (5-78)
Bureau of Reclamation
Formerly Basic Estimate DC-1

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BASIC PLAN CONSTRUCTION COST ESTIMATE

Planning Estimate

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Project Cost Estimate
(Basic Plan)

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PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04				DEEP WELLS (continued)										
	04			INJECTION WELL (1 WELL)								1,043,000	264,000	1,307,000
		100		Land and Rights							5,000			
			1	Acquiring land and rights	Lump sum	ls	ls	5,000						
				Field Cost 04.04.100				5,000						
				Other Costs (25 percent±)									(1,000)	
		130		Structures and Improvements							880,000			
			1	Mobilization and demobilization	Lump sum	ls	ls	65,000						
			2	Drill rig operation (1-5,000 ft TD)	20	day	4,500	90,000						
			3	Water	Lump sum	ls	ls	2,500						
			4	Drill bits	Lump sum	ls	ls	20,000						
			5	Rental equipment	Lump sum	ls	ls	8,000						
			6	Mud and chemicals	Lump sum	ls	ls	30,000						
			7	Consultant	Lump sum	ls	ls	15,500						
			8	Furnishing and setting 20-inch conductor casing in 26-inch hole and cementing to surface	60	lin ft	170.00	10,200						
			9	Furnishing and setting 13 5/8-inch casing in 18-inch hole and cementing to surface	1,500	lin ft	30.00	45,000						
			10	Furnishing and setting 9 5/8-inch casing in 12-inch hole and cementing to surface	4,000	lin ft	20.00	80,000						
			11	Furnishing and setting 9 5/8-inch slotted casing	1,000	lin ft	25.00	25,000						
			12	Furnishing and setting 5-inch tubing	5,000	lin ft	6.00	30,000						
			13	Borehole geophysical logging	Lump sum	ls	ls	25,000						
			14	Wellhead equipment	Lump sum	ls	ls	20,000						
			15	Packer	Lump sum	ls	ls	3,500						

(continued)

7-1482 (5-72)
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1				2	3		4		5		6	7	8	9
04	04			INJECTION WELL (continued)										
		130		Structures and Improvements (continued)										
			16	Miscellaneous control valves	Lump sum	ls	ls	15,000						
			17	Completion unit	Lump sum	ls	ls	15,000						
			18	Gravel Pack	Lump sum	ls	ls	25,000						
			19	Acid	Lump sum	ls	ls	25,000						
			20	Core drilling	2,000	in ft	60.00	120,000						
			21	Allowance for unlisted items	Lump sum	ls	ls	66,300						
				Subtotal				736,000						
				Contingencies (20 percent±)				144,000						
				Field Cost 04.04.130				880,000						
				Other Costs (25 percent±)									(222,000)	
		140		Roads and Road Structures							18,000			
			1	Access road and site preparation	Lump sum	ls	ls	15,000						
				Subtotal				15,000						
				Contingencies (20 percent±)				3,000						
				Field Cost 04.04.140				18,000						
				Other Cost (25 percent±)									(5,000)	
		160		Pumps and Prime Movers							126,000			
			1	Pump - 150 gpm with 60 hp motor	3	ea	21,100	63,300						
			2	Valves and manifolds	Lump sum	ls	ls	31,700						
			3	Allowance for unlisted items	Lump sum	ls	ls	10,000						
				Subtotal				105,000						
				Contingencies (20 percent±)				21,000						
				Field Cost 04.04.160				126,000						
				Other Cost (25 percent±)									(32,000)	

7-1488 (6-72)
Bureau of Reclamation
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INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

BASIC PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

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Project Cost Estimate
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OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04	04			INJECTION WELL (continued)										
		170		Accessory Electrical Equipment							8,000			
			1	Control panels	Lump sum	ls	ls	6,000						
			2	Allowance for unlisted items	Lump sum	ls	ls	1,000						
				Subtotal				7,000						
				Contingencies (20 percent±)				1,000						
				Field Cost 04.04.170				8,000						
				Other Cost (25 percent±)									(2,000)	
		199		Miscellaneous Installed Equipment							6,000			
			1	Miscellaneous electrical equipment	Lump sum	ls	ls	5,000						
				Subtotal				5,000						
				Contingencies (20 percent±)				1,000						
				Field Cost 04.04.199				6,000						
				Other Costs (25 percent±)									(2,000)	

7-1482 (5-72)
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1				2	3		4		5		6	7	8	9
04				DEEP WELLS (continued)										
	05			OBSERVATION WELLS (7 WELLS)								289,000	72,000	361,000
		100		Land and Rights							7,000			
			1	Acquiring land and rights	Lump sum	ls	ls	7,000						
				Field Cost 04.04.100				7,000						
				Other Costs (25 percent±)									(2,000)	
		130		Structures and Improvements							265,000			
			1	Mobilization and demobilization	Lump sum	ls	ls	18,000						
			2	Drill rig (7-500 ft TD)	21	days	2,000	42,000						
			3	Water	Lump sum	ls	ls	2,500						
			4	Drill bits	Lump sum	ls	ls	10,000						
			5	Rental equipment	Lump sum	ls	ls	5,000						
			6	Mud and chemicals	Lump sum	ls	ls	15,000						
			7	Consultant	Lump sum	ls	ls	3,000						
			8	Drilling 10 5/8-inch hole	3,500	lin ft	20.00	70,000						
			9	Furnishing and setting 2-inch casing and cementing in place	2,800	lin ft	8.00	22,400						
			10	Furnishing and setting 2-inch well screen	700	lin ft	10.00	7,000						
			11	Borehole geophysical logging	Lump sum	ls	ls	5,600						
			12	Allowance for unlisted items	Lump sum	ls	ls	20,000						
				Subtotal				220,500						
				Contingencies (20 percent±)				44,500						
				Field Cost 04.05.130				265,000						
				Other Costs (25 percent±)									(66,000)	
		140		Roads and Road Structures							17,000			
			1	Access to wells and site preparation	Lump sum	ls	ls	14,000						
				Subtotal				14,000						
				Contingencies (20 percent±)				3,000						
				Field Cost 04.05.140				17,000						
				Other Costs (25 percent±)									(4,000)	

GPO 839-818

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

BASIC PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-1 (Con.)
Project Cost Estimate
(Basic Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

Sheet 9 of 10

Property Class	Identified Property	Plant Account	Pay Item	Description	Quantity	Unit	Labor and Materials by Contractor: Unit Price	Labor and Materials by Contractor: Amount	Labor and Materials by Government: Unit Price	Labor and Materials by Government: Amount	Field Cost: Plant Account	Total Field Cost: Identified Property	Other Costs: Identified Property	Total Cost: Identified Property
1				2	3		4		5		6	7	8	9
05				CANALS AND CONDUITS										
	01			PIPELINE								440,000	111,000	451,000
		100		Land and Rights							18,000			
			1	Acquiring land and rights	Lump sum	ls	ls	18,000						
				Field Cost 05.01.100				18,000						
				Other Costs (25 percent±)									(5,000)	
		152		Waterways							422,000			
			1	Excavation	16,050	cy	5.00	80,250						
			2	Backfill	14,870	cy	3.00	44,610						
			3	Pipe 12B50 thru 12B250	22,900	lin ft	7.00	160,300						
			4	Revuelto Creek crossing	Lump sum	ls	ls	35,000						
			5	Allowance for unlisted items	Lump sum	ls	ls	31,840						
				Subtotal				352,000						
				Contingencies (20 percent±)				70,000						
				Field Cost 05.01.152				422,000						
				Other Costs (25 percent±)									(106,000)	
	02			BOOSTER PUMPING PLANT								60,000	15,000	75,000
		130		Structures and Improvements (curve estimate)							26,500			
		153		Waterway Structures (curve estimate)							6,500			
		160		Pumps and Prime Movers (curve estimate)							7,000			
		170		Accessory Electrical Equipment (curve estimate)							16,000			
		199		Miscellaneous Installed Equipment (curve estimate)							4,000			
				Other Costs (25 percent±)									(15,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

BASIC PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-1 (Con.)
Project Cost Estimate
(Basic Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
13				TRANSMISSION LINES, SWITCHYARDS AND SUBSTATIONS										
	01			MAIN SWITCHYARD								190,000	48,000	238,000
		175		Station Equipment (curve estimate)							59,000			
		182		Poles and Fixtures (curve estimate)							131,000			
				Other Costs (25 percent±)									(48,000)	
	02			BOOSTER PUMPING PLANT SUBSTATION								4,000	1,000	5,000
		170		Accessory Electrical Equipment (curve estimate)							4,000			
				Other Costs (25 percent±)									(1,000)	
	03			PRODUCTION WELL PUMP SUBSTATION								4,000	(1,000)	5,000
		170		Accessory Electrical Equipment (curve estimate)							4,000			
				Other Costs (25 percent±)									1,000	
	04			INJECTION WELL PUMP SUBSTATION								4,000	1,000	5,000
		170		Accessory Electrical Equipment (curve estimate)							4,000			
				Other Costs (25 percent±)									(1,000)	

7-1488 (5-78)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN

CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-2
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT: LAKE MEREDITH SALINITY STUDY
Date of Estimate: October 1984
Prices as of: October 1984

Sheet 1 of 12

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR		LABOR AND MATERIALS BY GOVERNMENT		FIELD COST	TOTAL FIELD COST	OTHER COSTS	TOTAL COST
							Unit Price	Amount	Unit Price	Amount	Plant Account	Identified Property	Identified Property	Identified Property
1				2	3		4		5		6	7	8	9
04				DEEP WELLS -										
				Lake Meredith Salinity Study is located in New Mexico about 1/2 mile south of the city of Logan and about 1 mile east of Ute Dam in Quay County. An expanded plan would consist of the basic plan plus any additional wells in any combination to make the project operational. This cost estimate is based on 3 production wells, 3 injection wells, 14 observation wells, and about 7 miles of 12-inch pressure pipe.										
	01			DESIGN DATA INVESTIGATIONS								266,000	66,000	332,000
		092		Investigations							266,000			
			1	Seismic Reflection Survey	25	miles	7,500	187,500						
			2	Resistivity/Electromagentic Survey	25	day	1,000	25,000						
				Subtotal				212,500						
				Contingencies (25 percent±)				53,500						
				Field Cost 04.01.092				266,000						
				Other Costs (25 percent±)									(66,000)	
	02			DEEP WELLS								50,000	12,000	62,000
		120		Clearing Lands - Archeology							50,000			
			1	Archeology survey and mitigation	Lump sum	ls	ls	50,000						
				Field Cost 04.02.120				50,000						
				Other Costs (25 percent±)									(12,000)	

GPO 835-013

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN

CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT: LAKE MEREDITH SALINITY STUDY
Date of Estimate: October 1984
Prices as of: October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR: Unit Price	LABOR AND MATERIALS BY CONTRACTOR: Amount	LABOR AND MATERIALS BY GOVERNMENT: Unit Price	LABOR AND MATERIALS BY GOVERNMENT: Amount	FIELD COST: Plant Account	TOTAL FIELD COST: Identified Property	OTHER COSTS: Identified Property	TOTAL COST: Identified Property
1				2	3		4		5		6	7	8	9
04				DEEP WELLS (continued)										
	03			PRODUCTION WELLS (3 WELLS)								1,013,000	255,000	1,268,000
		100		Land and Rights										
			1	Acquiring land and rights	Lump sum	ls	ls	15,000			15,000			
				Field Cost 04.03.100				15,000						
				Other Costs (25 percent±)									(4,000)	
		130		Structures and Improvements							834,000			
			1	Mobilization and demobilization	Lump sum	ls	ls	150,000						
			2	Drill rig operation (3-500 ft TD)	20	days	4,500	90,000						
			3	Water	Lump sum	ls	ls	3,000						
			4	Drill bits	Lump sum	ls	ls	15,000						
			5	Rental equipment	Lump sum	ls	ls	9,000						
			6	Mud and chemicals	Lump sum	ls	ls	15,000						
			7	Consultant	Lump sum	ls	ls	6,000						
			8	Furnishing and setting 20-inch conductor casing in 26-inch hole and cementing to surface	105	lin ft	170.00	17,850						
			9	Furnishing and setting 12-inch casing in 15-inch hole and cementing to surface	1,200	lin ft	70.00	84,000						
			10	Furnishing and setting 12-inch slotted casing in 15-inch hole	300	lin ft	60.00	18,000						
			11	Core drilling	1,200	lin ft	60.00	72,000						
			12	Gravel pack	Lump sum	ls	ls	15,000						
			13	Acid	Lump sum	ls	ls	15,000						
			14	Completion unit	Lump sum	ls	ls	9,000						
			15	Wellhead equipment	Lump sum	ls	ls	60,000						
			16	Borehole geophysical logging	Lump sum	ls	ls	15,000						
			17	Packer	Lump sum	ls	ls	7,500						
			18	Miscellaneous control valves	Lump sum	ls	ls	30,000						
			19	Allowance for unlisted items	Lump sum	ls	ls	63,650						
				Subtotal				695,000						
				Contingencies (20 percent±)				139,000						
				Field Cost 04.03.130				834,000						
				Other Costs (25 percent±)									(209,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04	03			PRODUCTION WELLS (continued)										
		140		Roads and Road Structures							54,000			
			1	Access roads to wells and site preparation	Lump sum	ls	ls	45,000						
				Subtotal				45,000						
				Contingencies (20 percent±)				9,000						
				Field Cost 04.03.140				54,000						
				Other Costs (25 percent±)									(14,000)	
		160		Pumps and Prime Movers							48,000			
			1	Pumps - 450 gpm and 40 hp motor	Lump sum	ls	ls	24,000						
			2	Manifolds and valves	Lump sum	ls	ls	12,000						
			3	Allowance for unlisted items	Lump sum	ls	ls	4,000						
				Subtotal				40,000						
				Contingencies (20 percent±)				8,000						
				Field Cost 04.03.160				48,000						
				Other Costs (25 percent±)									(12,000)	
		170		Accessory Electrical Equipment							48,000			
			1	Control panel	Lump sum	ls	ls	36,000						
			2	Allowance for unlisted items	Lump sum	ls	ls	4,000						
				Subtotal				40,000						
				Contingencies (20 percent±)				8,000						
				Field Cost 04.03.170				48,000						
				Other Costs (25 percent±)									(12,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04	03			PRODUCTION WELLS (continued)										
		199		Miscellaneous Installed Equipment							14,000			
			1	Miscellaneous electrical equipment	Lump sum	ls	ls	12,000						
				Subtotal				12,000						
				Contingencies (20 percent±)				2,000						
				Field Cost 04.03.199				14,000						
				Other Costs (25 percent±)									(4,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04				DEEP WELLS (continued)										
	04			INJECTION WELLS (3 WELLS)										
												3,211,000	800,000	4,011,000
		100		Land and Rights										
			1	Acquiring land and rights	Lump sum	ls	ls	15,000			15,000			
				Field Cost 04.04.100				15,000						
				Other Costs (25 percent+)									(4,000)	
		130		Structures and Improvements										
			1	Mobilization and demobilization	Lump sum	ls	ls	195,000			2,730,000			
			2	Drill rig operation (3-5,000 ft TD)	75	days	4,500	337,500						
			3	Water	Lump sum	ls	ls	7,500						
			4	Drill bits	Lump sum	ls	ls	60,000						
			5	Rental equipment	Lump sum	ls	ls	24,000						
			6	Mud and chemicals	Lump sum	ls	ls	90,000						
			7	Consultant	Lump sum	ls	ls	40,000						
			8	Furnishing and setting 20-inch conductor casing in 26-inch hole and cementing to surface	180	lin ft	170.00	30,600						
			9	Furnishing and setting 13 3/8-inch casing in 18-inch hole and cementing to surface	4,500	lin ft	30.00	135,000						
			10	Furnishing and setting 9 5/8-inch casing in 12-inch hole and cementing to surface	12,000	lin ft	20.00	240,000						
			11	Furnishing and setting 9 5/8-inch slotted casing	3,000	lin ft	25.00	75,000						
			12	Furnishing and setting 5-inch tubing	15,000	lin ft	6.00	90,000						
			13	Borehole geophysical logging	Lump sum	ls	ls	75,000						
			14	Wellhead equipment	Lump sum	ls	ls	60,000						
			15	Packer	Lump sum	ls	ls	10,500						

(continued)

7-1488 (6-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR		LABOR AND MATERIALS BY GOVERNMENT		FIELD COST	TOTAL FIELD COST	OTHER COSTS	TOTAL COST
							Unit Price	Amount	Unit Price	Amount	Plant Account	Identified Property	Identified Property	Identified Property
		1		2	3		4		5		6	7	8	9
04	04			INJECTION WELLS (continued)										
		130		Structures and Improvements (continued)										
			16	Miscellaneous control valves	Lump sum	ls	ls	45,000						
			17	Completion unit	Lump sum	ls	ls	45,000						
			18	Gravel pack	Lump sum	ls	ls	75,000						
			19	Acid	Lump sum	ls	ls	75,000						
			20	Core drilling	6,000	lin ft	60.00	360,000						
			21	Allowance for unlisted items	Lump sum	ls	ls	206,900						
				Subtotal				2,277,000						
				Contingencies (20 percent±)				453,000						
				Field Cost 04.04.130				2,730,000						
				Other Costs (25 percent±)									(678,000)	
		140		Roads and Road Structures							54,000			
			1	Access roads to wells and site preparation	Lump sum	ls	ls	45,000						
				Subtotal				45,000						
				Contingencies (20 percent±)				9,000						
				Field Cost 04.04.140				54,000						
				Other Costs (25 percent±)									(14,000)	
		160		Pumps and Prime Movers							370,000			
			1	Pump - 150 gpm with 60 hp motor	9	ea	21,100	189,900						
			2	Valves and manifolds	Lump sum	ls	ls	90,100						
			3	Allowance for unlisted items	Lump sum	ls	ls	28,000						
				Subtotal				308,000						
				Contingencies (20 percent±)				62,000						
				Field Cost 04.04.160				370,000						
				Other Costs (25 percent±)									(93,000)	

GPO 838-513

7-1482 (5-78)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04	04			INJECTION WELLS (continued)										
		170		Accessory Electrical Equipment							24,000			
			1	Control panels	Lump sum	ls	ls	18,000						
			1	Allowance for unlisted items	Lump sum	ls	ls	2,000						
				Subtotal				20,000						
				Contingencies (20 percent±)				4,000						
				Field Cost 04.04.170				24,000						
				Other Costs (25 percent±)									(6,000)	
		199		Miscellaneous Installed Equipment							18,000			
			1	Miscellaneous electrical equipment	Lump sum	ls	ls	15,000						
				Subtotal				15,000						
				Contingencies (20 percent±)				3,000						
				Field Cost 04.04.199				18,000						
				Other Costs (25 percent±)									(5,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
04				DEEP WELLS (continued)										
	05			OBSERVATION WELLS (14 WELLS)								588,000	148,000	736,000
		100		Land and Rights							14,000			
			1	Acquiring land and rights	Lump sum	ls	ls	14,000						
				Field Cost 04.05.100				14,000						
				Other Costs (25 percent±)									(4,000)	
		130		Structures and Improvements							540,000			
			1	Mobilization and demobilization	Lump sum	ls	ls	36,000						
			2	Drill rig (14-500 ft TD)	45	day	2,000	90,000						
			3	Water	Lump sum	ls	ls	5,000						
			4	Drill bits	Lump sum	ls	ls	20,000						
			5	Rental equipment	Lump sum	ls	ls	10,000						
			6	Mud and chemicals	Lump sum	ls	ls	30,000						
			7	Consultant	Lump sum	ls	ls	6,000						
			8	Drilling 10 5/8-inch hole	7,000	lin ft	20.00	140,000						
			9	Furnishing and setting 2-inch casing and cementing in place	5,600	lin ft	8.00	44,800						
			10	Furnishing and setting 2-inch well screen	1,400	lin ft	10.00	14,000						
			11	Borehole geophysical logging	Lump sum	ls	ls	11,200						
			12	Allowance for unlisted items	Lump sum	ls	ls	41,000						
				Subtotal				448,000						
				Contingencies (20 percent±)				92,000						
				Field Cost 04.05.130				540,000						
				Other Costs (25 percent±)									(135,000)	
		140		Roads and Road Structures							34,000			
			1	Access road to wells and site preparation	Lump sum	ls	ls	28,000						
				Subtotal				28,000						
				Contingencies (20 percent±)				6,000						
				Field Cost 04.05.140				34,000						
				Other Costs (25 percent±)									(9,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
1				2	3		4		5		6	7	8	9
05				CANALS AND CONDUITS										
	01			PIPELINES								696,000	174,000	870,000
		100		Land and Rights							25,000			
			1	Acquiring land and rights	50	ac	500.00	25,000						
				Field Cost 05.01.100				25,000						
				Other Costs (25 percent±)									(6,000)	
		152		Waterways							671,000			
				(1) Main Pipeline										
			1	Excavation	16,050	cy	5.00	80,250						
			2	Backfill	14,870	cy	3.00	44,610						
			3	Pipe 12B50 thru 12B250	22,900	lin ft	7.00	160,300						
			4	Revuelto Creek crossing	Lump sum	ls	ls	35,000						
			5	Allowance for unlisted items	Lump sum	ls	ls	31,840						
				Subtotal				352,000						
				Contingencies (20 percent±)				70,000						
				Field Cost 05.01.152(1)				422,000						
				(2) Reach #1 - Production well #2 to connecting point										
			1	Excavation	420	cy	5.00	2,100						
			2	Backfill	390	cy	3.00	1,170						
			3	Pipe	600	lin ft	7.00	4,200						
			4	Allowance for unlisted items	Lump sum	ls	ls	530						
				Subtotal				8,000						
				Contingencies (20 percent±)				2,000						
				Field Cost 05.01.152(2)				10,000						

7-1458 (5-78)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE
Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR		LABOR AND MATERIALS BY GOVERNMENT		FIELD COST	TOTAL FIELD COST	OTHER COSTS	TOTAL COST
							Unit Price	Amount	Unit Price	Amount	Plant Account	Identified Property	Identified Property	Identified Property
1				2	3		4		5		6	7	8	9
05	01			PIPELINES (continued)										
		152		Waterways (continued)										
				(3) Reach #2 - Production well #3 to connecting point										
			1	Excavation	3,435	cy	5.00	17,175						
			2	Backfill	3,180	cy	3.00	9,540						
			3	Pipe	4,900	lin ft	7.00	34,300						
			4	Allowance for unlisted items	Lump sum	ls	ls	5,985						
				Subtotal				67,000						
				Contingencies (20 percent±)				13,000						
				Field Cost 05.01.152(3)				80,000						
				(4) Reach #3 - Injection well #1 to injection well #2										
			1	Excavation	3,645	cy	5.00	18,225						
			2	Backfill	3,375	cy	3.00	10,125						
			3	Pipe 12B25	5,200	lin ft	7.00	36,400						
			4	Allowance for unlisted items	Lump sum	ls	ls	6,250						
				Subtotal				71,000						
				Contingencies (20 percent±)				14,000						
				Field Cost 05.01.152(4)				85,000						
				(5) Reach #4 - Injection well #2 to injection well #3										
			1	Excavation	3,155	cy	5.00	15,775						
			2	Backfill	2,920	cy	3.00	8,760						
			3	Pipe 12B25 thru 12B75	4,500	lin ft	7.00	31,500						
			4	Allowance for unlisted items	Lump sum	ls	ls	5,965						
				Subtotal				62,000						
				Contingencies (20 percent±)				12,000						
				Field Cost 05.01.152(5)				74,000						
				Field Cost 05.01.152				671,000						
				Other Costs (25 percent±)									(168,000)	

7-1482 (8-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN
CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

Sheet 11 of 12

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
		1		2	3		4		5		6	7	8	9
05				CANALS AND CONDUITS (continued)										
	02			BOOSTER PUMPING PLANT								136,000	34,000	170,000
		130		Structures and Improvements (curve estimate)							26,500			
		153		Waterway Structures (curve estimate)							20,000			
		160		Pumps and Prime Movers (curve estimate)							20,000			
		170		Accessory Electrical Equipment (curve estimate)							60,500			
		199		Miscellaneous Installed Equipment (curve estimate)							9,000			
				Other Costs (25 percent±)									(34,000)	

7-1482 (5-72)
Bureau of Reclamation
Formerly Basic Estimate DC-1

INSTRUCTIONS FOR USE OF THIS FORM ARE CONTAINED IN CHAPTER 6, PART 152 OF THE RECLAMATION INSTRUCTIONS

EXPANDED PLAN CONSTRUCTION COST ESTIMATE

Planning Estimate

Table A-2 (Con.)
Project Cost Estimate
(Expanded Plan)

OFFICE PREPARED BY: SW 760

PROJECT LAKE MEREDITH SALINITY STUDY
Date of Estimate October 1984
Prices as of October 1984

PROPERTY CLASS	IDENTIFIED PROPERTY	PLANT ACCOUNT	PAY ITEM	DESCRIPTION	QUANTITY	UNIT	LABOR AND MATERIALS BY CONTRACTOR Unit Price	LABOR AND MATERIALS BY CONTRACTOR Amount	LABOR AND MATERIALS BY GOVERNMENT Unit Price	LABOR AND MATERIALS BY GOVERNMENT Amount	FIELD COST Plant Account	TOTAL FIELD COST Identified Property	OTHER COSTS Identified Property	TOTAL COST Identified Property
		1		2	3		4		5		6	7	8	9
13				TRANSMISSION LINES, SWITCHYARDS AND SUBSTATIONS										
	01			MAIN SWITCHYARD								220,000	55,000	276,000
		175		Station Equipment (curve estimate)							89,000			
		182		Poles and Fixtures (curve estimate)							131,000			
				Other Costs (25 percent±)									(55,000)	
	02			BOOSTER PUMPING PLANT SUBSTATION (1)								4,000	1,000	5,000
		170		Accessory Electrical Equipment (curve estimate)							4,000			
				Other Costs (25 percent±)									(1,000)	
	03			PRODUCTION WELL PUMP SUBSTATIONS (3)								12,000	3,000	15,000
		170		Accessory Electrical Equipment (curve estimate							12,000			
				Other Costs (25 percent±)									(3,000)	
	04			INJECTION WELL PUMP SUBSTATIONS (3)								12,000	3,000	15,000
		170		Accessory Electrical Equipment (curve estimate)							12,000			
				Other Costs (25 percent±)									(3,000)	

GPO 836-513

ATTACHMENT B - ECONOMICS SUPPORTING DATA

ECONOMICS - SUPPORTING DATA

Overview

After an evaluation of the alternative methods for reducing salinity in Lake Meredith, the plan that is most acceptable to the Canadian River Municipal Water Authority (CRMWA) is brine removal at the point source and injection of the brine into a deep well. This plan would reduce brine seepage into the river by lowering the piezometric surface of the aquifer through pumping and discharging the brine into wells in a suitable, deep permeable layer. Based on hydraulic data obtained from recent evaluations, a production well with a pumping capacity of about 1 cubic foot per second (ft^3/s) (450 gallons a minute [gal/min]) could lower the artesian head of the aquifer sufficiently to prevent the upward seepage of brine into the river channel. The discharge from the well would be transported by pipeline and injected into a deep well.

A basic plan and an expanded plan are described in the Engineering and Hydrology sections. Cost estimates are shown for each plan. The basic plan would be the minimum features required to verify and/or operate the project and proposes pumping one well at about 1 ft^3/s to control brine leakage. If the basic plan does not produce the desired results, additional features could be required. Due to the uncertainties about the amount of pumpage required, the expansion of the "cone of depression" along the Canadian River, and the potential downward leakage of fresher water from the shallow ground water system, two additional production wells are proposed for the expanded plan.

After the geophysical data have been examined, exploratory drilling should be completed. Seven piezometric sites represent the exploratory drilling locations for the basic monitoring plan. Seven additional sites are proposed for the expanded plan. The expanded plan also includes two additional injection wells and other related cost increases, which are explained in the economic analysis.

The economic and financial analyses are presented for the basic plan and for the expanded plan to remove the brine at the point source and disposing of the brine in a deep well(s). The economic analysis includes the benefits and costs; interest during construction (IDC); annual operation, maintenance, replacement, and energy (OMR&E) costs: and the benefit-cost (B/C) ratio. The plan formulation rate applicable to the completion date of the report is 8.375 percent, and the amortization period is 100 years. The financial analysis addresses cost allocation, reimbursable costs, financial capability, and average annual repayment. The repayment period is 50 years at an interest rate of 10.403 percent.

Benefits and costs of the alternative salinity reduction methods are compared to the benefits and costs of the most likely alternative salinity reduction method in lieu of a Federal project. This information is shown in table VI-2 of the main report.

This water quality study focuses on economic and financial feasibility evaluations of methods designed to decrease the concentration of salts in Lake Meredith to levels considered desirable for drinking water by the Environmental Protection Agency (EPA) and the Texas Department of Health (TDH).

This water quality study sets forth some of the basic elements of a broad B/C approach in a framework of project design and selection including the recognition that water quality projects have impacts extending beyond those capable of monetary quantification. The study investigates economic feasibility of alternative solutions in relation to cost effectiveness and the ratio of benefit to cost. The willingness and ability of water users to finance the most effective method of achieving salinity reduction in Lake Meredith pertains to the financial feasibility. The results of applying these methods of analysis are helpful inputs to the decision process of water resource managers faced with the problem of obtaining maximum use of a limited resource. Persons interested in justifying expenditures are concerned about the problem in terms of present and future conditions, its impact, and comparison of solutions from an economical and financial viewpoint.

The objective pursued in water quality management is to secure water qualities within the mode that the marginal cost of improving water quality is equal to or less than the accruing marginal benefits. The total benefits or damages (loss of benefits) associated with water quality are difficult to assess when the major purpose of the water supply in the reservoir is for a single objective--municipal use--and the benefits are a function of the amount and time of occurrence of salinity reduction.

Alternatives Considered

The CRMWA believes that the quantity of water in Lake Meredith will be used more beneficially when the quality of the water is improved, thereby extending the time until water from other more expensive sources will be required. Economic and financial feasibility evaluations of methods designed to decrease the concentration of salts in Lake Meredith to levels considered desirable for drinking water by the U.S. Public Health Service, EPA, and TDH are presented.

Benefits and costs of the alternative salinity reduction methods are compared to the benefits and costs of the most likely (alternative) salinity reduction method in lieu of a Federal project, which is brine removal at the point source with deep-well injection of the brine. This information is shown in table VI-2 of the main report. Alternative methods that would reduce the salinity level of Lake Meredith water are comparatively analyzed. The primary objective of each alternative method is to achieve a total dissolved solids (TDS) level of approximately 800 milligrams per liter (mg/L), which represents a reduction of approximately 400 mg/L TDS in Lake Meredith water.

Well pumping with brine disposal in an evaporation pond

The October 1984 construction cost for brine removal at the point source and transporting the brine to a playa lake for storage and evaporation is estimated to be $13,900,000. Annual OMR&E costs for a surface discharge-surface evaporation pond will be $43,000 resulting in average annual costs of approximately $1,256,000 as shown in table VI-2 of the main report.

Well pumping with brine disposal in a deep well

The annual cost of brine removal at the point source and injecting the brine in a deep well is approximately $426,700 for the basic plan and $997,970 for the expanded plan. Economically and environmentally, deep-well injection of the brine is the most acceptable method of disposal. (Evaluation of this plan is presented in the Economic and Financial Analysis section of this report).

Hydrostatic control pool

The hydrostatic control pool method requires the construction of a diversion dam-type structure below the confluence of the Revuelto Creek (New Mexico) to provide a hydrostatic control pool over the brine seepage area. Undetermined aspects at this point in the study include the amount of head required in the vicinity of the test well to suppress the seepage areas, whether or not seepage would recur downstream from the structure and whether or not the brine seepage area is confined upstream from the confluence of the Canadian River and Revuelto Creek. The October 1984 construction cost was estimated to be $7,700,000; annual OMR&E costs were estimated to be approximately $770,000. The average annual cost would be approximately $1,442,000. At this level of study, the concept of using hydrostatic control ponds on the Canadian River is found to have less acceptability than other alternatives due to cost, effectiveness in obtaining desired results, and Canadian River Compact limitations; i.e., the interstate compact among the States of Texas, New Mexico, and Oklahoma permitting each State to impound a specified number of acre-feet of water in conservation storage in reservoirs for beneficial use.

Blending ground water with Lake Meredith water

The average annual cost for blending ground water with Lake Meredith water would be approximately $10 million, based on the cost per acre-foot of ground water required for blending from 1997 to 2023, formulated to coincide with the time when benefits of the most likely alternative are expected to occur (approximately 12 years from initial pumping of brine at the point source) and considering that by the year 2023 the benefits would be dependent on maintaining use of ground water for quality purposes over and above that necessary to meet demand. However, with the salinity control project, the benefits derived from salinity reduction will continue for the life of the project. Without the salinity control project, it is unlikely that the 800 mg/L TDS could be maintained over time based on:

1. As part of the Hydro Geo Chem. Inc. (HGC) investigation, salt and water balances extended 40 years into the future resulted in the finding that if no actions are taken to reduce the brine inflow to the Canadian River, long-term Lake Meredith chloride concentrations may approach 400 mg/L or even higher during sustained low-flow periods. Chloride concentrations averaged approximately 400 mg/L during the period 1964-1983.

2. The TDS concentration in local ground water varies from 300 mg/L to 500 mg/L. A continually better quality water is expected to be available with the salinity control project in place than would be available with the blending of ground water with Lake Meredith water without the salinity control project.

Although the CRMWA is granted broad powers of various kinds, it is restricted to development of surface waters, with acquisition or use of ground water being specifically prohibited. The proposal to blend ground water with Lake Meredith water may require the purchase and retirement of irrigation water rights. Due to restrictions and the fact that not all CRMWA member cities have locally available ground water of the quality required for a blending supply which would achieve a 400 mg/L reduction of TDS, the blending process is not an acceptable alternative at this time.

Desalination

This alternative provides for desalting Lake Meredith water along the Main Aqueduct. The product water from a Reverse Osmosis (RO) plant can range from 100 to 500 mg/L TDS. Blending product water from one RO plant with lake water of 1,200 mg/L TDS would result in approximately 800 to 900 mg/L TDS.

The annual construction cost and IDC of $10,501,495 was discounted to the time (12 years hence) when benefits from the most acceptable plan are expected to occur. This discounted investment cost, $3,998,293, added to OMR&E costs of $27,300,000, results in an average annual cost of $31,298,293.

The cost of the desalting plant exceeds the CRMWA's willingness to pay as compared to a more economical method of salinity reduction.

Findings

A recent contract HGC study and analysis of regional and site geology (New Mexico and Texas) relating to subsurface salt dissolution states that about 70 percent of the salt entering Lake Meredith comes from the New Mexico side of the Canadian River and that most of this salt originates from brine inflow to the river channel near Logan, New Mexico. Consequently, the State of Texas will need to apply to the State of New Mexico for a water right to permit pumping the saline aquifer. Information required in the application includes specific sites for wells and disposal zones. The report also states that an additional 10 to 15 percent enters the river channel between the Tascosa and Amarillo gauges.

The Water Quality Control Commission regulates deep-well injection in New Mexico. The TDS limits for freshwater zones are 10,000 TDS. Identification of a zone to confine the TDS concentration of approximately 30,000 mg/L from the brine aquifer would be required in the application for a permit to inject the brine into a suitable deep well. The approval process may require up to 12 months and discharge permits are renewable every 5 years. The New Mexico Environmental Improvement Division indicated that it does not have a problem with the proposal at this time.

Interstate compacts establishing effective agencies have benefited from the Federal Water Quality Act which simplifies obtaining consent of Congress for states to negotiate. State legislatures have come to regard compacts as desirable means for cooperative action.

As part of the HGC investigation, salt and water balances extended 40 years into the future resulted in the finding that if no actions are taken to reduce the brine inflow to the Canadian River, long-term Lake Meredith chloride concentrations may approach 400 mg/L or even higher during sustained low-flow periods. Chloride concentrations averaged approximately 300 mg/L during the period 1964-1983.

Palatability of drinking water and the rate of corrosiveness of water pipes, faucets, flushing equipment, and water-using appliances are affected by high levels of chloride. Water users purchase bottled water when tap water is distasteful or when their physical condition restricts the use of salty water.

Local data collection and studies (researchers in the field of salinity studies use a period of approximately 10 years) are required to determine a functional relationship between different levels and durations of chloride concentration and damage costs to water users.

Predicting the concentration over time at various distances from the original discharge point of inorganic chemicals, such as chloride, is complicated by variations in transmissibility, both vertically and horizontally; by the physical process, such as absorption and evaporation; and by chemical reactions.

Prediction of the actual time pattern of chloride concentration resulting from a saline discharge is affected by hydrologic uncertainty (quantity of water available for dilution) and the amount of salinity inflow reduction that can be achieved by pumping the aquifer.

At this time, estimates of performance are based on model simulations and demonstration operations in the absence of operating verification or full-scale installations. Actually pumping the saline aquifer will test the effectiveness of the method over time.

Results of a HGC simulation model show the effect, after 10 years of 100-percent reduction in brine inflow near Logan, to be about 24-percent reduction (in milligrams per liter) of TDS in the river near Lake Meredith. When the brine inflow was reduced by 50 percent, the time for the system to respond is nearly the same; but the amount of salinity reduction is about half of that from the model simulation of 100-percent reduction in brine inflow. The effect on Lake Meredith salinity would be direct but at a slightly slower rate. The model was designed to simulate low-flow characteristics and did not account for any high-flow salt transport.

The general economic problem is to use available scarce resources to maximize resultant human welfare. This maximization means that alternative configurations of resource use among types of use and through time must be compared in terms of the net benefits that the resources will generate--the benefits being interpreted in the broadest terms. The real costs of any particular configuration of resource use consist of the benefits that would be realized through other patterns of resource use.

The objective of salinity reduction to achieve a recommended quality standard is to approximate an economically optimum level of water quality at lowest cost in relation to chloride concentration. It takes into consideration both the damage costs and the chloride-reduction costs incurred by water users. The cost of salinity to municipal users relates to instances of damages experienced as a result of a given time of exposure to a given chloride concentration.

Based on the assumptions that the saline inflow to the Canadian River will be effectively reduced by pumping the aquifer and that the reduction of brine inflow will reduce salinity in Lake Meredith in approximately 12 years, the method will be economically and financially feasible.

Acknowledging that there are risks and uncertainties (amount of salinity reduction, amount of benefits, and time of occurrence of benefits), pumping the saline aquifer appears to be a cost-effective method to reduce salinity in Lake Meredith to the recommended water quality standard within the cost constraint of the CRMWA.

The comparison of costs of alternative methods of reducing salinity is implicit in the B/C analysis to provide assurance that the least-cost system for meeting the given quality objective has been identified.

When alternative sources of water are available, preferences for water quality could be represented in the market; i.e., buying water from sources that have less chloride. However, in the Lake Meredith case, each member city of the CRMWA is assessed for its allocation of water from the reservoir. Therefore, any additional cost for reducing salinity in its municipal water supply is less expensive than developing well fields or an alternate source of surface water.

Since salinity is not subject to treatment, except at very high cost, generally the only economically feasible way to reduce concentrations in watercourses is to reduce the salinity entering the watercourses.

Poor quality water imposes extra costs on municipal water systems; but except in cases of toxic or intolerable-tasting substances, municipalities ordinarily cannot justify levels of salinity control above that required to meet minimum water quality standards.

Nonquantifiable, nonmarketable benefits are being increasingly accepted by State legislatures, Congress, and the public as justification for new projects or new management policies. Examples are in the water quality area where the imposition of standards and large expenditures on treatment plants are justified on a nonquantified desire to improve human welfare rather than on a demonstration that monetarily measurable benefits exceed costs.

The economic and financial analyses would be enhanced by:

1. Site-specific data collection and studies to determine the effects of specific amounts of chloride and TDS on household water pipes, plumbing fixtures, and water-using appliances for households using Lake Meredith water; and

2. A verification period to determine the effectiveness of pumping the saline aquifer in reducing chloride in Lake Meredith.

ATTACHMENT C - TABLE OF METRIC CONVERSIONS

Electrical Terms and Factors for Converting
English Units to Metric Units

(International System, SI, units)

Electrical Terms

1 kilovolt	equals	1 thousand volts
1 kilowatt	equals	1 thousand watts
1 megawatt	equals	1 million watts
1 gigawatt	equals	1 billion watts

Factors for Converting English Units to Metric Units

Multiply English units	by	To obtain metric units
	Length	
inch (in)	2.54	centimeter (cm)
	25.4	millimeter (mm)
	0.0254	meter (m)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
rod	5.0292	meter (m)
mile (mi)	1.609344	kilometer (km)
	Area	
acre	4.04686×10^3	square meter (m^2)
	0.404686	1/ hectare (ha)
	0.404686	square hectometer (hm^2)
	0.004047	square kilometer (km^2)
square mile (mi^2)	2.589988	square kilometer (km^2)
	Volume	
gallon (gal)	3.785412	2/ liter (l)
	3.785412	cubic decimeter (dm^3)
	3.785412×10^{-3}	cubic meter (m^3)
million gallons (10^6 gal)	3.785412×10^3	cubic meter (m^3)
	3.785412×10^{-3}	cubic hectometer (hm^3)
cubic foot (ft^3)	28.31685	cubic decimeter (dm^3)
	2.831685×10^{-2}	cubic meter (m^3)
cubic foot per second day (ft^3/s day)	2.446576×10^3	cubic meter (m^3)
	2.446576×10^{-3}	cubic hectometer (hm^3)
acre-foot (acre-ft)	1.233482×10^3	cubic meter (m^3)
	1.233482×10^{-3}	cubic hectometer (hm^3)
	1.233482×10^{-6}	cubic kilometer (km^3)
	0.123348	3/ hectare-meter (ha.m)

Multiply English units	by	To obtain metric units
	Flow	
cubic foot per second (ft^3/s)	28.31685	liter per second (l/s)
	28.31685	cubic decimeter per second (dm^3/s)
	2.831685×10^{-2}	cubic meter per second (m^3/s)
gallon per minute (gpm)	6.309020×10^{-2}	liter per second (l/s)
	6.309020×10^{-2}	cubic decimeter per second (dm^3/s)
	6.309020×10^{-5}	cubic meter per second (m^3/s)
million gallons per day (mgd)	43.81264	cubic decimeter per second (dm^3/s)
	4.381264×10^{-2}	cubic meter per second (m^3/s)
4/ cubic foot per square foot per day (ft^3/ft^2d)	3.527778×10^{-6}	cubic meter per square meter per second (m^3/m^2s)
	Velocity-Speed	
mile per hour (mi/h)	4.470400×10^{-1}	meter per second (m/s)
	Mass	
ton (short)	9.071847×10^{2}	kilogram (kg)
	0.907185	tonne (t)
	Temperature	
degrees Fahrenheit (°F)	$(°F-32)\frac{5}{9}$	degrees Celsius (°C)
degrees Celsius (°C)	(°C x 1.8)+32	degrees Fahrenheit (°F)

1/ The unit hectare is approved for use with the International System (SI) for a limited time.
2/ The unit liter is accepted for use with the International System (SI).
3/ The unit hectare-meter (ha.m) is not approved for use with the International System (SI) at the present time.
4/ Hydraulic conductivity-permeability.