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**Colorado River Basin
Salinity Control Project**



**Paradox Valley Unit
Final Supplemental
Definite Plan Report and
Environmental Assessment**



May 1997



**United States
Department of the Interior**

Bureau of Reclamation



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Colorado River Basin Salinity Control Project

PARADOX VALLEY UNIT

Final Supplemental Definite Plan Report

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Chapter I Introduction

Purpose

The Paradox Valley Unit (Unit) of the Colorado River Basin Salinity Control Project (CRBSCP) is located in Montrose County in southwestern Colorado and is designed to control natural brine inflows into the Dolores River. The Paradox Valley has long been identified as a major contributor of salt loading in the Colorado River Basin. The Valley overlies a fractured gypsum cap that covers a formation of salt and salt-rich shale that begins at a depth of about 600 to 1,000 feet and extends downward for about 14,000 feet. The Dolores River picks up an estimated 205,000 tons of salt annually as it crosses the valley, primarily from the surfacing of natural brine groundwater. The purpose of the Unit is to intercept the brine and prevent this substantial salt load from entering the river and degrading the water quality of the main stem of the Colorado River.

The Bureau of Reclamation (Reclamation) began studies at Paradox Valley in 1971. By 1979, a Definite Plan Report and Final Environmental Statement had been approved recommending a plan that would prevent approximately 90 percent of the natural brine inflow (185,000 tons of salt annually) from entering the Dolores River. The recommended plan consisted of constructing a series of shallow brine production wells adjacent to the river, pumping the wells at a collective rate of 5 cubic feet per second (cfs) to intercept the brine, transporting the brine via a 21-mile-long pipeline and eight pumping stations to Dry Creek Basin, and disposing of the brine by evaporation in the 3,630-acre Radium Evaporation Pond. Deep well injection was one of the alternative brine disposal methods discussed briefly in the environmental statement but was eliminated because the proposed 5 cfs disposal rate was estimated to be higher than the geologic formations could absorb. The Region VIII Office of the Environmental Protection Agency reviewed the 1978 Draft Environmental Statement and stated that it "believes that disposal by deep well injection is the environmentally preferred solution and therefore should be seriously investigated for brine disposal" (BOR, 1978).

Subsequent investigations and testing of the brine well field indicated the desired reduction of 90% of brine flow into the river could be met by intercepting and disposing of approximately 2 cfs of brine. Based on this new information, in September 1978, Reclamation initiated an action to conduct a study to investigate the feasibility of brine disposal by injection. Two separate studies were conducted by consulting engineering firms and, in August 1985, the final design for a deep-well injection testing program was completed.

Construction of Test Injection Well No. 1 began in July 1986 at a site located approximately 1.2 miles south of Bedrock, Colorado, in the Dolores River Canyon. A well 16,000 feet deep was drilled into the underlying Mississippian and Precambrian rock formations. Preliminary tests indicated these formations would be favorable injection zones. Construction of a surface injection facility, brine treatment facility, and pipelines connecting these facilities with the brine well field proceeded concurrently with the injection well construction. All facilities were completed by January 1990.

Initial shakedown testing of the new facility equipment revealed several deficiencies in the mechanical and electrical equipment associated with pressurizing the brine up to 5,000 pounds per square inch injection pressure. These deficiencies were corrected, and in July 1991, injection testing was initiated to provide information concerning the necessary injection pressure and expected life of the well. Additional mechanical and electrical problems with the surface equipment were encountered which resulted in the injection test proceeding on an intermittent basis as the surface facilities and equipment were upgraded to sufficient production levels. By July 1994 the major equipment problems were resolved and an 8-month continuous injection sequence began. Results of the injection testing indicate that deep-well injection of the brine is a feasible method of brine disposal in the Paradox Valley.

This Supplement to the Definite Plan Report (SDPR) for the Paradox Valley Unit, Colorado, Colorado River Basin Salinity Control Project (CRBSCP), describes modifications to the project plan of development that have occurred since the original DPR was completed. The attached Environmental Assessment (EA) evaluates the environmental effects of operating the presently constructed deep-well injection facility as the Unit's contribution to the Colorado River Basin salinity control effort.

Need for Action

In the Colorado River Basin, salinity in rivers results from two general causes--salt loading and salt concentration. Salt loading is the addition of salt to the river from such sources as the dissolving of salt from saline geologic formations, as occurs in the Paradox Valley. Other sources include irrigation return flows and saline springs. Under present conditions, the annual salt load of the river into Lake Mead in the Lower Colorado River Basin is estimated at 9 million tons. Salt concentration results from consumptive use of water without reducing the total salt carried. Some examples include irrigation, municipal and industrial (M&I) use, transpiration by native vegetation, and evaporation.

When water is used and reused along the entire length of the Colorado River, salt loading and salt concentration contribute to increased levels of salinity and a deterioration of the quality of the river's water. At its headwaters in the mountains of north-central Colorado, the Colorado River has a salinity concentration of approximately 50 milligrams per liter (mg/L). Downstream, the concentration progressively increases. At Imperial Dam, the last major diversion point in the United States, the salinity in 1995 averaged 787 mg/L. Historical salinity concentrations fluctuate annually with the total basin water supply but, as the Upper Colorado River Basin States continue to use and develop their water, salinity will increase. It is estimated that by the year 2015, salinity at Imperial Dam will average 970 mg/L without controls.

Water of 1,000 mg/L or less is generally considered to be satisfactory for irrigating most crops, although concentrations of 500 mg/L can have detrimental effects on salt-sensitive crops. Water exceeding 1,000 mg/L may be used only on land with good drainage and for crops with high salt tolerances. According to the EPA's secondary drinking water standards, public drinking water should be less than 500 mg/L.

In the Lower Colorado River Basin, high salinity levels adversely affect more than 18 million people and about 2 million acres of irrigated farmland. Those most affected are the M&I water users in the Los Angeles-San Diego area, and irrigators in Arizona and southern California, especially in the Imperial Valley.

The estimated damages from salinity exceed \$750 million per year¹. The losses from M&I use occur mainly from increased water treatment costs, pipe corrosion, appliance wear, increased soap and detergent needs, automobile radiator deterioration, and decreased drinking water palatability. For irrigators, the higher salt concentrations cause decreased crop yields, loss of productive land, forced changes to more salt-tolerant crops, increased leaching and drainage needs, and increased management costs.

To limit the salinity of the Colorado River and in response to the Federal Water Pollution Control Act and its 1972 amendments, Public Law 92-500, the seven Colorado River Basin States, acting through the Colorado River Basin Salinity Control Forum, developed numeric criteria and a basin wide plan of implementation for salinity control. In 1975, the states adopted these water quality standards for salinity. The numeric criteria are shown in table I-1.

Table I-1.—Numeric criteria for the
Lower Colorado River

Station	Annual flow-weighted concentration (mg/L)
Below Hoover Dam	723
Below Parker Dam	747
At Imperial Dam	879

The goal of the CRBSCP is to maintain average concentrations at or below these criteria. About 1.4 million tons of salt per year needs to be removed by 2010 to maintain average salinity below the numeric criteria level of 879 mg/L at Imperial Dam. Even at this level of salinity reduction, temporary but significant amounts beyond 879 mg/L will still occur because of the natural variations in climatic conditions and water usage.

Authority

The Paradox Valley Unit was authorized for construction by the Colorado River Basin Salinity Control Act of 1974 (Public Law 93-320; amended in 1984 as Public Law 98-569) as part of a basin

¹ A comprehensive study to update the economic impacts of salinity in the Colorado River was published in February 1988 (*Estimating Economic Impacts of Salinity of the Colorado River*, Final Report, prepared for Reclamation). This study provided new estimates of salinity damages as a range of costs depending upon the assumptions based on current salinity levels and baseline total dissolved solids (TDS) conditions used in the analysis.

wide program to control salinity levels in the Colorado River while the Colorado River Basin States and the Republic of Mexico continue to develop and use their apportioned shares of water from the river and its tributaries. Title I of the Act, which was directed toward controlling the salinity of river water below Imperial Dam for use in the Republic of Mexico, authorized the construction of a desalting complex and other measures to ensure acceptable salinity levels. Title II, which was directed toward salinity control in the United States above Imperial Dam, authorized the construction of the Paradox Valley Unit and three other units. Preliminary information and cumulative impacts for the 16 original units in Title II have been presented in a FES of the Colorado River Water Quality Improvement Program (FES 77-15), prepared by Reclamation and the Soil Conservation Service of the Department of Agriculture (USDA).

Relationships to Other Activities

The Unit is related to Federal projects currently under investigation or construction elsewhere by USDA, which does not currently have any studies in the Unit area. Title II of Public Laws 93-320 and 98-569 authorizes the Secretaries of the Interior and Agriculture to cooperate in implementing any project involving control of salinity from irrigation sources. To establish a program for effective implementation of specific cooperative activities called for by Title II, Interior and the USDA entered into a Memorandum of Understanding effective November 1974 and renewed on August 25, 1986. Reclamation and the Natural Resource Conservation Service entered into a Memorandum of Agreement effective March 1975 and renewed on August 18, 1986.

Public Involvement

Throughout the study phase for the Unit modifications, the general public and interested and affected agencies, groups, and individuals had the opportunity to participate in the study. Reclamation considered information from and the opinions and desires of the public in evaluating project development and the salinity problem. Reclamation coordinated with and received assistance from the U.S. Fish and Wildlife Service (Service), the Colorado Division of Wildlife (CDOW), and the Bureau of Land Management (BLM).

On November 13, 1981, a public meeting was held at the Paradox Grade School, Paradox, Colorado, to explain the concept of deep well injection as a method of brine disposal. The meeting was conducted by Reclamation and William Brothers Engineering Company, the consulting company that conducted the feasibility study and preliminary designs for deep well injection. The day after this meeting, a tour of the brine well field test facilities was conducted.

After the project proceeded to the design phase, an informal presentation was made on June 9, 1982, to the Ute Trail Study Club in Redvale, Colorado. In June 1984, a newsletter with an update on the Unit was mailed to city and county governments, newspapers, and radio and television stations serving the area, as well as to residents in the affected area.

A Draft EA on the Deep Well Injection Testing Program was prepared in 1986 and was distributed to Federal and State agencies, public and private organizations, and interested individuals for review

and comment. Results of that review are reflected in this draft SDPR/EA.

Before construction of Unit facilities began, a public meeting was conducted in Naturita, Colorado, by Reclamation and Fenix and Scisson Inc., contractor for the injection well.

Since 1981, news articles on the Unit have appeared in Colorado in *The Denver Post*; *The Durango Herald*; *The San Miguel Basin Forum*, Nucla; *The Cortez Sentinel and Montezuma Valley Journal*, Cortez; *Montrose Daily Press*, Montrose; *Dolores Star*, Dolores; *Grand Junction Daily Sentinel*; and in *The Times Independent*, Moab, Utah.

Contact with local landowners and residents is continuing.

Chapter II Unit Setting

Location

The Paradox Valley Unit (Unit) is located in Montrose County in southwest Colorado just east of the Colorado-Utah State line near the Dolores River. The valley itself is about 24 miles long and 3 to 5 miles wide.

The only communities in Paradox Valley are the farming towns of Paradox (population 150) and Bedrock (population 90). Other nearby communities are Nucla (population 880), Uravan (population 650), and Naturita (population 760), all located on or near the San Miguel River east of the valley. The nearest commercial centers are Moab, Utah, 60 miles northwest of Bedrock; Montrose, Colorado, 70 miles northeast; Grand Junction, Colorado, 100 miles north; and Cortez, Colorado, 100 miles south of Bedrock.

Although relatively isolated, the area is served by a network of Federal and State highways and county and local roads. Colorado State Highway 90, Utah State Highway 46, U.S. Highways 163 and 6, and Interstates 15 and 70 provide access to Moab and Salt Lake City, Utah, about 300 miles northeast. Colorado State Highways 90 and 141, U.S. Highways 6 and 50, and Interstate 70 provide access to Montrose, Grand Junction, and Denver, Colorado (about 260 miles east of Grand Junction).

The nearest commercial rail service is located in Grand Junction and Montrose. Commercial air and bus service is available in Grand Junction, Montrose, Cortez, and Moab.

Agriculture is the main economic activity of the area. About 2,500 acres are under irrigation in the western half of Paradox Valley, where water supply is provided by local wells, West Paradox Creek, and Buckeye Reservoir in the La Sal Mountains to the northwest. Livestock and feeding livestock provide the principal source of income, although some barley is grown as a cash crop. The eastern half of the valley provides a limited amount of range in the winter and spring.

Mining also contributes to the local economy, but has recently declined considerably. Carnotite, a mineral containing vanadium and the radioactive elements uranium and radium, is mined on the mesas surrounding Paradox Valley. Most of the ore is shipped to a processing plant in Blanding, Utah. Brine from a private well is sold for use in local drilling operations.

Geology, Seismicity, and Tectonics

Paradox Valley lies on a northwest-southeast axis and has a relatively flat floor enclosed by steep walls of sandstone and shale. The Dolores River crosses the valley near its midpoint in a level and broad flood plain but flows through deep and narrow canyons both upstream and downstream from the valley. Elevations vary from about 5000 feet in the valley to about 6700 feet along the valley

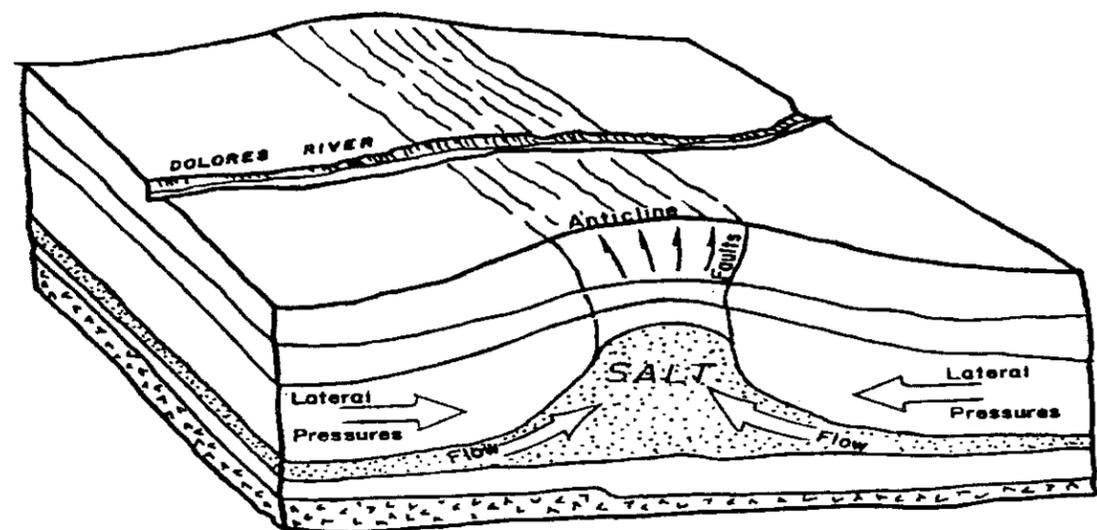
rim. The most prominent nearby features are the La Sal Mountains in the Manti-La Sal National Forest, which rise to an elevation of about 12,000 feet and border Paradox Valley on the northwest. The Dolores River picks up about 200,000 tons of salt annually, primarily for surfacing brine, in Paradox Valley, which lies along one of five major salt anticlines identified in southwestern Colorado and southeastern Utah. The valley was formed by the erosion of faulted and uplifted sandstone and shale formations, exposing a residual gypsum cap that covers approximately 14,000 feet of salt and salt-rich shale (Carter, 1970). Figure II-1 illustrates the development of the valley, which may have begun as long ago as 250 million years. The emergence of distant mountains on each side of the area placed lateral pressures on the intervening sedimentary formations, resulting in warping and fracturing along weak zones. Consequently, a deeply buried layer of salt began to flow upward into the fractured area, creating an elongated swell known as an anticline. The crest of the anticline has gradually collapsed as a result of the fracturing, and the Dolores River, combined with East and West Paradox Creeks and other erosional forces, has given the valley its present form.

The Dolores River has deposited considerable amounts of alluvium in the flood plain to replace soluble salts that groundwater has carried into the stream from the underlying salt formation. Measured at a depth of up to 129 feet in places, this material consists of silty sands on the surface and poorly graded sands with clay-filled gravels and cobbles appearing at increasing depths. Discontinuous clay lenses occur randomly throughout the deposits.

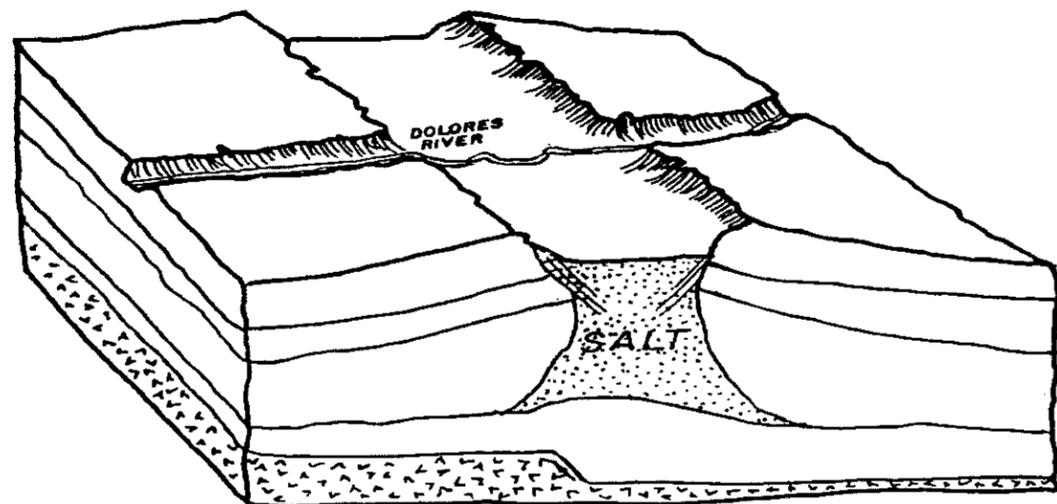
The deep well injection site, south of the Paradox salt anticline, is located so that the well bore penetrates all of the sedimentary rock formations and ends in the "basement" Precambrian rock. Figure II-2 shows the stratigraphic relationship of the rock units drilled through during injection well construction. The upper 14,068 feet of the bore, composed of all the Pennsylvanian, Permian, and Triassic Period formations, has been cased and grouted, isolating these from injected brine. The remaining 1,789 feet of the bore is the injection zone, with Mississippian-age Leadville limestone serving as the primary injection formation and lower Devonian- and Cambrian-age formations serving as secondary injection zones.

The geologic effects of deep-well injection of brine into the Mississippian-, Devonian-, and Cambrian-age formations underlying Paradox Valley are considered minimal. Based on the results of technical studies by Ken E. Davis Associates, Houston, Texas, Reclamation concludes that the Leadville, Ouray, and Elbert Formations have the desired characteristics for satisfactory long-term disposal of brine. These formations, 14,050 to 16,000 feet deep, are expected to have sufficient permeability and porosity to accept the injected brine under fracture pressure at the proposed flow rate. The in-situ formation water in this injection zone is already brine, and the injection of salt water from the brine well field would not affect a potentially usable source of potable water.

Injected brine would be expected to remain in the designated disposal formations, with no movement to the surface or to freshwater zones. Drilling for the injection well encountered 234 net feet of salt and 92 net feet of anhydrite in the Paradox formation overlying the injection zones. The 326 net feet of plastic evaporite section exceeds Environmental Protection Agency (EPA) requirements for an impermeable barrier necessary for an injection well to operate at fracture propagation pressure.



EARLY STAGE



PRESENT STAGE

PARADOX ANTICLINE
STAGES OF DEVELOPMENT
Colorado River Basin Salinity Control Project
Paradox Valley Unit

Figure II-1

PERIOD	FORMATION	LITHOLOGY	THICKNESS		
TRIASSIC	CHINLE		400		
	MOENKOPI		749		
PERMIAN	CUTLER		7190		
		PENN.	HONAKER TRAIL		3710
				LA SAL	77
				PARADOX	488
				ISMAY	268
				SALT	FLOWAGE ZONE 456
				PINKERTON TRAIL	123
				MOLDS	233
					49
				MISS.	LEADVILLE
DEVONIAN	OURAY			40	
	ELBERT	172			
	MCCRACKEN	21			
CAMBRIAN	LYNCH	223			
	MUAV	107			
	BRIGHT ANGEL	178			
PRECAMBRIAN	IGNACIO	175			
		511*			

STRATIGRAPHIC CHART OF PARADOX VALLEY UNIT
 Figure II-2

In addition to this barrier, the gross interval of 12,400 feet of Permo-Pennsylvanian shale, tight limestones and tight shaley, arkosic sandstones form another impermeable layer above the plastic evaporite barrier, creating a very effective barrier over the Leadville and deeper injection zones. Figure II-3 depicts the lateral extent of the confining salt or plastic evaporite layers and other confining rock formations above the Leadville injection zone. Operation of the Paradox Valley Unit would cause the injection formations to become abnormally highly pressurized in the immediate vicinity of the injection well. If future deep exploration occurs, the Bureau of Land Management (BLM) and/or the Colorado Oil and Gas Commission would specify in the lease that these pressurized conditions exist in particular locations in the Paradox Valley.

The Unit is located near the edge of the Colorado Plateau in an area of relatively few historic earthquakes. A total of 24 earthquakes within 150 kilometers (km) of the injection well site have been cataloged since 1850 by the National Oceanic and Atmospheric Administration. The largest of these events was a magnitude 5.5 earthquake that occurred in 1960 approximately 110 km due east of the well site near Ridgeway Colorado. The closest event to the Unit was a magnitude 2.6 event that occurred about 16 km north of the site in May 1989.

The apparent lack of historic seismicity near the Unit may be partly the result of very limited seismograph coverage of the area. Before the Paradox Valley Seismograph Network was installed in the Unit area in 1983, the closest seismograph stations were several hundred kilometers away. Only earthquakes greater than about magnitude 3.4 to 4.0 were routinely located in the area. The region is also sparsely populated and, therefore, many earthquakes could have occurred in the Unit area during historic times without being noticed or documented.

Water Resources

Streams

The major streams in the Unit area are the Dolores River and its largest tributary, the San Miguel River. Both exhibit the large seasonal fluctuations characteristic of streams in southwestern Colorado, with very high runoff during the spring because of melting snow in the mountains and very low flows after midsummer. Historically, the Dolores River was low and occasionally dry in Paradox Valley during the late summer and fall as a result of declining snowmelt runoff and large irrigation diversions in the upper part of the basin. However, occasional high flows of very short duration occur in the summer and fall from afternoon thunderstorms. As a result of the completion in 1988 of McPhee Dam and Reservoir, peak flows in the Dolores River have been reduced and low flows have been increased.

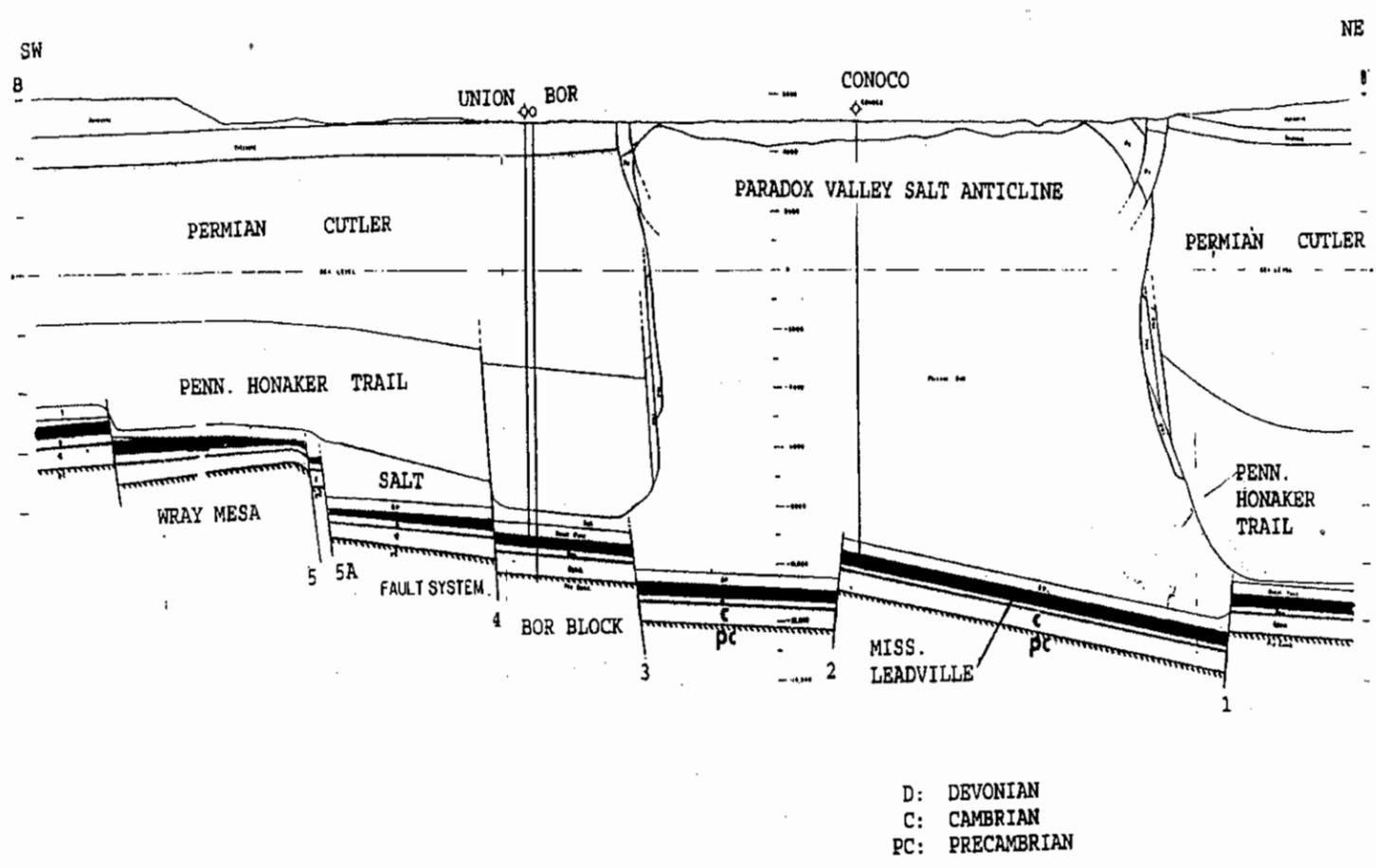


Figure II-3

9-II-6

CONFINING ROCK FORMATIONS ABOVE LEADVILLE INJECTION ZONE

Groundwater

Seeps and springs along the banks and beds of the Dolores River in Paradox Valley are of two general types: those with relatively fresh water, with salinity varying from about 1,500 milligrams per liter (mg/L) to 4,000 mg/L, and those with brine of about 250,000 mg/L. Water pumped from test wells near the river has a salinity of about 260,000 mg/L (Reclamation, 1978). The brine, which is nearly eight times as saline as sea water, consists almost entirely of sodium and chloride, with smaller amounts of sulfate, potassium, calcium, and other salts. Heavy metals, particularly iron and lead, and nonradioactive strontium are also present in limited amounts. Noticeable amounts of hydrogen sulfide gas are released into the atmosphere as the brine surfaces, creating a noxious odor.

As noted earlier, Reclamation studies indicate that groundwater contributes a total salt load of about 200,000 tons annually to the river, with daily values ranging from 100 to 1,430 tons. The brine evidently accounts for essentially all of the salt, since the seeps of relatively fresh water could contribute only about 16 tons per day at a flow rate of 4 cubic feet per second (cfs), estimated to be the maximum flow of all groundwater entering the river. However, at its estimated flow of 0.2 to 2.1 cfs and a salinity of 260,000 mg/L, the brine could produce 170 to 2,170 tons daily.

Climate

The climate of the Unit area is characteristic of semiarid southwestern Colorado, with low precipitation and humidity, abundant sunshine, moderately high evaporation rates, and wide ranges between daily low and high temperatures. The prevailing winds are from the southwest and are fairly strong in the spring.

Reclamation has maintained weather stations at Bedrock since 1975. From 1975 through 1989, the average annual precipitation in the Unit area has been about 8 inches. June is normally the driest part of the year, and July through October the wettest, primarily because of afternoon thunderstorms. Temperatures vary from daytime highs of more than 100 °F at Bedrock and 90 °F at Dry Creek Basin during July to nighttime lows of below -20 °F during January.

Vegetation

In the Paradox Valley vicinity, vegetation communities vary according to elevation, precipitation, soil, land use, and other factors.

Riparian vegetation composed of cottonwood is found along the Dolores River upstream from the brine seeps; below the brine seeps, the riparian community is characterized by tamarisk. Various forb and grass species make up the under story in the riparian communities. Marsh areas containing rushes are occasionally found along the river; a large wetland area exists where West Paradox Creek joins the Dolores River.

The greatest concentration of agricultural lands occurs in the western portion of Paradox Valley, where irrigated pasture, alfalfa, and small grains are the primary crops.

Extensive semiarid areas with saline soils are located in Paradox Valley. These semiarid areas are characterized by greasewood, seablite, winterfat, snakeweed, and other salt-tolerant species. Sagebrush occurs on higher slopes throughout the valley and, where overgrazing is not common, numerous species of grasses are found. Mesas and higher slopes support pinon-juniper woodlands.

Flood Plain and Wetland

A large wetland occurs on West Paradox Creek near the confluence with the Dolores River on its west side. Nearer the river, however, the vegetation becomes similar to that found on the east bank, predominantly tamarisk, which is low in density and randomly scattered. Flood plain and wetland communities along the Dolores River and West Paradox Creek will not be affected by Unit facility development.

Wildlife

Refer to the Environmental Assessment, Appendix A.

Fish

Refer to the Environmental Assessment, Appendix A.

Endangered Species

Refer to the Environmental Assessment, Appendix A.

Cultural Resources

Refer to the Environmental Assessment, Appendix A.

Chapter III Paradox Valley Hydrology

Water Resources

Surface Water

Surface water measurements for the Paradox Valley Unit (Unit) were begun in late 1971 with the establishment of three stream gaging stations; on the Dolores River at Bedrock where the river enters the valley, on the river near Bedrock where the river leaves the valley, and on West Paradox Creek, 2.6 miles above the creek's confluence with the river. Continuous flow measurements have been taken at the two stations on the river and the following discussion is based upon data for the full water years of 1972 through 1987. Measurements on West Paradox Creek were discontinued in 1973 because of difficulties maintaining the station, and records are available only for the full water years 1972 and 1973. No data have been obtained for East Paradox Creek, which is intermittent and has very little effect on the river. Table III-1 shows the average runoff in the vicinity of Paradox Valley.

Table III-1.—Average runoff in the Paradox Valley
(acre-feet)

	Dolores River October 1972 - September 1983		West Paradox Creek 1972-73	Dolores River October 1983 - September 1987	
	At Bedrock	Near Bedrock		At Bedrock	Near Bedrock
October	3,800	4,500	500	8,620	9,500
November	2,200	2,700	400	8,830	9,700
December	3,100	3,800	400	7,600	8,200
January	3,400	3,800	400	7,800	8,900
February	3,900	4,500	400	7,000	7,900
March	10,100	11,300	400	28,000	29,400
April	84,000	87,000	1,100	114,800	123,800
May	130,000	132,000	1,400	138,300	143,600
June	85,700	87,600	900	82,500	85,000
July	16,200	17,800	300	13,400	14,300
August	3,900	4,800	200	12,200	13,300
September	2,700	3,100	200	7,700	8,700
Total	349,280	363,550	6,600	436,700	462,300

The recorded flow of the Dolores River at Bedrock averaged 349,300 acre-feet annually during the period October 1972 through March 1984 when McPhee Reservoir began storing water. This compares to an annual average of 299,400 acre-feet for the period 1972-76 used in the 1978 Definite Plan Report (DPR). On the basis of the 1972-84 period of record, 86 percent of the annual average discharge of the Dolores River at the Bedrock gauge occurred during the months of April, May, and June from snowmelt runoff. The peak water year during the period was 1983, when 723,700 acre-feet of water were recorded at the Bedrock gauge. The lowest water year was 1977, when only 20,700 acre-feet were recorded. The maximum instantaneous discharge at the Bedrock gauge was 9,280 cfs, which occurred on April 30, 1973; the minimum has been no flow, which has been recorded on several occasions, including September 13, 1974, and August 15-18, 1978².

At the gauge near Bedrock, the Dolores River had an average annual flow of 363,550 acre-feet over the 1972 to 1984 period of record. This varied from a high of 748,400 acre-feet in water year 1973 to a low of 38,100 acre-feet in water year 1977. The increase of 14,250 acre-feet in average annual flow as the river crosses the valley can be attributed to inflows from West Paradox Creek, East Paradox Creek, and fresh and brine groundwater surfacing in the valley. Daily river flows were recorded at a maximum rate of 9,500 cfs on April 30, 1973, and a minimum rate of 0.12 cfs on July 17 and 18, 1977.

The annual flows of West Paradox Creek were recorded at 3,700 acre-feet in water year 1972 and 9,400 acre-feet in water year 1973 for an average of 6,600 acre-feet. Daily flow rates varied from a high of 82 cfs on May 4, 1973, to a low of 2.5 cfs on July 14 and August 23, 24, and 29, 1972. This stream does not generally have large variations in flow because the runoff is partially regulated by Buckeye Reservoir, a 1,600 acre-foot structure located northwest of Paradox Valley in the upper part of the drainage area. Water is stored in the reservoir during high spring runoff and released for irrigation in western Paradox Valley during the summer.

McPhee Reservoir, the principal feature of the Dolores Project (INT FES 89-10), has been predicted to decrease flows in the Dolores River in Paradox Valley during the spring runoff months, while increasing flows during the summer and fall.³ Table III-1 shows the monthly distribution of flow at the two Paradox Valley gauges. The discharge during the runoff months of April, May, and June is approximately 77 percent of the annual discharge. The equivalent figure in the pre-impoundment period was more than 85 percent. The increase in the flow between the two gauges during the 1984-88 period is 25,600 acre-feet, which is much greater than the 14,400 acre-foot average before any storage in McPhee Reservoir. The large increase would indicate that the basin as a whole received much greater than average runoff during the period. Despite any depletions caused by McPhee Reservoir, the average annual discharge at the Bedrock gauges is much greater than in the years preceding McPhee. These data do not represent the effects of the Dolores Project under full development.

² R.C. Uglund, J.T. Steinheimer, R.G. Kretschman, E.A. Wilson, and J.D. Bennett 1987. *Water Resources Data for Colorado, Water Year 1986*, Volume 2, Colorado River Basin. U.S. Geological Survey Water Data Report CO-86-2. Lakewood, CO. 448 pages.

³ Data collected since 1984, indicate that this has been the case, although the period of record is short and apparently not particularly representative of a long-term hydrologic record. Also, during this period, most facilities to deliver Dolores Project water were still under construction so depletions associated with the project did not occur.

Groundwater

Groundwater observations in the Paradox Valley were begun in 1971 with measurements of water table levels and piezometric heads in deep aquifers in private wells. To obtain additional information on subsurface geology and groundwater conditions, subsequent studies included drilling exploratory holes, drilling and pumping from test wells, and installing a network of observation wells and piezometers to monitor water table levels and piezometric heads.

Brine groundwater, which apparently underlies all of Paradox Valley, surfaces in and near the Dolores River channel in two general areas extending from the middle of the valley downstream to the river's exit from the valley. The depth to brine appears to increase upstream and west of the river, as indicated by measurements of brine at about 100 feet in an existing well located about a mile to the west. East of the river along the valley floor, the top of the brine layer is about the same level as the river, as measured in Reclamation's observation wells. Although it is impractical to directly measure the brine inflow to the river since it occurs as many small springs and seeps, Reclamation estimates that it varies from about 0.2 to 2.1 cfs and averages 0.8 cfs, based upon measurements of salt loading in the river. The flow exhibits a certain degree of seasonal fluctuation, generally reaching its lowest level sometime during spring or summer and its highest level during fall and winter.

A significant layer of comparatively fresh water overlies the brine in western Paradox Valley and is pumped from wells for irrigation. Estimated to be at least 100 feet thick about a mile west of the Dolores River, the lens gradually thins out closer to the river in the area of the surfacing brine. This water also surfaces as seeps and springs in the river and, combined with the brine, results in a total contribution to the river of between 1.5 and 4 cfs.

The brine and freshwater aquifers have a variety of potential recharge sources, including runoff from the La Sal Mountains, irrigation return flows from western Paradox Valley, seepage from West Paradox Creek, precipitation, and surface and subsurface runoff from the valley walls. Because brine evidently circulates over the top of the salt core at depths of 650 feet or more before surfacing, it probably originates from the farthest recharge source, while the fresh water originates from nearer sources.

Water Quality

Surface Water

Water quality data have been collected at the flow measurement gauges located at Bedrock as the Dolores River enters the valley and at the gauge near Bedrock as the river leaves the valley. In addition to these collection points, intermediate sites were established between these gauges with data collection since November 1981.

Samples collected from the Dolores River gauge at Bedrock had total dissolved solids (TDS)

concentrations that ranged from 110 to 2,000 milligrams per liter (mg/L). The lower readings usually occurred during the high spring runoff and the higher values during late summer and early fall. The data indicate the river has an average annual salt load of 141,000 tons as it enters Paradox Valley.

Samples collected at the gauge near Bedrock show a range in TDS from 120 to 20,850 mg/L. The annual salt load of the river at the gauge near Bedrock, as the river leaves the valley, has averaged 343,000 tons, or approximately 200,000 tons greater than the load at the gauge at Bedrock where the river enters the valley.

Using intermediate collection sites between the two gauging stations located at the river's entry and exit points from the valley, Reclamation has been able to deduce that this large salt load increase is contributed by groundwater and West Paradox Creek. The creek had an average salinity of about 1,000 mg/L, according to samples collected during the 1971-76 study period. Individual analyses ranged from a minimum of 260 mg/L during high runoff to a maximum of 1,970 mg/L during low runoff. The creek contributes an estimated 7,000 tons of salt—primarily of calcium and sulfate—annually to the Dolores River.

Groundwater

Reclamation studies indicate that brine groundwater accounts for essentially all the 200,000 tons of salt contributed annually to the Dolores River in the Paradox Valley. Samples of brine groundwater analyzed by Reclamation have varied in salinity from lows of 117,500 mg/L in an open pit one-half mile east of the river, to highs of 250,000 mg/L at brine seeps in the Dolores River channel, and up to 280,000 to 300,000 mg/L in wells drilled near the river. The variations probably result from different degrees of mixing with fresher groundwater in the area. About 94 percent of the TDS are sodium and chloride; other salts and heavy metals are present in comparatively small quantities. The brine also contains dissolved hydrogen sulfide gas at concentrations of more than 100 mg/L, which is released as the brine surfaces and causes an objectional odor at seepage areas and in open wells near the river. An analysis of brine pumped by Reclamation from production wells is shown in table III-2.

Table III-2.—Reclamation lab data averages per well; 1983-86
(mg/L)

Well number	2E	3E	4E	5E	7E	8E	9E	10E	11E	12E	13E	10W
TDS	254,912	255,780	253,801	252,466	271,489	275,534	250,300	242,483	210,638	245,492	250,557	243,653
EC lab, μ Mhos	232,444	232,726	241,071	239,549	323,177	228,770	239,660	228,147	213,676	227,572	224,688	234,576
pH lab	7.3	7.2	7.3	7.3	7.2	7.2	7.2	7.3	7.3	7.4	7.4	7.3
Calcium, Ca ⁺⁺	1,429	1,430	1,502	1,446	1,323	1,408	1,444	1,428	1,263	1,348	1,252	1,353
Magnesium, Mg ⁺⁺	1,619	1,630	1,686	1,751	1,944	1,641	1,628	1,747	1,500	1,752	1,772	1,742
Sodium, Na ⁺	93,744	93,586	93,376	92,683	100,309	94,963	91,551	89,296	77,141	90,640	92,543	88,953
Potassium, K ⁺	4,042	4,184	4,230	4,351	4,532	4,222	4,191	4,194	3,720	4,379	4,349	4,497
Chloride, Cl ⁻	148,360	149,174	147,259	146,533	157,782	149,550	145,923	139,972	122,072	141,670	145,207	141,706
Sulfate, SO ₄ ⁻	5,614	5,669	5,643	5,601	5,503	5,662	5,455	5,559	4,841	5,432	5,338	5,300
Bicarbonate, HCO ₃ ⁻	202	206	205	197	184	172	210	188	200	181	186	199

The layer of relatively fresh groundwater overlying the brine west of the river has a salinity ranging from 1,400 to 4,000 mg/L, depending upon location and time of year. Water from irrigation wells has varied in quality from 1,400 to 3,500 mg/L, and fresh water seeps along the river have varied from 1,500 to 4,000 mg/L. The predominant salts are calcium, magnesium, and sulfate, but large amounts of sodium and chloride are also found in water samples collected near the river because of mixing with the brine.

Efforts to characterize the immediate effect of brine pumping and disposal on salinity levels in the Dolores River have been made during testing of Unit facilities. In general, whenever the brine wells are pumped, the TDS level in river samples declines downstream from the brine well field. However, because of the many variables associated with quantifying the exact effect pumping has on the river's salinity, such as base salt load conditions, river flows and groundwater flow into the river, Reclamation has not considered these characterizations to be a valuable measure of the Unit's effectiveness. Instead, Reclamation has determined that any quantity of groundwater brine intercepted and disposed of is equal to a quantity that would eventually find its way to the river and thereby increase the river's total salt load. Therefore, the Unit's effectiveness is simply measured by the amount of brine and corresponding tons of salt pumped from the brine well field.

During the 233-day test conducted from August 1995 to March 1995, 66,868,070 total gallons of brine, with a salinity content averaging 260,000 mg/L, were pumped from the brine well field and disposed of in the deep-injection well. The corresponding quantity of salt prevented from entering the river was then 72,570 tons for this test injection period.

Potential for Scale Formation

The Paradox Valley brine, the resident Leadville formation brine, and cores from the Leadville formation were evaluated to determine their chemical compatibility and the potential for scaling problems under injection conditions. Experts from the Geological Survey, Oak Ridge National Laboratory, and Idaho National Engineering Laboratory directed the necessary studies and developed and evaluated alternative solutions. Table III-3 contains an analysis of the formation water.

The brine to be injected is predominantly a sodium-chloride type brine with high concentrations of sulphate and relatively high concentrations of potassium, magnesium, and calcium. The brine is close to saturation with calcium-sulphate at groundwater temperature. However, because the solubility of calcium-sulfate decreases with increasing temperature, the injected brine would become highly supersaturated under injection conditions of approximately 240 to 250 degrees Fahrenheit.

The primary injection zone is the Leadville formation, consisting mainly of calcite and dolomite, with dolomite predominant in the more highly fractured and weathered zones. Because the concentrations of magnesium in the injected brine are relatively high and the thermodynamic constraints are favorable, the dissolved magnesium would react with the calcite portions of the injection formation to form dolomite and add calcium to solution. The additional calcium would increase the potential for calcium-sulfate scale formation.

Table III-3.—Chemical composition of formation water
 Paradox Valley injection well (sample 88PVB-124)

pH	5.42	Mn	1.13 mg/L
Mg	1,200 mg/L	HCO ₃	148 mg/L
Ba	8.32 mg/L	TDS	218,000
Br	257 mg/L	K	2,100 mg/L
B	19.1 mg/L	Sr	433 mg/L
Na	70,000 mg/L	Fe	2.1 mg/L
Ca	10,900 mg/L	SO ₄	454

The resident formation brine is also predominantly a sodium-chloride type brine but with a much higher calcium concentration, a much lower sulfate concentration, and a somewhat lower magnesium concentration than the injected brine. Mixing of the brines under injection conditions would result in increased formation of calcium-sulfate scale due to the high sulfate concentration in the injected brine and the availability of additional calcium.

Numerous alternatives to prevent the formation of calcium-sulfate scale were developed and evaluated. Several commercially available scale inhibitors were evaluated under injection conditions but none appeared to be effective in preventing scale formation. Methods to remove sulfate from the brine before injection were evaluated but did not appear feasible due to the required addition of large quantities of chemicals to initiate precipitation and the required disposal of large volumes of precipitate. The selected alternative incorporated in the project plan consists of preventing mixing of the formation brine and injected brine, and diluting the brine to be injected to lower the sulfate concentration.

To prevent mixing of the formation brine and the injected brine, preliminary injection tests were conducted using fresh water. This provided a buffer between the resident brine and the brine that was later injected to prevent any mixing from occurring near the well bore. Intermediate injection tests were conducted using a mixture of two-thirds fresh water and one-third brine. This dilution provided the necessary chemistry to promote dolomitization of calcite (useful to increase porosity) near the well bore without precipitation of calcium-sulfate. Later injection tests used a mixture of two-thirds brine and one-third fresh water, a dilution sufficient to prevent precipitation of calcium sulfate due to increased temperatures of injection conditions. The project plan is to operate with this mixture until a more feasible method of sulfate concentration reduction is developed.

Chapter IV Unit Development

General

The Paradox Valley Unit (Unit) is designed to control salinity in the Dolores River by pumping brine groundwater from a well field located along the river in Paradox Valley to prevent it from surfacing in the river bed. The 1979 Definite Plan Report (DPR) provided for disposal of 5 cubic feet per second (cfs) of brine by pumping it through a series of lift stations and pipelines to an evaporation reservoir some 20 miles southeast of the well field. After the 1979 DPR plan was formulated, local groundwater studies conducted by Reclamation, indicated that disposing of 1.5 to 2.0 cfs of brine would probably meet the Unit's goal of reducing the salt load in the Dolores River by 90 percent, or 180,000 tons per year. The geology of the area indicated that this reduced quantity of brine might be disposed of by deep well injection, a previously identified preferable alternative for disposal of the brine. Consequently, an access road, brine treatment facility, brine transfer pipeline, surface injection facility, and test injection well were constructed to verify the feasibility of disposing of the brine by deep well injection. Testing of the well is complete, with results indicating that this method of brine disposal is physically and economically feasible.

Future-year construction of the additional facilities needed to realize the Unit's original salinity reduction goal of 90 percent is not foreseeable, due to construction funding limitations. To realize a significant salinity control benefit from the present investment, the test injection facility would be operated as currently constructed. The Bureau of Reclamation (Reclamation) estimates that the test injection facility, operated as a permanent facility, would effectively remove up to 128,000 tons of salt annually, or about 64 percent of the salt now entering the Dolores River in Paradox Valley. This estimate is based on the present facility's operational guidelines of limiting injection to a 70 percent brine/30 percent freshwater mixture at the rate of 400 gallons per minute (gpm), with a plant factor goal of 80 percent. Reclamation's Western Colorado Area Office would administer the facilities for salinity control and be responsible for their annual operation, maintenance, and replacement.

Project Features

Brine Well Field

Production Wells

Twenty-four brine production wells were constructed as part of the design data collection and verification program. Twenty-three of the wells were drilled into the alluvial aquifer of sand and gravel to depths of between 48 and 77 feet. The remaining well extended into cavities in the residual gypsum cap to a total depth of about 155 feet. The diameter of the wells varied from 8 to 12 inches, with the lower 15 to 40 feet consisting of well screens to allow the brine groundwater to enter. Gravel packing was placed around each well screen to stabilize the wells and prevent fine sand from

entering the screens. Submersible electric pumps, varying in capacity from 0.03 to 0.3 cfs, were installed in the wells along with brine level monitors to aid in optimizing production from the individual wells.

Data collected during the brine well field testing program indicated that only 10 of these wells—located on the east side of the river—would be required to supply the 1.5 cfs needed to achieve the Unit's original goal of reducing the salt inflow to the Dolores River by 180,000 tons annually. As a result of this information, these 10 wells were modified and used as permanent brine wells during the injection well test. Modifications included installation of additional pump control equipment, upgraded access roads, construction of high-density polyethylene pipelines to connect each well to the surface treatment facility, and permanent security fencing. Thirteen of the original 24 brine wells, on both sides of the river have been or will be plugged and abandoned. One well, on the east side of the river and not connected to the surface treatment facility, would be kept available for future contingencies.

In addition to the production wells, 68 groundwater monitoring wells have been drilled on both sides of the river, cased, and equipped with security caps. Water levels are checked in the wells during project operations and the data are used to determine what effect pumping the brine production wells has on the water table, how the freshwater and brine interact, and how brine moves within the aquifer. From this information, the most effective pumping rates and patterns for operating the production wells are established. These wells may be equipped with automatic recorders in the future as a refinement to allow continuous measurements and operation adjustments.

Injection well testing used about .62 cfs of brine pumped from various combinations of the 10 production wells on line. Because this volume of brine was well below the proven 1.5 cfs capability of the 10 wells, the present well field should be adequate for long-term operation. Long-term operation of the facility and subsequent well field monitoring data would enable the construction of a complete brine well field groundwater model. This model would develop optimum pumping schemes and identify well field modifications which would maximize salinity control benefits from the Unit as constructed.

Monitoring Wells

The monitoring wells are of two different categories. The first category consists of 39 shallow observation wells, generally about 25 feet deep and 1.5 inches in diameter, with 10-foot well screens placed between 10 and 25 feet deep to allow groundwater to enter. These wells are used to observe the water table and to measure changes in conductivity, an indicator of the interface between the brine and freshwater. The second category consists of 29 deep wells, each containing three pipes. Each pipe extends to a different depth and has a section of well screen at the bottom. A shallow pipe, screened from the 5- to 25-foot zone, is used to observe the water table and the point at which the brine and freshwater interact. A second pipe, screened near the base of the alluvial aquifer (between 56 and 120 feet deep), is used to measure the brine piezometric head in that zone. A third pipe, screened in the gypsum bedrock between 215 and 300 feet deep, is also used to measure the piezometric head of the brine. A grout seal has been placed between the pipes to prevent water from the three different zones from intermixing.

Surface Treatment Facility

The brine from individual well field production wells is piped to a central surface treatment facility adjacent to the well field on the east side of the Dolores River. This facility, constructed as part of the deep well injection testing program, consists of a 1.5-acre site where process equipment is housed in a prefabricated metal building with concrete masonry exterior walls. At this location, brine from the individual wells is combined into a single stream, then filtered and transferred to one of two 25,000-gallon buried storage tanks. A 60-horsepower turbine pump in each tank pumps the brine through a second filter and to the injection facility. The treatment facility also serves as the control center for the individual production wells. Equipment to monitor the rate of pumping, brine well water levels, pressure, and brine quality for each well is located within the facility along with program logic control devices to automatically control individual well operation. With proper maintenance, the equipment located within this facility is adequate to allow its use for long term brine injection without additional construction.

Brine Transfer Pipeline

Brine from 25,000-gallon tanks located at the treatment facility, is carried to the injection facility 3.5 miles to the south, in a buried, 10-inch high-density polyethylene pipeline. This pipeline was constructed for use during the deep well injection testing program and is satisfactory for permanent service.

Brine Injection Components

Brine Injection Facility

The Brine Injection Facility was also constructed as part of the deep well injection testing program. The injection facility is located adjacent to the injection well on the 6.5-acre, graded, and fenced site that was used during the injection well drilling. Components of the facility consist of a 50-by-80-foot prefabricated metal building with concrete masonry exterior walls for housing controls and injection pumps, a water treatment plant with associated storage tanks and ponds, and a Well Annulus Monitoring System (WAMS).

Brine from the brine transfer pipeline enters one of two 25,000-gallon buried, pressurized storage tanks at the injection facility. One tank is required for operation and the second serves as a backup to allow for maintenance during continuous operations. Fresh water which dilutes the brine to 70 percent (70 percent brine, 30 percent fresh) is added at the tank location to control calcium sulfate precipitation. Equipment necessary for additional chemical treatment has been installed at the tank location, but operations to date have required only the addition of a chemical oxygen scavenger to help reduce the corrosive effects of the brine on pumping equipment.

The tanks are equipped with 20-horsepower turbine pumps to transfer the diluted brine through a filter and through pressure-, temperature-, and flow-monitoring equipment to the intakes of the four injection pumps. These 350-horse power, alternating current, 100 gallons per minute (gpm) (each)

positive displacement pumps are used to increase injection pressures up to 5,000 pounds per square inch (psi). These large pumps can be operated singly or in tandem, allowing for maintenance. The pressurized brine flows to the injection well through a 5-inch-diameter nickel-alloy pipeline. During the injection well test, deficiencies in injection facility equipment caused interruptions in the test schedule. The deficient equipment has been modified and tested in continuous, 24-hour operation for 8 months. With proper maintenance, the presently constructed injection facility could be operated at an 80-percent plant factor as a permanent facility for the injection well.

Water Treatment Plant

The water treatment plant, located at the injection facility, pumps water from the Dolores River and provides the water necessary for diluting brine to 70 percent. The plant also provides facility service water. The plant has a 200-gpm capacity and consists of a lined flocculation pond; filter tanks; six 12,500-gallon, above-ground, treated-water storage tanks; a facility service water chlorination system; and a lined backwash pond.

Well Annulus Monitoring System

The Well Annulus Monitoring System (WAMS) consists of a fluid storage tank, triplex positive displacement pump for maintaining pressure, and electronic monitoring equipment to automatically adjust the pressure. The system is designed to maintain fluid pressure in the annulus between the wells exterior casing and the injection tubing down to the top of the injection zone. By pressurizing the annulus fluid, brine is prevented from entering the annulus space and the injection well can be operated. The annulus was originally designed to be filled with a static fluid which could be monitored with pressure gauges to detect leaks in the injection tube. Immediately after construction, a leak was detected in the polished bore receptacle at the top of the injection zone. Due to the high cost of repairing this defect, a decision was made to maintain pressure on the annulus fluid which would exceed the injection pressure.

Injection Well

Pressurized 70-percent brine from the injection facility enters the injection well at ground surface level and is carried through upper geologic formations in a 5-1/2-inch-diameter Hastelloy C-276 injection tube to a perforated injection liner which extends through the geologic formations identified as the injection zone. The brine leaves the injection liner and is permanently disposed of within the surrounding injection formation which serves as the injection reservoir.

Test Injection Well No.1 was drilled to a depth of 15,857 feet. The drill hole was cased with 30-inch-diameter casing through the surface formations and with 9-5/8-inch casing to the top of the injection formation at 14,068 feet. A perforated 5-1/2-inch-diameter, Hastelloy C-276 injection liner extends through the injection formation to the well's bottom depth. While the primary injection zone formation is Mississippian Age Leadville limestone, which lies directly below the salt formation, the injection zone extends through Devonian Age formations and into the Precambrian Formation.

This well and its injection reservoir formation have successfully disposed of a 70-percent brine at the rate of 400 gpm during the injection well test. The results of data collected during the injection test indicate that the well and its associated surface equipment would be capable of disposing of similar quantities of brine for at least 10 years and perhaps indefinitely.⁴ Should the injection formation begin to refuse acceptance of the brine, the pressure necessary to inject would increase. This would make the present equipment incapable of performing, or the facility would have to be operated at reduced injection rate that would no longer be cost effective. Should this situation occur, the Unit's future participation in the salinity control program would be examined and the Unit's facilities either abandoned or replaced with equipment needed for continued operation.

Electrical Power

A 69-kilovolt (kV) powerline, connecting existing lines near Colorado Highway 90 with the injection facility 1.2 miles to the south, was constructed for the injection well testing. A substation and transformer yard constructed near the injection facility enclosure compound is the terminal end of the line. The alternating current obtained from the transformers is converted to direct current (DC) power for use by the injection pumps with three silicone controlled rectifiers installed within the injection facility building.

The presently constructed power system is adequate to operate the Unit as a permanent injection facility.

Access Road and Office Facility

As part of the injection well test, a 20-foot-wide, 1.2-mile-long, gravel access road was constructed from Colorado Highway 90 to the injection well site. At the same time, at a site about .8 mile from and adjacent to the highway, a 1-acre parcel was graded, graveled, fenced, and equipped with water, power, sewer, and telephone utilities for mobile housing units which served as an office and living quarters during construction. The access road and office compound are adequate as constructed for permanent injection operation needs.

Seismic Monitoring Network

The Paradox Network is a 15-station, high-gain, radio-telemetered, seismic network operating near the Unit (see figure 1 of the Environmental Assessment). It was originally installed with the primary objective of determining the background level of naturally occurring seismicity near the deep well injection site before fluid injection began. Other associated goals during the preinjection phase included determining the state of stress in the crust and the corresponding likelihood of earthquakes being induced by injecting salt brine. The network would be continuously operated and maintained as presently configured for as long as the injection well is used. This precautionary provision would

⁴Envirocap Report of Evaluation

ensure the Unit is operated responsibly with respect to any seismicity in the region.⁵

Beginning 50 km east of the Paradox Network is the Ridgway Seismograph Network (Ridgway Network), an array of seven stations comprised of instrumentation identical to that used in the Paradox Network. Recorded and processed simultaneously with data from the Paradox Network, the Ridgway Network data enhances the Paradox Network analysis. The Ridgway Network expands the seismograph coverage of interest in defining earthquake hazards for the Unit and provides important data necessary to determine focal mechanisms of earthquakes near the Unit.

Dolores River Monitoring System

A river monitoring system was installed by Reclamation during the design data acquisition program and has been used to assess changes in streamflow and water quality occurring as a result of removing the brine groundwater. The system includes four electrical conductivity meters installed along the east side of the Dolores River within and upstream and downstream from the well field. These meters operate automatically to provide a continuous record of any changes in conductivity as the river flows through the valley. The conductivity readings, in turn, are indicators of the amount of salt in the water flowing past the meters and provide an estimate of the effect of brine pumping on reducing the salt load of the river. The other features of the monitoring system include two gauging and water-quality monitoring stations located where the Dolores River enters the valley upstream from the Unit and where it exits the valley downstream from the Unit. These stations provide a continuous record of flows in the river and continuous conductivity readings. Water samples are taken from these two locations and analyzed for exact water quality data. The system, as constructed, can be operated with the Unit's other features to provide information necessary for effective operation.

⁵ Analog seismic signals detected at each station are transmitted continuously via VHF or UHF radios, microwave, and telephone circuits to a central recording facility in Denver, Colorado, where the signals are digitized and interrogated. Suspected earthquakes are stored for future processing after being automatically reduced and analyzed for origin time, hypocentral location, and magnitude. Results from this initial process are typically available within 3 to 5 minutes from when the event occurs. The present network configuration can determine epicentral location to a precision of +/-0.1 to 0.2 km and focal depth to less than +/- 0.5 km for earthquakes that may occur near the injection well. Earthquakes as small as magnitude 0 can be detected and located within the interior of the Paradox Network.

Protection of Unit Works from Flood Hazards

The only project feature located in a flood hazard area is the brine well field. This feature has been designed and constructed to be protected from a 100-year flood event by locating surface electrical and mechanical equipment above the event's highest water level. Such a flood would have no effect on the below-ground-level components of the well field.

Water Rights, Permits, and Augmentation Plan

Reclamation obtained a conditional water right for 4.94 cfs with an appropriation date of April 1972 (Case No. W3549). In 1986, Reclamation obtained approval for *Changes in Water Rights and a Plan for Augmentation* in U.S. District Court, Water Divisions 4 and 7 (Cases No. 4-83CW45 and 7-83CW14; respectively). The augmentation plan would allow water to be stored in McPhee Reservoir and released to replace depletions in the Dolores River resulting from out-of-priority pumping of the brine production well field. In addition, Reclamation has obtained a water right for 10 gpm for domestic purposes for use at the Unit surface treatment and injection well facilities.

Reclamation has obtained a Class V injection well permit pursuant to Underground Injection Control Regulations of the Environmental Protection Agency.

Mineral Rights

Although Reclamation has determined that brine pumped by Unit is not a mineral, one mineral-right holder in the vicinity did contact the agency with the concern that operation of the injection well would affect his ability to use the brine. Reclamation was able to agree with this holder to provide a source of brine at the brine well field, provided that no salt or brine would be allowed to enter the river or groundwater system as a result of this use. Mineral rights in the vicinity of the injection well were acquired with the purchase of the 388 acres surrounding the injection well facility.

Rights-of-Way

Reclamation has a rights-of-way grant from the Bureau of Land Management (BLM) (C-27756) covering facilities in the brine collection well field, the brine storage pond area, and seismic stations. Reclamation has received an amendment to this grant for the following: (1) a 100-foot-wide, 2750-foot-long right-of-way on BLM land located north of Colorado Highway 90; (2) a 100-foot-wide, 310-foot-long right-of-way located south of Colorado Highway 90; and (3) two additional seismic stations.

Reclamation has obtained permits from the U.S. Forest Service and the Utah State Forest Service to place seismic stations and one repeater station on lands administered by these agencies.

Reclamation has acquired 565 acres in fee title and 150 acres of easements from private landowners for the remainder of the Unit features. No additional rights-of-way are anticipated for permanent

operation of the Unit as it is currently constructed.

Cultural Resources Program

Refer to the Environmental Assessment, Appendix A.

Wildlife Program

Refer to the Environmental Assessment, Appendix A.

Operation and Maintenance

General

The facilities constructed to conduct the deep well injection test would be operated and maintained by Reclamation as the Unit's participation in the Colorado River Basin Salinity Control Project (CRBSCP). The components, including the brine production wells, monitoring system, surface treatment facility, brine pipeline, brine injection facility and injection well would be operated from the control room located at the injection facility by an operator, assistant operator, and automatic control equipment. Information on the operating conditions of these facilities and malfunction warnings would be telemetered to the control room so that adjustments and maintenance can be made promptly. In addition to periodic checks and maintenance of equipment, normal operations would include readings at the monitoring wells, stream gauging stations, and water-quality stations in Paradox Valley.

Most equipment replacements for the Unit would be part of normal maintenance. The facilities constructed for the deep well injection test were equipped with backup or standby equipment to allow for continuous operations when repairs to malfunctioning equipment is required. Using this same equipment for permanent operations, continuous or near-continuous injection of brine could occur year round. The individual brine wells in the well field can be shut down for repairs and maintenance without affecting the other wells, making continuous brine production possible.

Power

The power requirements of the Unit would be approximately 7 million kilowatthours (kWh) annually, with a demand requirement of 1,000 kilowatts (kW). These requirements are based on historical data from the deep well injection test with the Unit injecting 1 cfs, an 80-percent operating factor, and the present Colorado River Storage Project (CRSP) rates of 8.9 mills per kWh and \$3.83 per kilowatt-month, with a wheeling rate equivalent of approximately 11.5 mills per kWh.

Unit Costs

Construction Costs

With completion of the deep well injection test, construction of the Unit is considered complete. Additional construction, if needed to optimize production or increase the Unit's effectiveness for salinity control, would require additional appropriations. The construction cost for the presently constructed facilities is capped at \$68,736,170. Return from this investment can be realized without expenditure of additional construction dollars by operating the test injection facilities as the permanent facility.

The life of the Unit would be dependent upon the injection well reservoir capacity, which is unknown. When the present injection reservoir is filled, pumping pressures and related costs would increase. Ultimately, the costs of operating the Unit could make use of the facilities impractical, at which time the Unit would be abandoned or revitalized with a second injection well. The as-constructed costs of the present facilities are shown in table IV-1.

Table IV-1.—Deep well injection (proposed action) estimated costs
(October 1994 dollars)

Description	Actual cost through FY94 ¹	Estimated future costs ²	Total cost
Brine well field	3,683,310	0	3,683,310
Brine pipeline	1,851,362	0	1,851,362
Surface treatment facilities	9,227,663	1,575,000	10,802,663
Deep injection well	28,012,091	1,075,000	29,087,091
Permanent operating facilities	40,067	0	40,067
Operation and maintenance housing	36,141	0	36,141
Service facilities	652,987	0	652,987
Depreciation and salvage	<570,846>	0	<570,846>
Investigations and abandoned works through 1986	19,238,543	0	19,238,543
Emergency reserve O&M fund	455,600	0	455,600
Wildlife mitigation	60,136	0	60,136
O&M during construction	2,208,415	0	2,208,415
Other noncontract costs ³	1,190,701	0	1,190,701
Total cost	66,086,170	2,650,000	68,736,170
Annual equivalent cost of construction ⁴			5,457,714
Annual operation, maintenance, replacement, and power costs			3,300,000
Total annual costs			8,800,000
Annual cost per ton of salt removed ⁵			69

¹ From PF-2B (working version) - revised date: 12/28/94.

² Based on FY95 estimate of \$2,350,000 and FY96 estimate of 300,000. (75-percent surface facilities and 25-percent injection well).

³ Includes actual office general expense, materials, and equipment, etc., from PF-2B.

⁴ Based on 50-year life at 7.75-percent interest rate.

⁵ Based on estimated 128,000 tons of salt removed per year.

Annual Operation, Maintenance, and Replacement Costs

The annual operation, maintenance, and replacement (OM&R) costs of the Unit are estimated at about \$3.3 million annually for operating the existing facility (based on injection test data and 1994 prices).

Financial and Economic Analysis

Benefits

Benefits from the operation of the test injection well facility as a permanent injection well facility would accrue to users of Colorado River water both within and outside the Colorado River Basin. Presently, the indexed annual value is \$334 for each ton of salt removed.⁶ Salt reduction expected from operating the presently constructed facility is 128,000 tons annually, resulting in annual benefits of \$42,752,000.

Water users outside the Lower Basin would also benefit from the salinity reduction in Paradox Valley and from other units of the basin-wide salinity control program. Some of the benefits would occur directly, such as those that would be realized by users of water for culinary purposes and for irrigation. Additional benefits would occur indirectly, particularly those accruing to users of fossil or other fuels processed with Colorado River water. Because of the widespread and diffuse nature of these benefits, however, they cannot be fully quantified in monetary terms.

Cost Per Ton of Salt Removed

The annual cost for each ton of salinity reduction for operating the present facility as the Unit's contribution to the salinity control effort is shown in table IV-1 and is based on the annual equivalent cost and an estimated annual reduction of 128,000 tons of salt. The annual equivalent cost consists of the sum of the annual value of the capital investment amortized over 50 years at a 7.75 percent interest rate.

Table IV-2 displays the cost allocation and repayment summary for the presently constructed facility. The reimbursable amount for construction and OM&R would be \$2,180,000 annually. Annual nonreimbursable costs total \$6,577,000.

⁶ Derivation of the interim salinity value of \$257 (1986 dollars) per ton is outlined in a Reclamation memo, *Interim Salinity Control Benefit Value (Salinity Control Coordination, May 4, 1993)*. This figure, which is based on direct benefits only, was indexed to January 1993 dollars (\$334) using the consumer price index.

Table IV-2.—Cost allocation and repayment summary
 deep well injection (proposed action)

Cost allocation ¹	October 1994 construction costs	Annual OM&R costs
Total construction cost and annual OM&R	68,736,000	3,300,000
Repayment		
Reimbursable		
Lower Basin Fund	14,510,000	701,000
Upper Basin Fund	2,180,000	124,000
Total reimbursable costs ²	17,070,000	825,000
Annualized reimbursable construction cost	1,355,000	
Total annual reimbursable (construction plus OM&R)	2,180,000	
Nonreimbursable		
Total nonreimbursable costs	51,666,000	2,475,000
Annualized nonreimbursable construction cost	4,102,000	
Total annual nonreimbursable (construction plus OM&R)	6,577,000	
Total annual cost (reimbursable plus nonreimbursable)	8,758,000	

¹ Total cost allocation includes interest during construction.

² Public Law 93-320, section 205, states that 75 percent of the costs will be nonreimbursable. The other 25 percent is divided between the Lower Colorado River Basin Development Fund and the Upper Colorado River Basin Fund based on benefits to be derived by each basin for the use of water of improved quality, causes of salinity, and availability of revenues, provided that costs allocated to the Upper Basin shall not exceed 15 percent of the costs allocated to the Upper and Lower Basin funds. The costs to which the percentage division is applied do not include \$456,000 of pre-authorized costs which are nonreimbursable pursuant to Public Law 92-149.

Cost Allocation and Repayment

In accordance with the Colorado River Basin Salinity Control Act, 75 percent of the total costs of construction and OM&R for each of the four authorized units of the salinity control program would be nonreimbursable. The remaining 25 percent would be reimbursable and would be allocated between the Lower Colorado River Basin Development Fund and the Upper Colorado River Basin Fund, with no more than 15 percent of the reimbursable costs allocated to the Upper Basin fund. The authorizing legislation also directs that the Secretary of the Interior, after consulting with representatives of the Basin States who form the Colorado River Basin Salinity Control Advisory Council, make the final allocation of reimbursable costs on the basis of the benefits to be derived in each basin, the causes of salinity, and the availability of revenues in the two basin funds. The reimbursable costs would be repaid without interest within a 50-year period after the Unit became operational. The nonreimbursable costs and the reimbursable costs to be repaid from each basin fund

are shown in table IV-2 based upon an allocation of 15 percent of the reimbursable costs to the Upper Basin fund and 85 percent to the Lower Basin fund. The costs of the cultural resources program would be nonreimbursable under Public Law 93-291.

The Secretary of the Interior is authorized by the Salinity Control Act to increase the rates charged for electricity generated by the CRSP to provide revenues for repayment of the Upper Colorado River Basin's share of the reimbursable costs of the Paradox Valley Unit and other units authorized by the Act. Rates chargeable to cover such costs were included in a rate schedule announced by the Assistant Secretary of the Interior. The nonreimbursable portion of the annual OM&R costs would be funded by annual Congressional appropriations.

Chapter V Alternatives

Introduction

As presented in the Paradox Valley Unit (Unit) 1978 Definite Plan Report (DPR), the Bureau of Reclamation (Reclamation) studied several methods of reducing the salt contribution from Paradox Valley to the Colorado River system. Several of the options studied were based on the presumption that 5 cfs of brine must be pumped and disposed of to achieve the Unit's 90-percent salt loading reduction goal. The 1978 DPR concluded that the Radium Evaporation Pond Alternative would be the preferred alternative, because (1) the geologic stratum into which the brine would be pumped, under the injection well alternative, would not accept 5 cfs of brine and (2) the economics of the other alternatives made them undesirable. However, the 1978 DPR did state that the deep well injection alternative would warrant further investigation to determine its feasibility if the pumping rate required to achieve the Unit's goal was found to be as low as 2 cfs.

Subsequent testing of the brine well field showed that a pumping rate of 1.5 cfs was adequate to achieve the Unit's salinity reduction goal. As a result, the deep well injection method of disposal was thoroughly investigated and tested. The test has concluded that the test facility used to investigate deep well injection is capable of disposing of about 128,000 tons of salt, or 64 percent of the total salt entering the Dolores River in the Unit area.

In addition to the Proposed Plan, three alternatives are discussed in this chapter: (1) a No Action alternative; (2) construction of a second injection well, which would allow the Unit to meet its original 90-percent salinity reduction goal; and (3) construction of a downsized Radium Evaporation Reservoir capable of disposing of the entire 1.5 cfs of brine necessary to achieve the Unit's original goal of a 90-percent salinity reduction, or 180,000 tons of salt.

Proposed Action—Continue Operation of Test Injection Well

The proposed action is to continue operating the already-constructed test injection well facility described in chapter IV as the Unit's permanent contribution to the CRBSCP.

No Action Alternative

The No Action Alternative would be to abandon the present facility and discontinue efforts to control salinity from the Unit area. Approximately 200,000 tons of salt would enter the Dolores River annually from the brine water inflows located in the Paradox Valley. Other methods of limiting the salinity of the Colorado River would be needed to meet the goals of the Federal salinity control

program, and no benefit would be realized from the nearly \$69,000,000 investment in the Unit to date. Abandoning the present facility would require an additional \$300,000 in estimated construction costs to plug the injection well, most of the brine production wells, and observation wells in the brine well field. Plugging these wells would be necessary because existing regulations do not permit wells to remain open if they are not used and maintained. The costs of dismantling structures and performing environmental restoration have not been determined and are not included in the plugging cost.

PARADOX VALLEY UNIT

FINAL ENVIRONMENTAL ASSESSMENT

Appendix A

ENVIRONMENTAL ASSESSMENT

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Paradox Valley Unit
Supplemental Definite Plan Report/Environmental Assessment

Introduction

The Paradox Valley Unit (Unit) of the Colorado River Basin Salinity Control Project is located in southwestern Colorado and is designed to control natural brine inflows into the Dolores River. The Valley overlies a fractured gypsum cap that covers a formation of salt and salt-rich shale that begins at a depth of about 600 to 1,000 feet and extends downward for about 14,000 feet. The Dolores River picks up an estimated 205,000 tons of salt annually as it crosses the valley. This salt comes primarily from the surfacing of natural brine groundwater. The purpose of the Unit is to intercept the brine and prevent this salt load from entering the Dolores River and eventually degrading the water quality of the Colorado River.

Reclamation began studies at Paradox Valley in 1971. By 1979, a Definite Plan Report and Final Environmental Statement had been approved recommending a plan that would prevent approximately 90 percent of the natural brine inflow (185,000 tons of salt annually) from entering the Dolores River. The recommended plan consisted of constructing a series of shallow brine production wells adjacent to the river, pumping the wells at a collective rate of 5 cubic feet per second (cfs) to intercept the brine, transporting the brine via a 21-mile-long pipeline and eight pumping stations to Dry Creek Basin, and disposing of the brine by evaporation in the 3,630-acre Radium Evaporation Pond. Deep well injection was one of the alternative brine disposal methods discussed briefly in the environmental statement. This Alternative was eliminated from further study because the proposed 5-cfs disposal rate was estimated to be higher than the geologic formations could absorb. The Region VIII Office of the Environmental Protection Agency reviewed the 1978 Draft Environmental Statement and stated that it "believes that disposal by deep well injection is the environmentally preferred solution and therefore should be seriously investigated for brine disposal" (BOR, 1978).

Test brine well field facilities were constructed and a verification program was initiated in 1978. Investigations and testing proved that pumping the brine well field was a highly effective method for controlling the brine inflow to the river and indicated a pumping rate of 1.5 to 2 cfs instead of the originally proposed rate of 5 cfs, would achieve the Unit's goal. As a result, the brine disposal plan was re-evaluated and the alternative of deep well injection appeared to be more feasible.

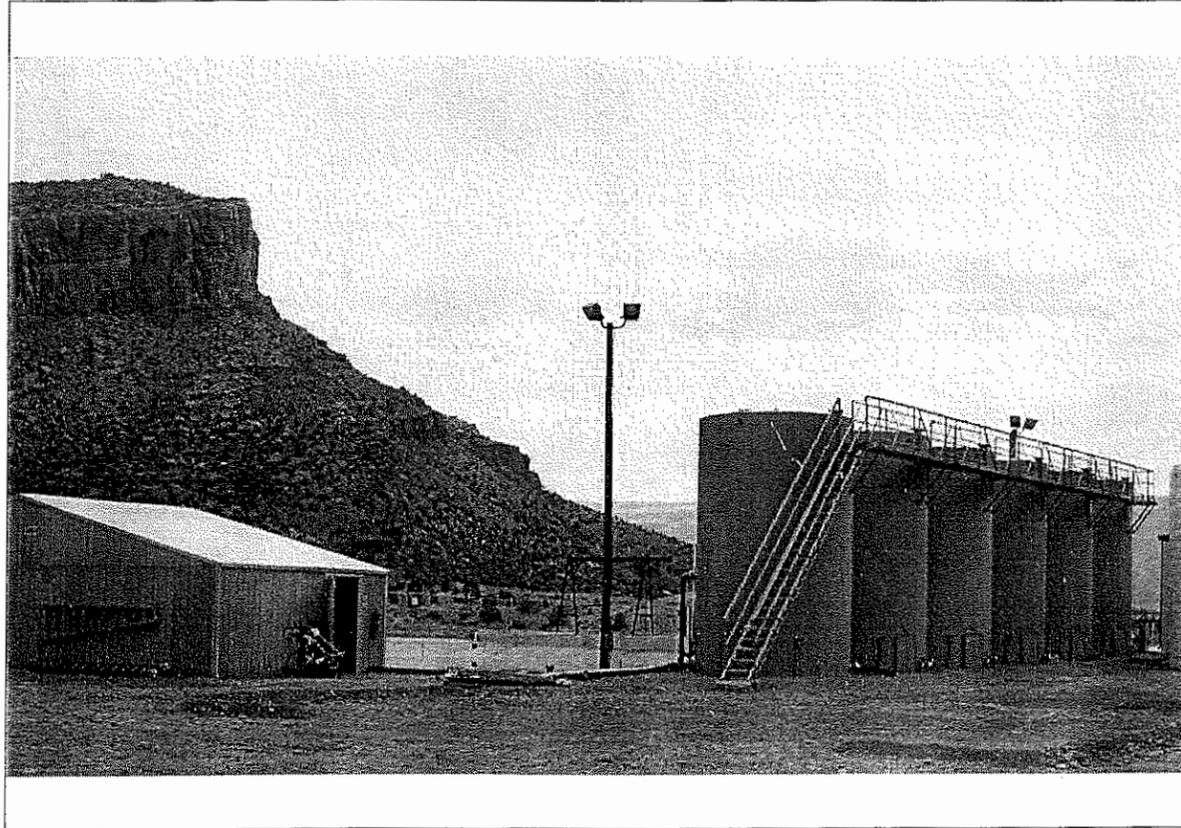
A consulting engineering firm completed a feasibility study of deep well injection and concluded it to be technically, economically, and environmentally feasible. An injection testing program was designed, test facilities were constructed, and the testing program was initiated.

Data collected from the injection test program confirmed that injection is a physically, economically, and environmentally feasible method of brine disposal. The test program also determined that two injection wells would be necessary to dispose of the required brine production of 1.5 to 2 cfs. In 1989, Reclamation formulated an alternative project plan which incorporated 24 brine production wells located on both sides of the Dolores River and construction of a second brine injection well. This alternative would achieve the goal of 90-percent reduction in salt loading to the Dolores River. Funding constraints have eliminated any further consideration of this alternative.

The proposed plan addressed in this document is to operate the presently constructed test facilities on a long term basis. The existing test facilities consists of a brine production well field and associated collecting pipelines and access roads located on the east side to the Dolores River, a surface treatment facility, a 3.7 mile long connecting pipeline, one brine deep well injection facility, 1.2 miles of access road to the injection facility and about 1.2 miles of 69-kilovolt (kV) power line to the injection facility. This Environmental Assessment evaluates the environmental effects of operating and maintaining the presently constructed facility as a contribution to the Colorado River Basin Salinity Control Project.



**Injection Well No. 1 and Derrick
July 1990 Bureau of Reclamation Photo by Tom Wamsley**



Six Freshwater Storage Tanks -- July 1990 official file photo



**Interior of Brine Injection Facility
Three PZ-11 Triplex Positive Displacement Pumps in the Background
July 1990 Bureau of Reclamation photo by Tom Wamsley**

Chapter 1 - Purpose of and Need for Action

The Unit was authorized for construction by the Colorado River Basin Salinity Control Act of 1974 (PL93-320, amended; PL98-569) as part of a basin wide program to improve water quality in the Colorado River for the benefit of water users in the United States and Mexico. Title II of the Act is directed toward salinity control in the United States above Imperial Dam. It authorized construction of this Unit and three other projects. The goal of these projects is to reduce salt concentrations to threshold levels adopted in 1975 by member states comprising the Colorado River Basin Salinity Control Forum (Forum). It is estimated that more than a million tons of salt per year will need to be removed from the Colorado River system by the year 2010 to meet the Forum's established criteria.

Chapter 2 - Alternatives

Proposed Action

The proposed action consists of operating the presently constructed deep well injection test facility as the Unit's permanent contribution to the salinity control effort. While the proposed action does not achieve the Unit's original goal of eliminating 90 percent of the salt entering the Dolores River from the Unit area, it does provide a significant reduction in the total salt loading to the Colorado River, without expending additional construction dollars. The Unit, as presently constructed, will achieve a 50- to 71-percent reduction in salt loading to the river from the Unit area.

Facilities to be operated and maintained include the injection well and facilities located approximately 1.2 miles south from Colorado Highway 90, a 20-foot-wide access road to the injection well, a brine production well field located on the east side of the Dolores River, a surface treatment facility located adjacent to the brine production field, a 3.7-mile buried pipeline from the brine well field to the injection well, and a 69-kV power line from Highway 90 to the injection well.

No Action Alternative

The No Action Alternative would allow the continued inflow of approximately 205,000 tons of salt annually to the Dolores River. This alternative would require the abandonment of existing facilities. Abandoning the Unit would be costly, as well.

Chapter 3 - Affected Environment and Environmental Consequences

Introduction

Construction of the Unit is now complete and all environmental effects resulting from that construction have occurred. The 1979 FES addressed impacts to the environment which would result from construction of the Unit's brine well field. The 1986 Final Environmental Assessment, *Deep Well Injection Testing Program*, described the environmental effects of the construction and test operation of the Unit facilities and resulted in a Finding of No Significant Impact (FONSI). There are three possible impacts that have not been addressed in either of the NEPA documents prepared for this project. These are:

- (1) Deep well injection testing has quantified the amount of brine fluid the facility is capable of injecting and has revealed the necessity of using some freshwater during the injection process. Therefore, the Unit's effect on water resources and associated impacts to vegetation, fish and wildlife will be evaluated in this document.
- (2) Test operations of the Unit's facilities have provided additional data concerning seismic occurrences resulting from operation. Therefore, the Unit's effect on seismicity and tectonics in the area will be evaluated here.
- (3) Threatened and Endangered Species lists have changed since the 1986 EA. These changes have resulted in a need to prepare a Biological Assessment on how permanent operations of the Unit might affect the presently threatened or endangered species. The Biological Assessment and Biological Opinion are attached to this document as Appendices B and C, respectively.

Surface Water Resources

Affected Environment

The Dolores River, West Paradox Creek, and the ephemeral East Paradox Creek are the primary streams in the Unit area. Several small intermittent streams flow into these larger water courses during spring snow melts or during thunderstorm activity. The SDPR, Chapter III, describes in detail the flow characteristics of the Dolores River and West Paradox Creek.

Environmental Consequences

Operation of the Unit would inject up to 400 gallons per minute (gpm) or 0.89 cfs of fluid into the underlying geologic formations. The fluid would consist of (1) a mixture of 70 percent brine, which would be pumped from the brine production well field, and (2) 30 percent fresh water obtained from the Dolores River. Due to the mixing requirement, only 10 brine production wells located on the east side of the Dolores River would be pumped at a sustained rate of about 280 gallons per minute (0.62 cfs). Operation of the Unit with a plant factor of 80 percent would result in an annual depletion to the Dolores River of about 516 acre-feet. Operation of the Unit would not affect East or West Paradox Creeks.

McPhee Reservoir, a feature of the Dolores Project, was completed in 1985 and is located upstream from the Unit on the main stem of the Dolores River near the town of Dolores, Colorado. Operating criteria for the Reservoir provides for year-round releases downstream to the Dolores River that will eliminate the chronic summer low/no flow conditions which historically occurred during dry years. In 1996, Reclamation acquired additional water for release from McPhee Reservoir downstream to the Dolores River. These releases will more than offset the small depletion to the river caused by operation of the Unit.

Reclamation has water rights from the Dolores River totaling 4.95 cfs for the purpose of salinity control. Reclamation also has an Augmentation Plan, approved by the District Court for use in Water Divisions 4 and 7. This Plan allows for out of priority pumping of the brine production wells should a call be placed on the Dolores River.

Groundwater Resources

Affected Environment

An aquifer of brine appears to underlie the entire Paradox Valley at varying depths. The brine groundwater is very close to the surface along the Dolores River and is in contact with the bottom and sides of the river channel for about 1.5 miles, beginning in the middle of the valley and extending downstream to near the exit of the valley. The depth to the top of the brine appears to increase as you move upstream and to the west. In a well about a mile west of the river, the depth to brine has been measured at over 100 feet. To the east of the river, the brine remains near the surface. It is impractical to directly measure the brine inflow, because it comes from many small springs and seeps. Reclamation estimates that the brine inflow varies from about 0.2 to 2.1 cfs, and average about 0.8 cfs. This inflow exhibits a certain degree of annual and seasonal fluctuation.

A layer of comparatively fresh water overlies this brine groundwater in the Paradox Valley. In west Paradox Valley, the top of the fresh water lies from 10 to 40 feet below the surface, depending upon location. The fresh water is pumped from wells for irrigation. The closest irrigation well is about 1 mile west of the river. The layer of fresh water is at least 100 feet thick about a mile west of the river and gradually becomes thinner as it approaches the river. The fresh water layer is very limited on the east side of the river. The combination of fresh and brine groundwater contributes between 1.5 and 4 cfs to the Dolores River's flow in the Paradox Valley.

Environmental Consequences

Pumping brine from the brine production well field would lower the elevation of the interface between the brine and upper fresh water aquifers. Since the brine pumped from the aquifer will be replaced by fresh water from the river, the elevation of the groundwater table will remain approximately the same. Some localized lowering of the water table will occur in the immediate vicinity of the brine wells. But, pumping the brine production wells will not affect wells completed in the fresh water aquifer.

Water Quality

Affected Environment

Surface Water Quality.—The SDPR, Chapter III, describes in detail the changes that occur in the water quality of the Dolores River as it flows through the Paradox Valley. Water quality of the Dolores River is monitored at the United States Geological Survey (USGS) gauging station at Bedrock as the river enters the Valley and at the USGS gauging station near Bedrock as the river exits the valley. TDS concentration ranges from 110 to 2,000 mg/l as the river enters the valley and from 120 to 20,850 mg/l as the river exits the valley.

Groundwater Quality.—Water quality of groundwater in the Unit area is discussed in the SDPR, Chapter III. Groundwater in the Unit area consists of a brine aquifer which underlies almost the entire Paradox Valley and a fresh water aquifer which overlies the brine primarily in west Paradox Valley. Samples of the brine groundwater have varied in salinity from about 117,500 mg/l to near 300,000 mg/l. The brine produced from the Unit's production wells have a TDS concentration of over 250,000 mg/l. Variations in quality probably result from different degrees of mixing with fresher groundwater in the area. About 94 percent of the TDS are sodium and chloride. The inflow of brine groundwater to the Dolores River accounts for essentially all of the salt picked up through the Paradox Valley.

As part of the program to complete the test injection well, water samples were obtained from the injection zone. The lower formations (Precambrian, Ignacio, and McCracken) contain no water. Samples obtained from the Leadville Formation were sodium-calcium-chlorine brine with a total dissolved solids concentration of approximately 218,000 milligrams per liter.

Environmental Consequences

Surface Water Quality.—The proposed action would improve the quality of water in the Dolores River by intercepting and disposing of brine groundwater before it enters the river. The proposed action would prevent an estimated 100,000 to 145,000 tons of salt from entering the Dolores River annually, and significantly decrease the average annual flow-weighted salinity of the river. The largest reductions would occur in concentrations of sodium and chloride, with relatively small reductions in sulfate, potassium, magnesium, and calcium. Overall, the water quality of the river as it leaves the valley would be significantly improved over existing conditions. It would, however, still exhibit an increase in salinity, because the project would not prevent all of the salts from entering the river as it crosses the valley.

Groundwater Quality.—The quality of the groundwater in the Unit area would not change. The injection of Paradox Valley brine, averaging approximately 251,000 mg/L TDS into the Leadville Formation, would slightly increase the salinity of the in-situ water located some 15,000 feet below the surface. The depth and isolation of this formation render the migration of the brine into useable aquifers virtually impossible.

Vegetation

Affected Environment

Vegetation communities in Paradox Valley vary according to elevation, precipitation, soil type, land use, and other factors. Vegetation composition and density in the general vicinity of the Unit vary according to the seasonal availability and quality of water and soil type. Vegetation communities include riparian associations along the Dolores River and West Paradox Creek; irrigated agriculture in the western portion of Paradox Valley; sagebrush and semidesert shrublands of greasewood, seablite, and winterfat-snakeweed in the eastern portion of the valley; and pinyon-juniper woodland at the higher elevations on the sides of the valley.

The riparian vegetation is dominated by tamarisk, which varies from sparse along the east side of the river to dense groves up to 100 yards wide supported by the meandering of the lower portion of West Paradox Creek. Grasses, with rushes and sedges in marshy areas, form the understory on the west bank of the Dolores River, while no significant understory is found on the east bank.

Stands of cottonwood trees with a tall shrub understory of New Mexico forestiera and a lower understory of grasses are scattered along both sides of the river upstream from the brine inflow area. In the brine production well field (area of brine groundwater) and downstream along the river, the riparian vegetation consists almost entirely of sparse tamarisk with little to no understory.

Irrigated land occupies much of the valley floor west of the river, with major crops consisting of alfalfa, grains, and pasture. Sagebrush communities occupy most of valley east of the river. The understory is sparse and consists of perennial grasses and mixed annual forbs. In many areas, poor soil conditions, sometimes exacerbated by overgrazing, have reduced the understory to primarily cheatgrass.

The greasewood community is found in the vicinity of the brine well field, along East Paradox Creek, and in other intermittent drainage and arroyos in eastern Paradox Valley and Dry Creek Basin. The dominant plant is black greasewood which may be found in association with other species such as seablite and scattered big sagebrush. In most instances, the understory is very sparse or totally absent. Seablite is the dominant plant in areas near the well field where greasewood is not found. In general, little or no understory of grasses is present in these areas, which are characterized by salt-encrusted ground.

Pinyon-juniper woodland is found on the slopes of Paradox Valley and on the surrounding mesas. Pinyon pine and Utah juniper dominate, although Rocky Mountain and common juniper are also present. The understory consists of woody shrubs, such as mountain snowberry, antelope bitterbrush, mountain mahogany, and serviceberry. Also found in this community are big sagebrush, rabbitbrush, prickly pear cactus, and various forbs and grasses.

Environmental Consequences

Continued, permanent operation of the facility would not result in any additional, adverse impacts to vegetation other than those which have already occurred. All areas disturbed during construction have been regraded back to contour and reseeded.

McPhee Reservoir, a feature of the Dolores Project, was completed in 1985 and is located upstream from the Unit on the main stem of the Dolores River near the town of Dolores, Colorado. Operating criteria for the reservoir provides for year-round releases downstream to the Dolores River that will eliminate the chronic summer low/no flow conditions which historically occurred during dry years. In 1996, Reclamation acquired additional water for release from McPhee Reservoir downstream to the Dolores River. These releases will more than offset the

small depletion to the river caused by operation of the Unit and will benefit the riparian vegetation more than historic conditions.

Seventy percent of the depletion to the river resulting from project operation will be brine with a TDS concentration of over 250,000 mg/l. Lowering the brine water table in the brine production well field area and the resulting improved water quality in the Dolores River may allow the growth of more riparian vegetation in the well field area and provide benefits to the riparian areas downstream from the Unit.

Wetlands and Riparian Habitats

Affected Environment

Riparian habitat in the vicinity of the Unit is sparse along most of the Dolores River in and below the area of brine inflow and consists mainly of scattered tamarisk. Superior riparian habitat above the brine inflow area consists of cottonwood stands scattered along both sides of the river upstream from the confluence with West Paradox Creek. The stands are associated with a tall shrub understory of New Mexico forestiera and a lower understory of grasses. The most significant wetland habitat near the project is located across the river from the brine well field on the west bank of the Dolores River. This wetland, which would be classified as a scrub-shrub wetland (Cowardin et.al., 1979), is dominated by tamarisk in fairly large patches and situated along the river and the lower portions of West Paradox Creek. This wetland is supported by saturated soils resulting from the meandering and overflows of West Paradox Creek caused by spring snow melt, summer storm runoff, return flows from up-slope irrigated lands, and possibly percolating groundwater flowing from West Paradox Valley. There are approximately 60 acres of scattered riparian vegetation along the Dolores River below the Unit area to the confluence with the San Miguel River.

Environmental Consequences

All disturbances associated with construction of the Unit have ceased and long-term operation of the Unit would not result in additional disruption to the existing habitat. All project major facilities and structures are located on the east side of the river. The wetland located along the west bank of the Dolores River is supported by West Paradox Creek and possibly surfacing groundwater flowing from Paradox Valley. Brine well pumping from groundwater on the east side of the river would not affect this wetland.

McPhee Reservoir, a feature of the Dolores Project, was completed in 1985 and is located upstream from the Unit on the main stem of the Dolores River near the town of Dolores,

Colorado. Operating criteria for the Reservoir provides for year-round releases downstream to the Dolores River that will eliminate the chronic summer low/no flow conditions which historically occurred during dry years. These releases will more than offset the small depletion to the river caused by operation of the Unit and will benefit riparian vegetation more than historic conditions.

Seventy percent of the depletion to the river resulting from project operation will be brine with a TDS concentration of over 250,000 mg/l. Lowering the brine water table in the brine production well field area and the resulting improved water quality in the Dolores River may allow the growth of more riparian vegetation in the well field area and provide benefits to the riparian areas downstream from the Unit.

Fisheries Resources

Affected Environment

Nineteen species of fish representing seven families were captured from the Dolores River in fisheries investigations by BIO/WEST Inc., in 1990 and 1991. Of the nineteen species collected, 13 were non-native or exotic and 6 were native or endemic to the Colorado River system. Non-native species comprised 81 per cent of the total collections. Three non-native species, red shiner, sand shiner, and fathead minnow, were the most common of all species collected. These species comprised 75 per cent of the total catch. Other non-native species collected were white sucker, bluegill, green sunfish, largemouth bass, common, plains killifish, black bullhead, channel catfish, brown trout, and rainbow trout (Valdez, 1992).

Table III-1. LIST OF NON-NATIVE FISH SPECIES

	Common Name	Scientific Name
Non-native Species	red shiner	<i>Cyprinella lutrensis</i>
	sand shiner	<i>Notropis stramineus</i>
	fathead minnow	<i>Pimephales promelas</i>
	white sucker	<i>Catostomus commersoni</i>
	bluegill	<i>Lepomis macrochirus</i>
	green sunfish	<i>Lepomis cyanellus</i>

	largemouth bass	<i>Micropterus salmoides</i>
	common carp	<i>Cyprinus carpio</i>
	plains killifish	<i>Fundulus zebrinus</i>
	black bullhead	<i>Ameiurus melas</i>
	channel catfish	<i>Ictalurus punctatus</i>
	brown trout	<i>Salmo trutta</i>
	rainbow trout	<i>Oncorhynchus mykiss</i>

Native species comprised the remaining 19 per cent of the total catch. Of the 6 native species sampled, flannelmouth sucker was the most abundant and comprised 9 per cent of the total catch of native species. Other native species sampled in order of abundance included roundtail chub, bluehead sucker, speckled dace, mottled sculpin, and Colorado squawfish. The composition of native species in the Dolores River is four times higher than in the adjacent Colorado River. This trend is indicative of a relatively good native fish fauna. No significant changes in species composition were evident when compared to similar surveys conducted on the Dolores River in 1981, indicating that the fish community had remained stable over the last ten years (Valdez, 1992).

Table III-2. LIST OF NATIVE FISH SPECIES

	Common Name	Scientific Name
Native Species	flannelmouth sucker	<i>Catostomus latipinnis</i>
	roundtail chub	<i>Gila robusta</i>
	bluehead sucker	<i>Catostomus discobolus</i>
	speckled dace	<i>Rhinichthys osculus</i>
	mottled sculpin	<i>Cottus bairdi</i>
	Colorado squawfish	<i>Ptychocheilus lucius</i>

The four Colorado squawfish captured in the lower 2 km of the Dolores River during the 1991 study may constitute the first record of this species since 1965. Although the species was

reported in the Dolores River in the 1950's and 1960's, spills of uranium mill wastes in the lower San Miguel river in mid-1960 killed most of the fish in the lower 60 miles of the river (Valdez, 1992).

Environmental Consequences

Operation of the Unit as presently constructed would result in annual water depletions of the Dolores River of 516 acre-feet. This represents a significant reduction in depletions from plans proposed in 1977 and 1989. Improvements in water quality which will be achieved as a result of the Unit's long-term operation will benefit the aquatic and fishery resources of the Dolores River.

McPhee Reservoir, a feature of the Dolores Project, was completed in 1985 and is located upstream from the Unit on the main stem of the Dolores River near the town of Dolores, Colorado. Operating criteria for the Reservoir provides for year-round releases downstream to the Dolores River that will eliminate the chronic summer low/no flow conditions which historically occurred during dry years. In 1996, Reclamation acquired additional water for release from McPhee Reservoir downstream to the Dolores River. These release will more than offset the small depletion to the river caused by operation of the Unit and will provide benefits to the endangered and other fish species in the Dolores River.

Wildlife

Affected Environment

Mule deer, elk, black bear, and mountain lion are the major big game species found near Paradox Valley. Approximately 300 mule deer are estimated to winter in the Paradox Valley. While few deer are harvested in the Unit area, approximately 100 to 300 are harvested annually in the eastern portions of Dry Creek and the La Sal Mountains.

Although their numbers have been increasing, elk normally do not use Paradox Valley as extensively as mule deer. The valley is potential annual winter elk range, and it serves as winter range during high snowfall years. A few elk occasionally visit the valley during the summer. Annual harvest is minimal since elk are usually in their summer ranges at higher elevations during the hunting season.

Black bear are occasional but rare residents in the general project area, since they normally are found at higher elevations on the east side of the La Sal Mountains in Utah. They are

occasionally sighted by the landowners at the west end of Paradox Valley.

An estimated 6 to 10 mountain lions were in the Unit area in 1975. The western portion of the valley appears to be the best mountain lion habitat. Hunting for mountain lion has been allowed since 1965.

The only small game animal found in the Unit area is the desert cottontail, which occurs throughout the area and is especially abundant in the sagebrush habitat to the east and in the riparian habitat along the Dolores River. Although no numbers are available, populations undergo moderate hunting pressure.

The beaver, black-tailed jackrabbit, coyote, muskrat, ringtail, martin, long-tailed weasel, badger, gray fox, and striped and spotted skunks are the principal furbearers that inhabit the overall area. Beaver and muskrat are by far the most common; they are found primarily along area streams and also along irrigation ditches and drainage systems in western Paradox Valley. The coyote, common throughout the Unit area, tends to concentrate at lower elevations during the winter. The black-tailed jackrabbit is widely distributed in grasslands, croplands, and sagebrush flats. Although trapping pressure is light to nonexistent, beaver and muskrat, which are trapped commercially to prevent damage to irrigation ditches, constitute the greatest portion of the annual harvest. The coyote has also become a valuable fur resource in the valley due to recent population increases and increased hunting and trapping pressure.

Although the ringtail is rarely seen because of its strictly nocturnal and secretive nature, it is quite common in the rocky areas along the lower Dolores and San Miguel Rivers. The martin is rare and likely only found in the forests west of Paradox Valley. The long-tailed weasel population is considered to be small due to the valley's low altitude which is not considered good habitat for this species. Although badgers are not common, they do occur in most habitats in the valley. The gray fox is quite common, mainly along stream bottoms and in other riparian areas, particularly West Paradox Creek. Striped skunks are often seen in lower-elevation stream valleys and farmlands closely associated with man. Spotted skunks are rare, preferring rocky habitats at lower elevations.

Other less common furbearers found in Paradox Valley are the bobcat, red fox, raccoon, and porcupine. Bobcats are uncommon but occur in canyons along the Dolores River and on mesas southwest of the valley. The red fox is rare but may occur at the confluence of the Dolores River and West Paradox Creek. Raccoons are generally limited to specific areas along the Dolores River, West Paradox Creek, and western valley agricultural areas. Porcupines are not common in the Unit area but are more common in the pinyon-juniper habitats on the boundaries of Paradox Valley.

Small mammals or rodents that provide an important prey base for predators in the area are the deer mouse, western harvest mouse, pinyon mouse, brush mouse, valley pocket gopher, white-throated woodrat, Mexican woodrat, least chipmunk, Colorado chipmunk, Ord's kangaroo rat, rock squirrel, Gunnison's prairie dog, and white-tailed antelope ground squirrel. The deer mouse is the most abundant and the white-tailed ground squirrel is the least abundant prey species. Gunnison's prairie dog is not common in the Unit area.

The Unit area provides habitat for at least 13 species of raptors. The golden eagle, northern harrier, Cooper's hawk, sharp-shinned hawk, red-tailed hawk, American kestrel, prairie falcon, goshawk, and great horned owl are year-round residents. Northern harriers and American kestrel populations may increase dramatically in the breeding season. The turkey vulture, bald eagle, ferruginous hawk, and rough-legged hawk are seasonal residents. Peregrine falcons nest in Paradox Valley near the Unit, with at least one confirmed nest active in 1995.

Golden eagles nest in the Dolores River Canyon and along Rock Creek, a tributary to the river downstream from Paradox Valley. Preferred hunting areas are normally open and include the whole valley. Cooper's hawk, sharp-shinned hawks and goshawk are not common but are found in riparian and pinyon-juniper habitats. Northern harrier and red-tailed hawks generally prefer open areas.

The American kestrel, the most common raptor in the Unit area, can be found in croplands, desert shrub, pinyon-juniper, and riparian habitats and is frequently seen on fences and power lines near roads. Prairie falcons are rare in the area, but, an active eyrie was found on the north rim of eastern Paradox Valley during the spring of 1976. Rough-legged hawks are winter residents only and prefer cropland, grassland, and low desert shrub habitats with prominent perching sites. The great horned owl is fairly common in riparian and pinyon-juniper habitats that have suitable nest and roost trees. Turkey vultures are common during the late spring and summer but are not known to nest in the area.

Mourning dove, band-tailed pigeon, and ring-necked pheasant are the primary gamebirds of the Paradox Valley. The ring-necked pheasant is a year-round resident, while doves and pigeons inhabit the area from spring through fall. Doves receive moderate hunting pressure, feed in agricultural and semidesert shrub lands, and nest in riparian and pinyon-juniper habitats. Band-tailed pigeons are not common, seeming to prefer higher elevations north of the valley. Ring-necked pheasants are common in agricultural and riparian habitats; hunting pressure is low since populations are found mainly on private ground. In 1988, in cooperation with the Colorado Division of Wildlife (CDOW), Reclamation sponsored the release of 233 chukars at four locations in Paradox Valley to stabilize existing populations, provide a prey base for the

endangered peregrine falcon, and increase recreational hunting opportunities.

The Dolores River serves as an important feeding and resting area for numerous species of waterfowl and shorebirds. Although most species found here vary widely from season to season, mallards are the most common species annually. Gadwall, Canada goose, pintail, green-winged teal, redhead, common merganser, and American coot are species that use the river and stock tanks. Hunting pressure is considered moderate in the fall and winter.

The shorebirds identified in the Unit area were the killdeer, common snipe, and spotted sandpiper. Other species of shorebirds are likely to frequent the area, especially the wetland area along West Paradox Creek during spring and fall migrations.

Of approximately 150 species of nongame birds that could frequent the Unit area, 92 species were identified during the inventories completed in 1976. Many of the nongame birds identified are typical of southwestern Colorado and include whippoorwill, ashthroated flycatcher, bank swallow, plain titmouse, common bushtit, Bewick's wren, rock wren, gray catbird, yellowthroat, blue grosbeak, Lazuli bunting, brown-capped rosy finch, gray-crowned rosy finch, lark sparrow, sage sparrow, and Brewer's sparrow.

The floodplain (riparian) and wetland habitats along the Dolores River, together with that of West Paradox Creek, probably constitute the most important of the vegetation habitat communities in the Unit area. In descending order of importance, the other communities include: pinyon-juniper woodland, agricultural land, sagebrush, native grassland, and monocultures of desert shrub habitats of seablite, winterfat-snakeweed, and greasewood. The habitat value of the desert shrub communities for wildlife would be slightly increased if communities were mixed. Streams, springs, wetlands, and stock ponds in the Unit area support such amphibians as the red-spotted, Rocky Mountain, and Hammond's spade-foot toads, and western leopard frog. Reptiles inhabiting the unit right-of-way near the Dolores River include the wandering garter snake and the short-horned lizard. Sagebrush and pinyon-juniper habitats contain such species as northern sagebrush, northern plateau, and short-horned lizards; plateau whiptail; Great Basin gopher snake; and midget faded rattlesnake. Semidesert shrublands and rocky outcrops provide

habitat for short-horned, northern sagebrush, northern plateau, and northern tree lizards; Great Basin gopher and wandering garter snakes; western yellow-bellied racer; and midget faded rattlesnake.

Environmental Consequences

Construction of the Unit is now complete and all environmental effects resulting from that construction have occurred. Vegetation loss has been mitigated with reseeded efforts in all areas except where permanent facilities have been constructed. Continued permanent operation of the facility would not result in any additional adverse impacts to existing wildlife species except for impacts from water depletions to the Dolores and Colorado Rivers of approximately 516 acre-feet/year. Wildlife may experience permanent, limited disruption caused by human activity as a result of operating the Unit on a long-term basis.

McPhee Reservoir, a feature of the Dolores Project, was completed in 1985 and is located upstream from the Unit on the main stem of the Dolores River near the town of Dolores, Colorado. Operating criteria for the Reservoir provides for year-round releases downstream to the Dolores River that will eliminate the chronic summer low/no flow conditions which historically occurred during dry years. In 1996, Reclamation acquired additional water for release from McPhee Reservoir downstream to the Dolores River. These releases will more than offset the small depletion to the river caused by operation of the Unit.

Riparian vegetation in the 7 miles downstream along the Dolores River to the confluence with the San Miguel River would slowly improve due to a decrease in overall salinity resulting from operation of the Unit. Waterfowl and shorebird habitat would be enhanced by the decrease of salinity in the Dolores River and resulting improvement of riparian and aquatic communities downstream of the brine well field. Amphibian populations are expected to increase with the replacement of existing brine pools and salt deposits along the river with fresh water during spring and early summer high flows.

Threatened and Endangered Species

Reclamation prepared a Biological Assessment to address potential impacts of long term operation of the Unit on threatened and endangered species. The Biological Assessment and the Biological Opinion prepared by the Fish and Wildlife Service are included in Appendices B and C, respectively. The following table summarizes Reclamation's assessment of the impacts of operation of the Unit.

SUMMARY OF POTENTIAL IMPACTS

SPECIES	POTENTIAL PROJECT IMPACTS	RECOMMENDED MITIGATION MEASURES
American peregrine falcon	No impacts; species habitat not affected by project	No species-specific mitigation measures recommended
Bald eagle	No impacts; minor depletions will not affect existing habitat.	No species-specific mitigation measures recommended. Water quality improvements will benefit species
Black-footed ferret	No impacts; species habitat not affected by project	No species-specific mitigation measures recommended
Bonytail chub	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvement and upstream flow releases will benefit species
Colorado squawfish	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation recommended. Water quality improvement and upstream flow releases will benefit species
Humpback chub	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvements and upstream flow releases will benefit species
Mexican spotted owl	No impacts; affected environment does not provide suitable habitat for species	No species-specific mitigation measures recommended
Razorback sucker	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvement and upstream flow releases will benefit species
Southwest river otter	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvements and upstream flow releases will benefit species
Southwestern willow flycatcher	No impacts; minor depletions will not affect existing environment	No species-specific mitigation measures recommended. Water quality improvements and upstream flow releases in addition to control of overgrazing and exotic vegetation would benefit species

The Service did not agree with Reclamation's finding of no significant impacts to any threatened or endangered species. The Service concluded that operation of the Unit "is likely to jeopardize the continued existence of the Colorado squawfish, humpback chub, bonytail, and razorback sucker and

result in the destruction or adverse modification of their critical habitat.” The Service determined that the depletion resulting from the Unit’s operation would reduce the physical habitat available to the endangered fish, contribute to an increase in nonnative fish, and increase the concentrations of heavy metal, selenium, salts, PHA’s, pesticides, and other contaminants in the Colorado River. However, the Service concluded that because the Unit’s average annual depletion of 516 AF is below the current sufficient progress threshold of 1,500 AF, continued participation by Reclamation in the Colorado River Recovery Implementation Program would allow operation of the Unit and avoid the likelihood of jeopardy to the endangered fishes and avoid destruction or adverse modification of critical habitat. The Service concluded that these actions would serve as the reasonable and prudent alternative.

Reclamation concurs with the Service’s determination of the reasonable and prudent alternative. However, Reclamation continues to disagree with the conclusion by the Service that operation of the Unit would deteriorate water quality in the Colorado River. The Unit’s operation will prevent approximately 128,000 tons of salt from entering the Colorado River system annually resulting in improved water quality in the River.

Seismicity and Tectonics

Affected Environment

The seismotectonic setting of the area is discussed in general terms in chapter II of the SDPR. The observations regarding seismicity in the area can be summarized as follows:

- ▶ The Unit is within a zone exhibiting a low rate of naturally occurring seismicity,
- ▶ no events with magnitudes greater than 0 have been detected within 5 km of the well in about 5 years of monitoring prior to injection.
- ▶ Pre-injection seismicity is shown on figure 1;
- ▶ the closest significant seismicity appears to be associated with faults bounding the southwest side of the Uncompahgre Plateau (~100 km east of the Unit near Ridgway, Colorado).
- ▶ The possible occurrence of earthquakes as a consequence of deep well injection at this site was considered in the *Deep Well Injection Testing Program Final Environmental Assessment*.

Since the submission of these documents, Reclamation has conducted several test injection sequences

with all but one of the sequences resulting in earthquakes of sufficient size to be detected by the 14-station Paradox Valley Seismic Network (PVSN). An oblique view of the well bore and injection related seismicity is shown as figure 2. As of the end of March 1995, more than 750 events had been located near the well. All of these events appear to be related (spatially and temporally) to the injection process. The duration of injection, wellhead pressure, injection rate, and fluid composition have varied for each injection period, and the level of seismicity has been generally correlated with these injection parameters. The relationship between injection parameters and earthquake occurrence is shown in figure 3.

Earthquake Location Procedure.—In an area with a low level of naturally occurring background seismicity (such as the Paradox Valley area), the association of abundant seismicity with fluid injection and subsequent migration of injectate appears clear. The ability to define where the fluid is flowing in the subsurface is related to the ability to define where the earthquakes are located in three dimensions. The process of estimating an earthquake's location involves a number of unknowns: the location of the hypocenter (x,y, and z), the origin time of the event, the ability to correctly interpret and read the seismograms for seismic phase arrival times, the distribution and quality of seismograph stations, and the velocity structure of the region for both compressional (P) and shear (S) waves. A considerable amount of effort has gone into estimating these parameters for the Paradox site. Several factors provide positive constraints on several of the unknowns at this site. A partial suite of well logs acquired during construction provide velocity information along the well bore. It is reasonable to infer that the first set of earthquakes occurring within the first few hours of injection must have occurred near the well. This fact provides a "known" location for some of the events. This enables future events to be identified as injection induced or naturally occurring by their relative location to the well. Negative factors at this site include an obviously three-dimensional character to the velocity structure, rather broad spacing of the seismograph stations, and the lack of more than one three-component station. To provide the best possible earthquake locations, a simultaneous hypocenter-velocity inversion was performed. Arrival time data collected during injection sequence seven (September 1994-March 1995) were used. Only earthquakes with magnitudes greater or equal to 0.7 were used in the analysis (to maximize signal-to-noise ratio). A total of 382 events from injection sequence seven were included in the analysis. All 22 of the events that occurred during the first injection sequence (July 1991) were included in the inversion as well. The locations of these 22 events were fixed at the center of the perforated zone of the borehole which was computed from the deviation survey. These events with fixed locations were included to minimize the trade-off between hypocenter, velocities, and station corrections that occur in joint velocity-hypocenter inversions. To provide additional ray coverage for the velocity inversion, data from other earthquakes away from the well and some explosions near Uravan were included in the procedure.

Earthquake Location Results.—Figures 2 and 4 display the results of the three-

dimensional velocity inversion procedure for 630 selected events associated with injection. Also displayed on these figures is a digital elevation model of topography in the Paradox area, the deviated well bore, as well as a subsurface rendering of the top of the Leadville Formation (the target horizon) and faults within the formation that were previously inferred from seismic reflection data. Figure 2 is an oblique view approximately parallel to the strike of the inferred faults and shows nearly all of the hypocenters. The orientation of figure 4 displays the hypocenters that lie above the top of the Leadville Formation. Figure 4 clearly shows that a large number of earthquakes are occurring above the Leadville Formation. Uncertainties in hypocentral depths are judged to be approximately 300 meters. The evolution of earthquake focal depths (and by inference migration of fluid) with time is illustrated on figure 3. During the first three injection sequences, earthquakes occurred near the well bore and in a depth interval within or below the Leadville Formation. Beginning with the fourth injection sequence and continuing through the end of the seventh test sequence, the earthquakes migrated west-northwest and shallowed slightly. The minimum depth of events appears to be ~3 km. The trend of the events in plan view is subparallel to the strike of the Paradox Valley and associated structural features.

A procedure that was previously developed for mapping fractured planes—produced by high pressure fluid injection for geothermal development—was applied to the data set of hypocenters shown on figures 2 and 4. This procedure evaluates groups of earthquakes to determine if the events could lie on a common planar surface. Once a surface has been defined, the earthquakes that are associated with that surface are removed from the data set and the procedure is repeated to define additional planes. Utilizing this methodology, three planes were defined by the earthquake hypocenters. Over 69 percent of the located hypocenters are contained on the planes (shown on figure 5). The orientations and trends of these planes are consistent with the general structural framework of the Paradox area (cf. the previously inferred faults shown on figures 2 and 4). An independent evaluation of fault plane solutions for larger events produced a tripart representation of least compressive stress orientation ("T-axes") that is very consistent with what would be expected for the three planes shown on figure 5.

Figure 6 is a Mohr circle representation of conditions inferred to exist at the bottom of the well (from well logs and other information), demonstrating that induced earthquakes are a natural consequence of high pressure fluid injection. The hydrostatic case suggests a stable condition prior to injection; this is consistent with the very low rate of naturally occurring seismicity observed near the Unit. During high pressure injection, the normal stress is reduced in accordance with the effective stress law and the circle shifts towards conditions of Coulomb failure. Maximum injection pressures are sufficient to produce failure of rocks with intact strengths as great as 140 bars. However, if preexisting planes of weakness exist, they will become the loci of fracture events.

Environmental Consequences

Seismicity.—No significant tectonic earthquakes have occurred within 50 km of the site. To date the largest event associated with injection at the Paradox facility is M 2.6. It cannot be precluded that somewhat larger earthquakes may be produced at this site. This is especially true since it appears likely that much of the injected fluid is moving along planar surfaces favorably oriented to fail in the current tectonic stress regime.

Fluid Migration.—The occurrence of earthquakes at depths above the "confining layer" discussed in earlier studies is contradictory to hypotheses that inferred fluid migration (and hence earthquakes) would be confined to the Mississippian Leadville and/or deeper strata. Clearly, fluid pressure changes are being manifested at depths shallower than initially proposed. The depth of seismicity appears to be inversely correlated with maximum surface injection pressure and injection volume. Based upon the observations of injection sequences six and seven, Reclamation considers it unlikely that fluid pressure changes would extend above the -3 km depth observed to date for injection rates and surface injection pressures at or below those used in test sequences. In order to fully document earthquake occurrence (and hence fluid pressure changes) at the site, continuous monitoring of the injection parameters and seismicity would be necessary. Accurate determination of earthquake focal depths is a critical issue to evaluating and minimizing environmental impacts at this site. To that end, an additional three-component station may be necessary to more accurately locate earthquake focal depths in the vicinity of the well.

In summary, deep well injection at the pressures and injection rates to be used at this site would produce micro earthquakes. These events would, in general, map out the areas where pore pressures are being increased. If earthquakes with magnitudes large enough to cause damage begin to occur, injection would be halted and operational parameters reevaluated. If earthquakes with reliable focal depths of less than 2 km occur, injection would be halted and operational parameters re-evaluated. The addition of another three-component seismic station near the well may be necessary to improve estimation of hypocentral locations.

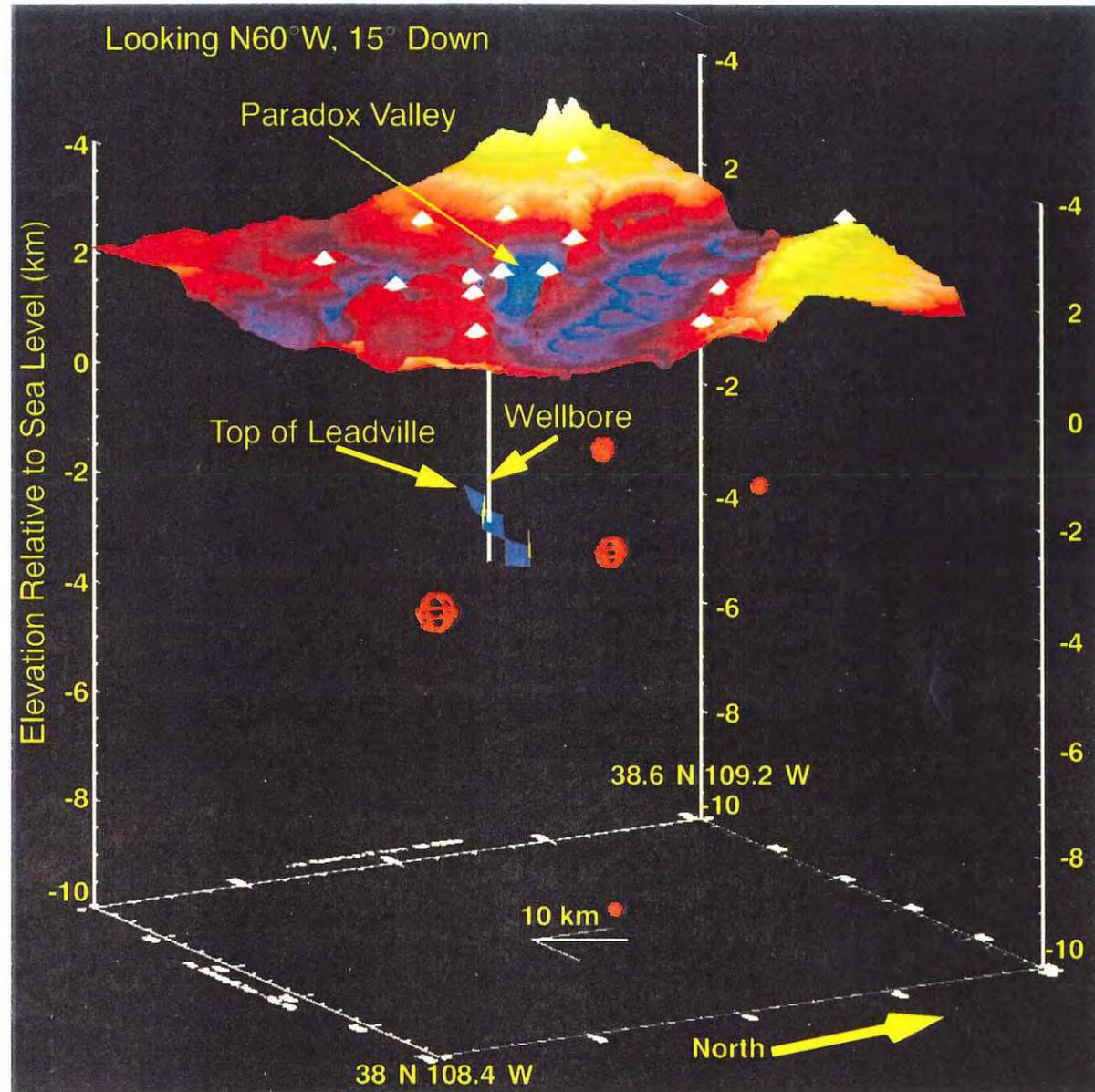


Figure 1. Pre-injection earthquake hypocenters (red 3d wireframes) located by the 14 station Paradox Valley Seismic Network (PVSN) in a 3d projection looking N60°W. Wellbore is the thick white line. The top of the Leadville formation near the wellbore is shown in dark blue cut by faults inferred from seismic reflection data. The shaded DEM at the top shows Paradox Valley and the Dolores River valleys in blue and green with surrounding mesas in red through light yellow. PVSN seismic stations are shown as white tetrahedra. No earthquakes occurred within 5 km of the wellbore during the 5 years of seismic monitoring prior to the first injection test.

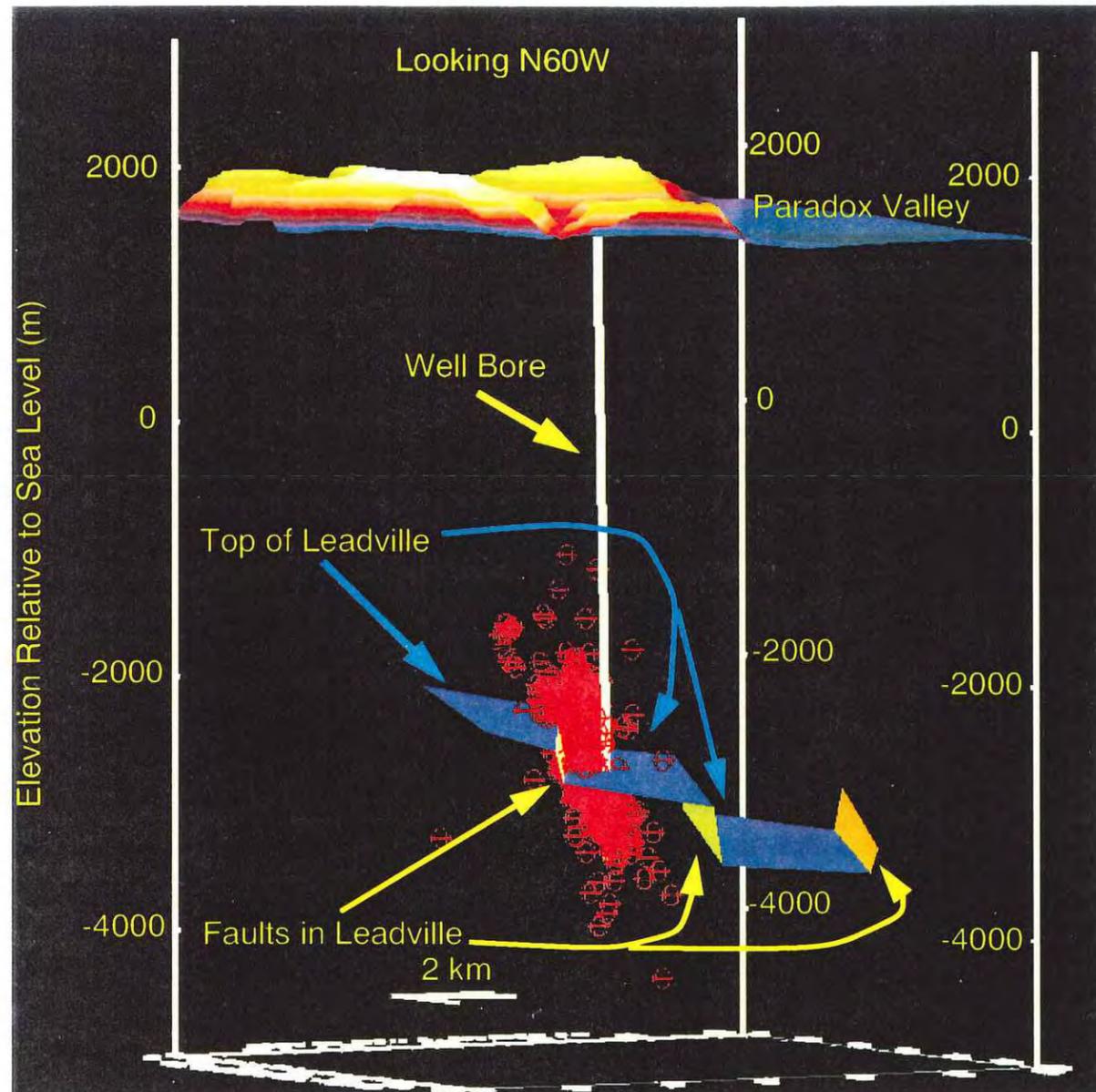


Figure 2. Hypocenters (red 3d wireframes) located above the top of the Leadville formation in a 3d projection looking N60W. The top of the Leadville formation is shown in dark blue and faults cutting the Leadville formation inferred from seismic reflection data are shown in yellow, green, and orange. The shaded DEM at the top shows the Paradox valley in blue and green with surrounding mesas in red through light yellow. Well bore is the thick white line.

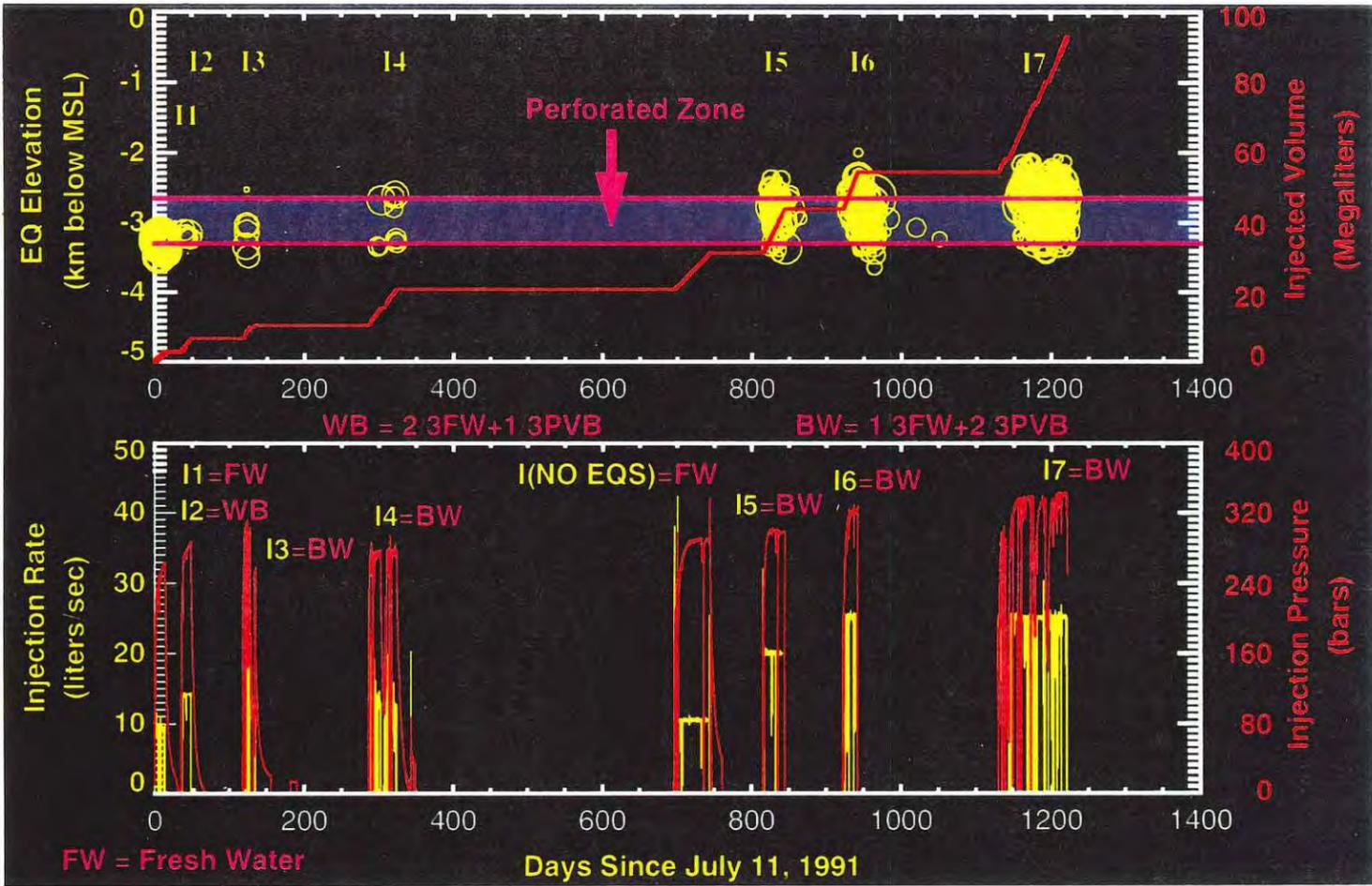


Figure 3. The top plot shows the cumulative fluid injection volume as the red curve, the elevation of earthquake hypocenters as yellow circles, and the elevation range of the perforated zone in the well as the blue elevation region between the magenta lines. Earthquake symbols are scaled by magnitude which ranges from -0.5 to 2.5. The bottom plot shows injection rate in yellow and surface injection pressure in red. There are eight total injection sequences and the seven injection sequences that produced earthquakes are labeled I1 through I7. Fluid composition is denoted as follows, FW = fresh water, PVB = Paradox Valley brine, WB = 2/3FW+1/3PVB, and BW = 1/3FW+2/3PVB. Time is in days since the first date of injection.

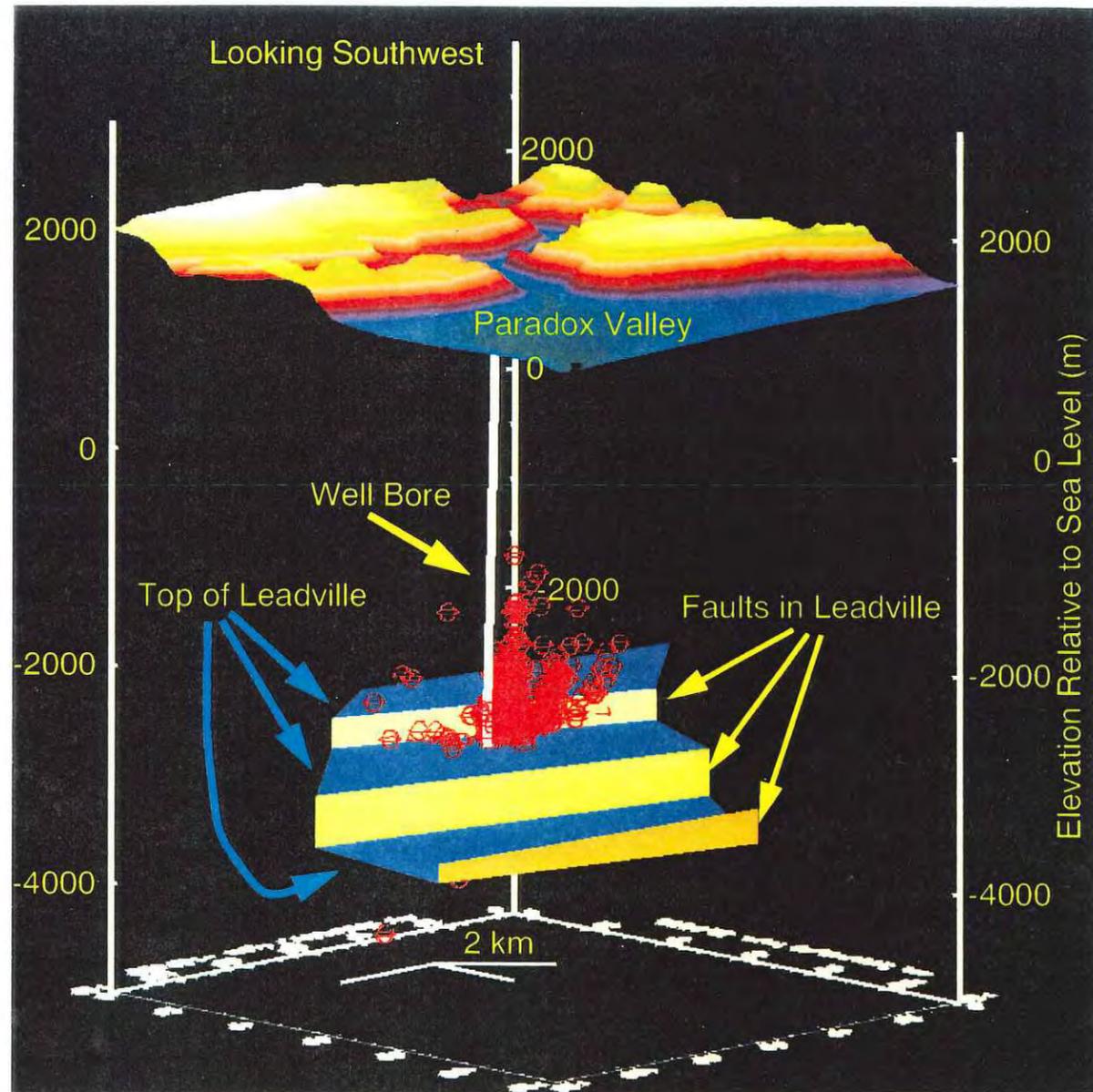


Figure 4. Hypocenters (red 3d wireframes) located above the top of the Leadville formation in a 3d projection looking southwest. The top of the Leadville formation is shown in dark blue and faults cutting the Leadville formation inferred from seismic reflection data are shown in yellow, green, and orange. The shaded DEM at the top shows the Paradox valley and Dolores River valleys in blue and green with surrounding mesas in red through light yellow. Well bore is the thick white line.

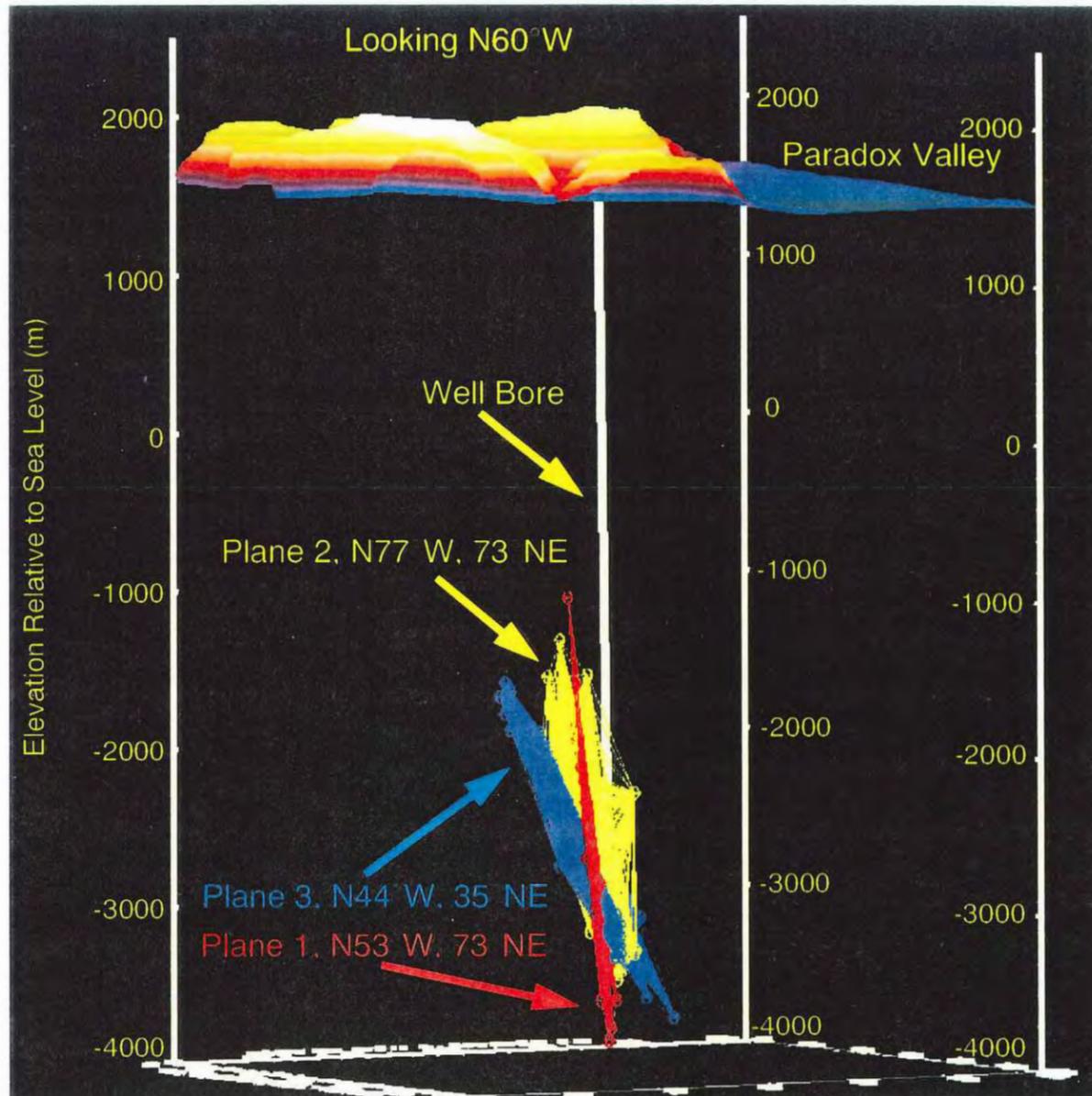


Figure 5. Three subsets of hypocenters (representing 69% of all hypocenters) that show strong planar alignment are shown by connecting all hypocenters in each color coded group with lines to delineate the plane orientations in three dimensions. A color shaded DEM is shown at the top with the Paradox Valley shown in blue and green and surrounding mesas in red through white. Total diagonal horizontal dimension is about 12 km. Plane 1 contains 212 hypocenters, plane 2 contains 136 hypocenters, and plane 3 contains 85 hypocenters. Vantage point is looking N60°W.

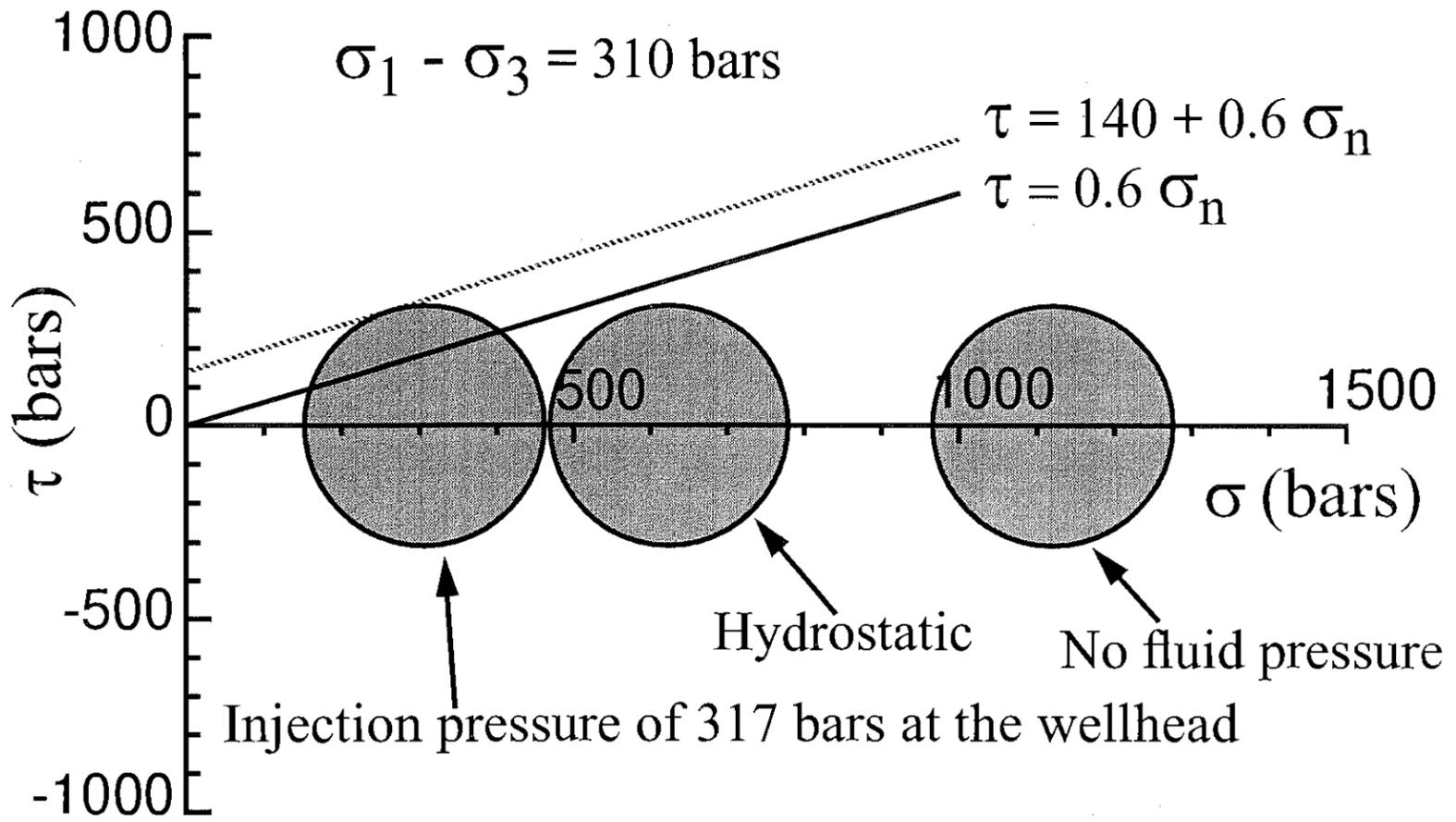


Figure 6. Mohr circle diagram showing inferred state of stress at the bottom of the Paradox Valley injection well (4.9 km depth). The two lines indicate failure criteria for Mohr-Coulomb failure; failure occurs if the Mohr's circle intersects (or lies to the left of) the failure line. The circle at the right indicates in-situ stresses (estimated from the mechanical properties well logs) in the absence of fluid pressure. In the center Mohr's circle, the principle stresses have been shifted to the left by the hydrostatic fluid pressure in accordance with the effective stress law. The leftmost circle indicates stresses at the well bottom during injection (fluid pressure = hydrostatic + surface injection pressure). The fact that the circle intersects both lines indicates that pressures at the well bottom are not only sufficient to produce faulting on pre-existing faults with zero strength (lower solid failure line), but are sufficient to cause faulting even in intact rock with a shear strength of 140 bars (upper dashed failure line).

Chapter 4 - Consultation and Coordination

Development of the Proposed Plan

During the salinity investigations for the Paradox Valley Unit, issues and opinions identified by and received from individuals, groups, and other agencies were carefully considered. Deep well injection of brine was suggested by EPA as an environmentally preferred solution to evaporation in the agency's comments on the Unit's Draft Environmental Statement in 1978. Subsequent testing has revealed that this preferred solution is viable, and disposal of brine by deep well injection has been adopted as part of the project.

Consultation and Coordination Activities (Environment)

In September 1994, as testing of the injection well program was being completed and future operation plans were being finalized, Reclamation questioned the Service as to the need to reinitiate Section 7 consultation on the Unit. The Service responded with a recommendation that Section 7 consultation be reinitiated because of changes in the project plan and changes in endangered species status since the last consultation.

Results and Implementation (Environment)

Reclamation has implemented each of the mitigation measures outlined above by the Service in the following ways:

- (1) A vegetation monitoring program has been initiated to determine if the removal of 516 acre-feet annually of brine from the Dolores River alluvium would affect existing floodplain vegetation. Infrared aerial photography will be obtained during the growing season at specific time intervals. Baseline conditions will be established before brine pumping is begun (project operation) as the basis for analyzing photography obtained at future dates. The monitoring program is scheduled to be conducted during the first years of project operation; continuation or cessation of the monitoring would be contingent upon the findings after this initial time period.
- (2) All new powerlines constructed for project facilities were designed to eliminate electrocution hazards for raptors.
- (3) All disturbed areas (pipeline rights-of-way, injection well, and operation and maintenance

facilities) were reshaped and revegetated with native shrub and grass species to provide food and cover for wildlife and increase the diversity of plant species.

Reclamation funded an "out-of-kind" chukar release mitigation measure recommended by the CDOW in Paradox Valley. The goal was to stabilize the existing population, increase the prey base for peregrine falcons, and provide increased hunting opportunity for sportsmen. In October 1988, the CDOW released 232 chukar at four locations in the valley.

Consultation and Coordination Activities (Endangered Species)

On November 12, 1996, the Service commented on the Draft SDPR and EA taking exception to Reclamation's determination of "no-effect" on endangered fishes or their critical habitat. Due to the agency's "may-effect" opinion, the Service recommended that Reclamation reinitiate formal consultation. On December 17, 1996, Reclamation reinitiated consultation based on the current Unit plan for long-term operation and maintenance of facilities constructed for the injection test. The current plan consists of pumping the brine well field at a rate of about 0.89 cfs and disposing of the produced brine in the existing injection well, resulting in an annual depletion to the Dolores river of about 516 acre feet. A Biological Assessment was prepared and is included as Appendix B. Reclamation concluded that operation of the Unit would have "no effect" on endangered species.

On January 17, 1997, Reclamation received a Final Biological Opinion for the Paradox Valley Salinity Control Unit from the Service which is included as Appendix C. The Biological Opinion (BO) concluded that while the project could jeopardize the continued existence of the Colorado squawfish, humpback chub, bonytail, and razorback suckers and their critical habitat, a Reasonable and Prudent Alternative (RPA) to ameliorate this threat was available and being implemented. The RPA is comprised of: (1) Continued participation in the *Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin*; (2) the commitment by Reclamation to operate Upper Colorado River Basin projects under its control to provide instream flows for endangered fishes; and, (3) the fact that the depletion is below the sufficient progress threshold of 1,500 acre-feet.

In 1988, Reclamation became a party to the *Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin*. Reclamation agreed to contribute \$1.5 million annually for 10 years to the recovery program and to operate its units to provide instream flow for endangered species as described in the recovery implementation program. In its biological opinion, the Service did not request any additional contribution for the maximum 1,448-acre-feet (or 2.0 cfs) depletion resulting from operating the Unit.

Results and Implementation (Endangered Species)

The Paradox Unit will be operated and maintained as presented in this EA and the SDPR. Reclamation will continue to participate in the Colorado River Recovery Implementation Program.

Indian Trust Assets

Indian Trust Assets (ITAs) are legal interests in property held in trust by the United States for Indian tribes or individuals. The Secretary of the Interior is the trustee for the United States on behalf of Indian tribes. All Department of the Interior agencies, including Reclamation, share the Secretary's duty to act responsibly to protect and maintain ITAs reserved by or granted to Indian tribes or Indian individuals by treaties, statutes, and executive orders. These rights are sometimes further interpreted through court decisions and regulations. Examples of trust assets are lands, minerals, hunting and fishing rights, and water rights. In accordance with this policy, Reclamation has determined that the Unit area is not near any Indian lands; therefore, Reclamation's activities have no effect on these assets.

Cultural Resources

Affected Environment

Both prehistoric and historic archaeological sites are known within the Paradox Valley Unit. The Paradox Valley lies at the northeastern periphery of the prehistoric Puebloan (Anasazi) culture area and the southeastern periphery of the prehistoric Fremont culture area. Indications are that both groups had abandoned the area prior to 1200 AD. Archaic (pre-Puebloan/Fremont) sites are also known in the Paradox Valley area, with a strong possibility that Paleo-Indian sites also exist. While it cannot be determined when the Utes arrived in the area, they were well established in western Colorado by the 1600's and some sites in the Paradox Valley Unit may be associated with the Utes. There are also a number of historic Euro-American sites in the Paradox Valley associated with early mining and cattle ranching activities.

Environmental Consequences

Several laws and executive orders are intended to preserve, protect, and maintain cultural resources on public lands. They include, but are not limited to: the Antiquities Act of 1906, the National Historic Preservation Act of 1966 (most recently amended in 1992), and the Archaeological Resources Protection Act of 1979. Reclamation identified several sites within the acquired lands that

are eligible or potentially eligible to the national Register of Historic Places. The brine pipeline and injection well, and associated facilities were designed to avoid impacting any archaeological and historic properties. Reclamation concluded in consultation with the Colorado State Historic Preservation Officer, that no effect on cultural resources would occur as a result of the construction, operation, and maintenance of the brine pipeline and injection well, and associated facilities.

Conservation Measures

In keeping with aforesaid laws on cultural resources, Reclamation will manage cultural resource sites within the areas acquired through fee title and easement. Management activities will include : 1) monitoring of impacts not directly related to operation of the brine injection facility (such as erosion and visitation), and 2) evaluating the resources for potential to answer key research problems such as determining the age and cultural affiliation of archaeological deposits.

Environmental Justice

The project has been analyzed in accordance with Reclamation Policy of August 17, 1994, for sensitivity to environmental impacts on minority populations and low-income groups. It has been determined that the project would have no adverse impacts on such groups. Environmental impacts from construction are complete, and placing the project in operation would improve the quality of surface water in the Colorado River Basin downstream of the Unit. Water quality improvement directly affects all population groups using the water in a beneficial manner. Economic loss from salinity is reduced for these users which, in turn, provides better economic health for the entire basin. This would have a positive effect on all population groups living in the region.

Environmental Commitment Plan

Because the project's average annual new depletion of 516 acre-feet is below the current sufficient progress threshold of 1,500 acre-feet, the Bureau of Reclamation's continued participation in the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin will serve as the reasonable and prudent alternative to avoid jeopardy to the Colorado squawfish, razorback sucker, humpback chub, and bonytail. It will also serve as the reasonable and prudent alternative to avoid destruction or adverse modification of critical habitat caused by the project's depletion. Reclamation contributes \$1.5 million annually to the Recovery Program.

All construction associated with the Unit has been completed and the impacts therefrom have been mitigated for as required by the Final Environmental Statement and as noted in this final Supplemental DPR/EA. Long-term operations will not further impact the environment.

A vegetation monitoring program is underway. Baseline data, including aerial photography, was taken during the growing season before operations began and is being compared against similar data gathered since. Continuation or cessation of the program will be contingent upon the observed results. If it is established that the decreased salinity benefits the vegetative community, monitoring will cease.

Public Involvement and Information

Throughout the study phase for the project modifications, the public and interested and affected agencies, groups, and individuals had the opportunity to participate in the study. Reclamation considered the information, opinions, and expressed desires of the public in evaluating project development and the salinity problem. Reclamation also coordinated with and received assistance from the Service, BLM, and CDOW. General information on project development was provided to local residents through newspapers, radio and television programs, and public meetings.

Chapter 5 - References Cited

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PARADOX VALLEY UNIT

BIOLOGICAL ASSESSMENT

Appendix B

BIOLOGICAL ASSESSMENT

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INTRODUCTION

This Biological Assessment was prepared in accordance with requirements of Section 7(c) of the Endangered Species Act of 1973 (Act) as amended in conjunction with the Paradox Valley Deep Well Injection Unit (Unit). By memoranda dated March 20, 1989; September 23, 1994; and subsequent informal consultations, as required by the Act, the U.S. Fish and Wildlife Service (Service) provided the Bureau of Reclamation (Reclamation) with names of 16 listed and candidate species that may occur in the affected environment of the project (USFWS, 1994;1989). The list was updated by communication with Mr. Terry Ireland located at the Grand Junction, Colorado, U.S. Fish and Wildlife Service Office, on February 29, 1996. This communication resulted in reducing the list to 15 species and a change in status for the bald eagle which has been downlisted to threatened, the flannelmouth sucker which has been listed as a category 2 species, and the loggerhead shrike which has also been listed as a category 2 species. A similar list identifying State-listed species was provided by the Colorado Division of Wildlife (CDOW) following informal consultations during February and March, 1995. This list was also updated by communication with CDOW at the Montrose District Office and by a request to the Colorado Natural Heritage Program. These species are identified in Table 2.

Additional modifications have been proposed by the Service to 50 CFR Part 17, Endangered and Threatened Wildlife and Plants; Plant and Animal Taxa that are Candidates for listing as Endangered or Threatened Species. The Service issued in the Federal Register, February 28, 1996, a Proposed Rule to reclassify those species classified as candidates. The designation of those species known as category 2 candidates will be discontinued and those known as category 1 will be referred to simply as candidate species. Additional consultations were initiated to clarify the status of category 2 species with the Endangered Species Coordinator in the Service's Region 6 Office and with the Chief, Division of Endangered Species in Washington, D.C. Each confirmed that the guidance issued in the Federal Register Notice of Review (Federal Register, 1996) for candidate species is the current procedure to follow and the category 2 classification no longer exists. As a result of this consultation, category 2 species addressed in the previous Biological Assessment will not be addressed in this revised document. Six species were addressed as category 2 species in the previous assessment. These species will not be addressed, however, those species listed by the State of Colorado as threatened or endangered will be addressed.

This assessment summarizes distribution; abundance; life requisites; and potential project impacts on endangered, threatened, and candidate species that might be affected by the proposal to operate the Unit on a long term basis (Table 2). The document proposes mitigation concepts to address potential impacts where appropriate. At the present time, no action is the only alternative to the proposed action.

The purpose of this assessment is to promote interagency cooperation and consultation in project decision making which may affect listed and candidate species, and to develop possible conservation and mitigation measures to avoid or reduce identified impacts.

Information presented in this assessment was obtained from field evaluations of the Unit area, extensive literature reviews, and communications with the Service and CDOW personnel.

PROJECT AUTHORITY AND PURPOSE

The Unit was authorized for construction by the Colorado River Basin Salinity Control Act of 1974 (PL93-320, amended; PL98-569) as part of a basinwide program to improve water quality in the Colorado River for the benefit of water users in the United States and Mexico. Title I of the act authorized construction of a desalting complex and associated measures to ensure acceptable salinity levels below Imperial Dam on the mainstem of the Colorado River (near Yuma, Arizona). Title II, which was directed toward salinity control in the United States above Imperial Dam, authorized construction of the Unit and three other projects. The goal of these efforts is to reduce salt concentrations to threshold levels adopted in 1975 by member states comprising the Colorado River Basin Salinity Control Forum (Forum). It is estimated that more than a million tons of salt per year will need to be removed from the Colorado River system by the year 2010 to meet the Forum's established criteria.

The Paradox Valley has long been identified as a major contributor of salt loading in the Colorado River Basin. The valley overlies a fractured gypsum cap that covers a formation of salt and salt-rich shale that begins at a depth of about 600 to 1,000 feet and extends downward for about 14,000 feet. The Dolores River picks up an estimated 205,000 tons of salt annually as it crosses the valley, primarily from the surfacing of natural brine groundwater. The purpose of the Unit is to intercept the brine and prevent this substantial salt load from entering the river and degrading the water quality of the mainstem of the Colorado River.

PROJECT HISTORY

Reclamation began studies at Paradox Valley in 1971. By 1979, a Definite Plan Report and Final Environmental Statement had been approved recommending a plan that would prevent approximately 90 percent of the natural brine inflow (185,000 tons of salt annually) from entering the Dolores River. This would lower the salinity of the Colorado River by approximately 16.4 milligrams per liter at Imperial Dam near Yuma, Arizona (BOR, 1979; 1978).

The recommended plan in 1979 consisted of constructing a series of shallow brine production wells adjacent to the river, pumping the wells at a collective rate of 5 cubic feet per second (cfs) to intercept the brine, transporting the brine via a 21-mile-long pipeline and eight pumping stations

to Dry Creek Basin, and disposing of the brine by evaporation in the 3,630-acre Radium Evaporation Pond. Deep well injection of brine was one of the alternatives to pumping and evaporation of brine discussed briefly in the environmental statement but was eliminated because the proposed 5-cfs disposal rate was estimated to be higher than the geologic formations could absorb. The Region VIII Office of the EPA reviewed the 1978 Draft Environmental Statement and stated that it "believes that disposal by deep well injection is the environmentally preferred solution and therefore should be seriously investigated for brine disposal" (BOR, 1978). Continuing investigations and testing of the brine well field indicated the desired reduction of brine flow into the river could be achieved by disposing of 1.5 to 2.0 cfs of brine instead of the 5.0 cfs. Test facilities were constructed and a verification program was initiated in 1978. Testing proved this plan to be a highly effective method for controlling the brine inflow and indicated a pumping rate of 1.5 to 2 cfs would achieve the project's goal. As a result, the brine disposal plan was re-evaluated and the alternative of deep well injection appeared to be more feasible.

A consulting firm completed a feasibility study of deep well injection and concluded it to be technically, economically, and environmentally feasible. A testing program was designed, test facilities were constructed, and the testing program was initiated.

Results of the injection test program have confirmed that injection is a physically, economically, and environmentally feasible method of brine disposal. However, the test program also determined that two injection wells would be necessary to dispose of the required brine production of 1.5 to 2 cfs. In 1989, Reclamation formulated an alternative project plan which incorporated 24 brine production wells located on both sides of the Dolores River and the construction of a second brine injection well. This alternative would allow the Unit to achieve the goal of 90-percent reduction in salt loading to the Dolores River.

Funding constraints have eliminated the consideration of the alternative developed in 1989. The proposed action evaluated in this Biological Assessment is to operate the already constructed test facilities on a long term basis. Existing test facilities consist of one brine deep well injection unit, a brine production well field located on the east side of the Dolores, a relief pumping plant adjacent to the well field, and a 3.7-mile pipeline connecting the pumping station to the deep well injection unit.

PREVIOUS SECTION 7 CONSULTATION

Reclamation and the Service have been in consultation, both formally and informally, on the Unit's potential effects to endangered species since 1975. A memorandum from the Service dated February 15, 1977, rendered a conditional "no effect" opinion on the original project plan—pending completion of additional studies on life cycles and habitat requirements of the Colorado squawfish and humpback chub. A later memorandum from the Service dated October 18, 1977, supplemented the February 15, 1977, opinion adding that the Unit would in "no likelihood

jeopardize the continued existence of the American peregrine falcon." These opinions were rendered on the preferred plan for the Unit as it was described in the 1979 FES, which included the 3,630-acre Radium Evaporation Pond in Dry Creek Basin and an estimated pumping rate of 5 cfs resulting in an annual depletion to the river of 3,619 acre-feet (USFWS, 1977a; 1977b).

In 1986, Reclamation reinitiated Section 7 consultations regarding the proposal to construct and operate testing facilities to evaluate injection as an alternative method of brine disposal. The Service responded to the proposal in a Planning Aid Memorandum dated May 4, 1988 (USFWS, 1988), concurring with Reclamation's assessment that the testing program would have no effect on the project area's listed terrestrial species, but expressing concern that "any net depletion of water from the Upper Colorado River Basin may affect the listed endangered fish." As a result of this "may affect" determination, the Service requested that formal consultation be initiated. Subsequent formal consultation resolved the testing program's flow-related issues with a commitment by Reclamation to offset depletion-caused impacts during the testing period with releases from McPhee Reservoir of up to 1,086 acre-feet and to reinitiate formal consultation when a final plan was developed.

In early 1989, based on the new information from the injection testing program, Reclamation reinitiated formal Section 7 consultation. The new proposed action consisted of the development of 2 injection wells, 24 brine production wells located on both sides of the Dolores River, and an estimated pumping rate of 1.5 to 2 cfs resulting in a depletion to the river of 1,086 to 1,448 acre-feet/year. In March 1989, Reclamation completed a Biological Assessment on the proposed action and concluded that (1) none of the listed terrestrial species would be adversely affected and (2) the minor annual flow depletions estimated at 1,448 acre-feet/year could be mitigated under the exemption described in the Recovery Implementation Program for Rare and Endangered Fish Species in the Upper Colorado River Basin and/or would be offset by the anticipated improvement in downstream water quality that would result from interception and removal of the valley's brine inflows (BOR, 1989). The Service did not concur with the "no affect" determination for the endangered fish but concluded the proposed action was not likely to jeopardize the continued existence of the fish and would result in an incidental take of zero.

Current consultations, including this Biological Assessment, are updating the list of threatened and endangered species that might be affected by the project and addressing the potential impacts that may result from implementation of the proposed action.

PROJECT SETTING

The Unit is located in the Paradox Valley which is located in extreme western Colorado in Montrose County. The area lies within the Juniper-Pinyon Woodland+Sagebrush-Saltbrush Mosaic Section of the Colorado Plateau Province Ecoregion. The climate in this section is characterized by cold winters, hot summer days, and cool nights. Annual average temperatures are 40° to 55 °F and decrease as altitude increases. Average annual precipitation is about 20 inches but less than 10 inches in some parts of the province. Soils are Entisols along the floodplains of major streams

Irrigated land occupies much of the valley floor to the west of the river, with major crops consisting of alfalfa, grains, and pasture. Sagebrush communities occupy most of valley east of the river. The under story is sparse and consists of perennial grasses and mixed annual forbs. In many areas, overgrazing has reduced the under story to primarily cheatgrass.

The greasewood community is found in the vicinity of the brine well field, along East Paradox Creek, and in other intermittent drainages and arroyos in eastern Paradox Valley and Dry Creek Basin. The dominant plant is black greasewood which may be found in association with other species such as seablite and scattered big sagebrush. In most instances, the under story is very sparse or totally absent. Seablite is the dominant plant in areas near the well field where greasewood is not found. In general, little or no under story of grasses is present in these areas, which are characterized by salt-encrusted ground.

Pinyon-juniper woodland is found on the slopes of Paradox Valley and on the surrounding mesas. Pinyon pine and Utah juniper predominate, although Rocky Mountain and common juniper are also present. The under story consists of woody shrubs, such as mountain snowberry, antelope bitterbrush, mountain mahogany, and serviceberry. Also found in this community are big sagebrush, rabbitbrush, prickly pear cactus, and various forbs and grasses.

PROPOSED ACTION AND ALTERNATIVES

The proposed action is to continue operating the already-constructed test injection facilities as the Unit's permanent contribution to the salinity control effort. While the proposed action does not achieve the Unit's original goal of eliminating 90 percent of the salt entering the Dolores River in Paradox Valley, it does provide significant reduction in the total salt loading to the Colorado River without expenditure of additional construction dollars. The proposed action will also reduce water depletions to the Dolores River. The Unit, as presently constructed, would be able to achieve an approximate 64-percent reduction in the natural salt loading to the river, thus, preventing approximately 128,000 tons of salt from entering the Colorado River system annually. This estimate is based on the present facility's ability to inject a mixture of 70 percent brine and 30 percent fresh water with an 80 percent plant factor.

Due to funding limitations, the only alternative considered is no action. Under this alternative, existing facilities would be abandoned and salinity control efforts would be discontinued in the Paradox Valley. Approximately 205,000 tons of salt would continue to enter the Dolores River annually. No benefits would be realized from the substantial investment made in the Unit to date.

PROJECT IMPACTS

The construction of the Unit is now complete and all environmental effects resulting from that construction have occurred. Facilities constructed include the injection well and facilities located

and Aridisols occupy the plateau tops, older terraces, and alluvial fans. Badlands of rough, broken land are extensive in the mountains and on plateaus (Bailey, 1980). Reclamation has maintained a weather station at bedrock near the facility since 1975. During this time, the average annual precipitation has been about 8 inches, occurring primarily from July through October in the form of afternoon thunderstorms. Temperatures have varied from daytime highs of about 100 °F in the summer to nighttime lows of about -20 °F in the winter.

The Unit is situated at the first 1.2 miles of the Dolores River Canyon upstream from the valley. Paradox Valley is from 3 to 5 miles wide, approximately 24 miles long, and aligned on a northwest-southeast axis. Elevations in the area vary from under 5,000 feet along the Dolores River to about 7,000 feet on the divide between the valley and Dry Creek Basin. This area is characteristic of the semiarid Southwestern United States with low precipitation and humidity, abundant sunshine, high evaporation rates, and wide ranges in daily high and low temperatures. Communities in the area include the two small farming towns of Paradox and Bedrock, and the larger towns of Nucla and Naturita to the southeast.

The Dolores River crosses the valley perpendicularly near its midpoint, and eventually confluences with the Colorado River approximately 70 miles downstream from the valley. In crossing the valley, the river picks up an estimated 205,000 tons of salt annually primarily from the surfacing of highly saline groundwater. Salinity levels over 260,000 mg/L (nearly eight times as saline as seawater) have been recorded in brine groundwater pumped from wells near the river. About 7 miles downstream of the valley, the Dolores' major tributary—the San Miguel River—joins the mainstem and provides a source of "dilution" for the salt-laden Dolores, particularly during periods of low flow.

Vegetation composition and density in the general vicinity of the Unit varies according to the seasonal availability and quality of water and soil type. Vegetation communities include riparian associations along the Dolores River and West Paradox Creek; irrigated agriculture in the western portion of Paradox Valley; sagebrush and semidesert shrublands of greasewood, seablite, and winterfat-snakeweed in the eastern portion of the valley; and pinyon-juniper woodland at the higher elevations on the sides of the valley.

The riparian vegetation is dominated by tamarisk, which varies from sparse along the river to dense groves up to 100 yards wide along West Paradox Creek. Grasses, with rushes in marshy areas, form the under story on the west bank of the river, while no significant under story is found on the east bank. Stands of cottonwood trees are scattered along both sides of the river upstream from the confluence with West Paradox Creek, with a tall shrub under story of New Mexico forestiera and a lower under story of grasses. In the area of the brine production well field (area of brine groundwater) and downstream along the river, the riparian vegetation consists almost entirely of sparse tamarisk with little to no under story.

approximately 1.2 miles south from Colorado Highway 90, a 20-foot-wide access road to the injection well, a brine production well field located on the east side of the Dolores River, a relift pumping plant adjacent to the brine production field, a 3.7-mile buried pipeline running from the brine well field to the injection well, and a 69-kV powerline from Highway 90 to the injection well. The 1979 Final Environmental Statement addressed impacts to the environment which would result from construction of the Unit's brine well field. The 1986 Final Environmental Assessment entitled "Deep Well Injection Testing Program" described the environmental affects of the construction and operation of the Unit facilities in a test mode and concluded with a finding of No Significant Impact (BOR, 1986a; 1986b).

The continued permanent operations of the facility will not result in any additional impacts other than those which have already occurred to listed or candidate species in the area except for annual water depletions to the Dolores and Colorado Rivers of approximately 516 acre-feet/year. The operation of the test unit would result in 3,103 acre-feet/year less depletions from the original proposal to pump to the evaporation pond and 932 acre-feet/year less depletions than if two deep injection well units were operated. The construction of an additional deep injection unit is no longer feasible due to funding limitations. However, the reduction in water depletions will also result in the increase of brine water into the Dolores and Colorado Rivers, and the goal of reducing natural brine inflows by 90 percent will not be achieved. Potential project impacts to threatened and endangered species and conservation measures are summarized in Table 1.

CONSERVATION MEASURES

Several conservation measures and other actions have been or will be implemented to protect and conserve endangered fish in the Dolores and Colorado Rivers. The Recovery Implementation Program for Endangered Fishes in the Upper Colorado River Basin has been executed to recover the four endangered fishes indigenous to the basin while providing for existing and new water developments to proceed in the Upper Colorado River Basin. The Service has determined that the Recovery Program has made sufficient progress for projects which deplete less than 3,000 acre-feet/year to go forward, subject to payment of a depletion charge. Reclamation is not subject to this charge since it is a participant in the Recovery Program and contributes annually to the program's \$3 million operating budget (USFWS, 1994).

Reclamation has proposed to modify the operation of McPhee Reservoir located on the Dolores River 15 miles north of Cortez, Colorado, for fish and wildlife purposes (BOR, n.d.). Reclamation proposes to modify water releases and acquire additional water to increase the total volume for fish and wildlife purposes. Endangered and other fish species in the Dolores River would benefit from the proposed modifications since normal operations at McPhee Reservoir result in low flows in the Dolores River during dry years, and all alternatives would increase flows in the Dolores River. Releases from McPhee Reservoir could supplement water depletions to the Dolores River resulting from operation of the Unit.

Other conservation measures implemented with the project include design of new transmission lines to prevent electrocution of raptor species that utilize the area. Financial contributions were also transferred to the CDOW to assist in transplanting chukars to the Paradox Valley to provide additional recreational opportunities and an additional prey base for raptors in the valley.

TABLE 1
 Summary of potential environmental impacts associated with the
 proposal to operate the Paradox Unit on a long term basis

SPECIES	POTENTIAL PROJECT IMPACTS	RECOMMENDED MITIGATION MEASURES
American peregrine falcon	No impacts; species habitat not affected by project	No species-specific mitigation measures recommended
Bald eagle	No impacts; minor depletions will not affect existing habitat.	No species-specific mitigation measures recommended. Water quality improvements will benefit species
Black-footed ferret	No impacts; species habitat not affected by project	No species-specific mitigation measures recommended
Bonytail chub	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvement and upstream flow releases will benefit species
Colorado squawfish	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation recommended. Water quality improvement and upstream flow releases will benefit species
Humpback chub	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvements and upstream flow releases will benefit species
Mexican spotted owl	No impacts; affected environment does not provide suitable habitat for species	No species-specific mitigation measures recommended
Razorback sucker	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvement and upstream flow releases will benefit species
Southwest river otter	No impacts; minor depletions will not affect existing habitat	No species-specific mitigation measures recommended. Water quality improvements and upstream flow releases will benefit species
Southwestern willow flycatcher	No impacts; minor depletions will not affect existing environment	No species-specific mitigation measures recommended. Water quality improvements and upstream flow releases in addition to control of overgrazing and exotic vegetation would benefit species

TABLE 2
Endangered, threatened and candidate species
addressed in the biological assessment

SPECIES	STATUS ₁	
	FEDERAL	STATE
American peregrine falcon (<i>Falco peregrinus anatum</i>)	Endangered	Endangered
Bald eagle (<i>Haliaeetus leucocephalus</i>)	Threatened	Endangered
Black-footed ferret (<i>Mustela nigripes</i>)	Endangered	Endangered
Bonytail chub (<i>Gila elegans</i>)	Endangered	Endangered
Colorado squawfish (<i>Ptychocheilus lucius</i>)	Endangered	Endangered
Humpback chub (<i>Gila cypha</i>)	Endangered	Endangered
Mexican spotted owl (<i>Strix occidentalis lucida</i>)	Threatened	Threatened
Razorback sucker (<i>Xyrauchen texanus</i>)	Endangered	Endangered
Southwest river otter (<i>Lutra canadensis sonorae</i>)	Not listed	Endangered
Southwestern willow flycatcher (<i>Empidonax traillii extimus</i>)	Endangered	SU

a. **Federal Endangered** - Species which are in danger of extinction within the foreseeable future throughout all or a significant portion of their ranges.

Federal Threatened - Species likely to become endangered within the foreseeable future throughout all or a significant portions of their ranges.

State Endangered - Same as Federal Endangered.

State Threatened - Same as Federal Threatened.

State SC (Species of Special Concern) - Native species for which data indicate that there is a long term downward trend in numbers and distribution and the decline is likely to lead to threatened or endangered status. Also, recently delisted species whose abundance and distribution are stable and growing or whose abundance and distribution have attained Recovery Plan or Conservation Plan goals within the past 5 years.

State SU (Species of Undetermined Status) - Native species for which historical and current data are inadequate to demonstrate a decline in numbers or distribution.

a. All native populations of *L. canadensis* were believed to have been extirpated from Colorado in the 1900's. The State Endangered status applies to all populations of otters that have been reintroduced throughout the state, regardless of species and/or subspecies.

THREATENED AND ENDANGERED SPECIES

Reclamation requested a list of threatened and endangered species that may be present in areas affected by the proposed action. The Service identified listed, proposed listed, and candidate species to be added to the latest project list. The table on the following page shows the endangered, threatened, and candidate species identified by the Service.

While the Endangered Species Act does not require Federal agencies to address candidate species in a biological assessment, Reclamation recognizes the importance of addressing potentially threatened species to assist in preventing further decline of the species ultimately requiring formal protection under the Act. However, due to the issuance of new procedures for the classification of candidate species by the Service, no candidate species are identified that will be affected by the project.

AMERICAN PEREGRINE FALCON *(Falco peregrinus anatum)*

Status, Distribution, and Abundance

Three subspecies of peregrine falcons are found in North America. The subspecies endemic to Colorado is *Falco peregrinus anatum*. This subspecies was listed by the Service as endangered in 1970 and is listed by the State of Colorado as an endangered species. *F. peregrinus anatum* occurs from Mexico north to the arctic tundra.

Evidence indicates that the peregrine falcon was present in the Western United States at least 30,000 years ago. Historically about 180 pairs of peregrines nested in the Rocky Mountain/Southwest Region. In the 1950's, the breeding populations throughout much of the Northern Hemisphere began an unprecedented decline. *F. peregrinus anatum* has shown the most drastic decline. In 1964, six of 31 historic nest sites in Colorado were occupied. In 1975, seven of 25 historic peregrine falcon sites visited in Colorado had pairs. A decline in active peregrine falcon aeries in the northwestern and other sections of the United States prior to 1948 were attributed to changes in climate (increases in temperature and decreases in precipitation); however, the major causes for declines have been attributed to DDT contamination leading to eggshell thinning. Other causes leading to the demise of the peregrine falcon include shooting, poisoning by pesticides, destruction of nestlings, and interference at the nest causing abandonment or interruption of parental care (Rocky Mountain/Southwestern Peregrine Falcon Recovery Team, 1977).

Peregrine falcons occur in the Dolores River Canyon upstream from Paradox Valley and in the Paradox Valley area. An aerie is located approximately 44 miles downstream from McPhee Dam, and two other nesting pairs are located along the river between Slick Rock and Bedrock, Colorado (Colorado Division of Wildlife unpublished data, 1993).

In the early summer of 1977, a peregrine falcon aerie was discovered on the north end of Paradox Valley approximately 1 mile north of the Unit's temporary evaporation pond high on a precipitous cliff (BOR, 1977). While the falcons have periodically relocated the aerie along this cliff from year to year, the same nesting pair successfully nested through 1995 (Pers. Comm. Bob Welch, BLM, 1995), and CDOW confirmed nesting activity also up through 1995 (Tom Beck, 1996). The Colorado Natural Heritage Program confirmed a breeding occurrence in 1994 (Grunau, 1996). Through this period, construction and testing of various project facilities have not adversely affected nesting success of the peregrines.

Life Requisites

The habitat requirements of the peregrine falcon may be divided into three parts: (1) nesting sites, the cliff or substrate upon which eggs are laid, young are reared, and reproduction activities take place; (2) hunting sites, the environs or territory where food is obtained; and (3) migration and wintering sites, the winter resting and hunting sites or habitats through which it migrates (Rocky Mountain/Southwestern Peregrine Falcon Recovery Team, 1977).

Nesting Sites. - Peregrine falcons in the Rocky Mountains and Southwest Region now persist mainly on mountain cliffs and river gorges. Active aeries are usually present upon cliffs which exceed 200 feet in height. Nests are situated on open ledges, and a preference for a southern exposure increases with latitude. Peregrines nest from the lowest elevations in the region to above 9,000 feet, but nesting above 8,500 feet is rare. In the Rocky Mountain Region, the majority of known remaining pairs are near scrub-oak or pinyon-juniper woodlands. Prey abundance and diversity provided by these situations are probably a major factor in aerie selection. Nest sites also are adjacent to water courses and impoundments because of the abundance of avian prey frequenting such areas.

Hunting Sites. - Peregrines may travel up to 17 miles from nesting cliffs to hunting areas. Flight speeds in excess of 60 miles per hour allow this falcon to hunt large areas with little effort. Preferred hunting habitats are cropland, meadows, river bottoms, marshes, and lakes which attract abundant bird life. The peregrine's principal food items are passerine birds, waterfowl, and shorebirds.

Migration. - Migratory behavior is largely restricted to *F.p. tundrius* falcons, although *F.p. anatum* in the more northern latitudes will move southward if the food supply is not adequate for the winter (Snow, 1972).

Consequences of the Proposed Action

The Unit has been constructed and operated in a test mode for several years and nesting activity was reported through 1995. The minimal water depletions resulting from this action would not change or affect the habitat for the peregrine falcon. The proposed action will not impact or change

the existing environment, therefore, it will not affect peregrine falcon nesting, hunting, or migration habitat.

Recommended Mitigation Measures

In order to prevent electrocution of raptors, all powerlines at the Unit were constructed to conform with criteria outlined in Suggested Practices for Raptor Protection on Powerlines - The State of the Art, 1981; Raptor Research Foundation, Inc. In addition, efforts to supplement the prey base for peregrine falcons and other raptors have been attempted by the release of chukar. Since the proposed action would not affect the existing environment, no additional mitigation measures would be implemented for the peregrine falcon.

Summary of Project Impacts

All disturbances resulting from construction and operation of the Unit have occurred. Minor water depletions would result from the proposal to operate the already constructed test facility on a long term basis. Peregrine falcons utilize the Paradox Valley and riparian habitats as feeding and migratory habitat. Additional depletions to the Dolores River would not affect peregrine habitat; therefore, the existing prey base would not be affected, and peregrine falcons would not be impacted by the proposed action.

BALD EAGLE

(Haliaeetus leucocephalus)

Status, Distribution, and Abundance

The first listing of the bald eagle occurred in 1967 when the Service listed the southern bald eagle as endangered (March 11, 1967; 32 FR 4001). This listing was made under the Endangered Species Preservation Act of 1966 and did not include the northern bald eagle primarily because the Alaskan and the central and western Canadian populations of that subspecies were not considered endangered. Subsequently, the Service published a second bald eagle ruling (February 14, 1978; 43 FR 6233) under the authorities granted by the Act, listing the bald eagle as endangered throughout the 48 conterminous states, except in Washington, Oregon, Minnesota, Wisconsin, and Michigan where it was listed as threatened.

The bald eagle has been reclassified from endangered to threatened. The Service issued notice on July 12, 1994, to reclassify the bald eagle from endangered to threatened in most of the lower 48 states (Federal Register, 1994b). The Final Rule to reclassify the bald eagle from endangered to threatened was published in the Federal Register July 12, 1995, with an effective date of August 11, 1995 (Federal Register, 1995).

The bald eagle has an overall range encompassing Canada, Alaska, northern Mexico, and the

48 conterminous states. Wintering bald eagles begin arriving in southwestern Colorado in October and November and usually depart by March or April. Numerous raptor surveys were conducted by the CDOW in 1976, and aerial reconnaissance surveys were conducted by the Service in both 1985 and 1986 for evidence of endangered raptors. While numerous wintering bald eagles were observed in the general area, no bald eagle aeries were observed within the Unit affected area. Bald eagles are known to prefer fish and waterfowl for food. Most of the wintering bald eagles have been observed in the Dry Creek Basin areas, southeast of Paradox Valley. The Dolores River is not a part of the annual CDOW midwinter bald eagle surveys. The predominant wintering use appears to be the 20-mile stretch of the river below McPhee Dam (Beck, 1996). Since there is little open water in the area during the winter months, fish and waterfowl probably comprise a small percentage of their winter diet. Instead, eagles are commonly seen feeding on carrion, primarily sheep, deer and elk (BOR, n.d.).

Life Requisites

Wintering bald eagles are associated with unfrozen lake, river, and wetland habitats. Distribution is dependent on prey density, suitable perch and roost sites, weather conditions, and freedom from human disturbance (Ohmart and Sell, 1980). Eagle numbers normally fluctuate considerably at particular wintering areas.

Although most wintering eagles depend primarily on fish, other prey is also taken including jack rabbits, waterfowl, and carrion (Spencer, 1976). Food habits of the bald eagle are opportunistic and vary regionally in the Southwest. Important food items include fish, especially carp, channel catfish, waterfowl, carrion, and small mammals. Dams have caused changes in wintering bald eagle distribution by concentrating populations to newly created food sources. The presence of a fishery does not necessarily ensure its attractiveness to bald eagles. Eagles often depend on fish that are dead, dying, or otherwise vulnerable (Steenhof, 1978).

Communal roosting is prevalent in wintering bald eagles with protection from the wind being a primary consideration (Steenhof, 1978). The night roost is almost invariably a tree protruding above the forest canopy which permits an unobstructed approach and takeoff. The absence of small branches makes a dead tree or snag the perch-of-choice (Spencer, 1976).

Diurnal hunting and loafing perch sites are usually trees with large horizontal branches, bordering open areas, especially on the edges of rivers or lakes. Proximity to a food source and visibility are key factors influencing perch selection by eagles (Steenhof, 1978). Eagles often select the tallest trees available with branches overlooking a food source. Specific trees and even branches are habitually used.

Bald eagles are sensitive to human activities and may abandon favorable sites if disturbed. Although bald eagles can become conditioned to automobile traffic, vehicles such as motor boats and snowmobiles disrupt eagle activity patterns. Hunting and chainsaw activities have been known to displace eagles from winter roosting areas (Steenhof, 1978).

Most populations appear to be recovering from earlier reproductive difficulties associated with DDT and related chemical contamination. Illegal shooting remains the greatest single known source of bald eagle mortality. Roughly half of all recorded bald eagle deaths are a direct result of shooting (Evans, 1982).

Consequences of the Proposed Action

All disturbances associated with the construction and operation of the Unit have already occurred. Preliminary conclusions, based upon the Animas-La Plata bald eagle habitat surveys, indicate prime bald eagle habitat for roosting and feeding activities in southwestern Colorado consists of cottonwood forests or isolated cottonwoods usually located adjacent to wetlands (BOR, 1994). This type of habitat exists in the area on the west side of the Dolores River and upstream from the area of disturbance on the east side. The main water depletions associated with pumping from the brine well field occur downstream of prime bald eagle habitat associated with existing cottonwood forest and will not be affected by the project.

Recommended Conservation Measures

In order to prevent electrocution of raptors, all powerlines at the Unit were constructed to conform with criteria outlined in Suggested Practices for Raptor Protection on Powerlines - The State of the Art, 1981; Raptor Research Foundation, Inc. The proposed modifications in the operation of McPhee Reservoir and improved water quality resulting from operation of the Unit will enhance fisheries and waterfowl habitat and improve the food base for the bald eagle.

Summary of Project Impacts

There would be no impacts resulting from the proposed project that would impact the bald eagle.

BLACK-FOOTED FERRET *(Mustela nigripes)*

Status, Distribution, and Abundance

Widespread poisoning of prairie dogs and agricultural cultivation of their habitat drastically reduced prairie dog abundance and distribution in the last century. Sylvatic plague, which may have been introduced to North America around the turn of the century, also determined prairie dog numbers, particularly in the southern portion of their range. The severe decline of prairie dogs nearly resulted in the extinction of black-footed ferrets. The ferret's decline may be partially attributable to other factors such as secondary poisoning from prairie dog toxicants and canine distemper. The black-footed ferret was listed by the Service as an endangered species on March 11, 1967 (Federal Register, 1995).

Historically, the black-footed ferret was found over a wide area, but it is difficult to make a conclusive statement on its historical abundance due to its nocturnal and secretive habits. The historical range of the species, based on specimen collections, includes 12 states (Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming) and the Canadian Provinces of Alberta and Saskatchewan. There is prehistoric evidence of this ferret occurring from the Yukon Territory in Canada to New Mexico and Texas (Federal Register, 1995).

There are no historical records indicating black-footed ferrets ever occurred in Paradox Valley. However, Paradox Valley once contained a large population of Gunnison prairie dogs (*Cynomys gunnisoni zumiensis*), a preferred food source for the ferret (Cressey and Grad, 1975). They further state these prairie dog populations have been greatly reduced by human extermination. Currently, remnant populations of prairie dogs exist sporadically in the valley at ground elevations where the water table is relatively low.

Life Requisites

Black-footed ferrets primarily prey on prairie dogs and use their burrows for shelter and denning and depend almost exclusively on prairie dogs for food and shelter (Federal Register, 1995). Although black-footed ferrets observations have been reported in prairie dog towns as small as 14 acres in South Dakota, more recent information suggests that minimum habitat requirements are much larger. At one time near Meeteetse, Wyoming, an estimated 40 to 60 adult ferrets were supported by 21 prairie dog towns covering 6,000 to 7,200 acres with mean burrow densities of 4 or more per acre (Clark, 1989). The 21 colonies averaged 338 acres each and covered 8.5 percent of the Meeteetse study area (USFS, 1989). The smallest town supporting an adult ferret at the Meeteetse site was approximately 118 acres (Clark, 1989). Minimal habitat for black-footed ferrets in South Dakota should support at least eight prairie dog colonies per township, with each dog town covering at least 30 acres, and two or more colonies covering at least 100 acres (Hillman et al., 1979). This 380 acres per township was considered a minimum habitat size for black-footed ferrets.

Consequences of the Proposed Action

There is evidence that small remnant prairie dog towns may exist along West Paradox Creek of the site; however, based upon past studies, these prairie dog towns—if active—are far too small to support black-footed ferrets.

All populations of prairie dogs are located away from project features or disturbances; therefore,

we do not believe these prairie dog populations or any rare chance of associated black-footed populations would be affected by the proposed action.

Recommended Mitigation Measures

Since the proposed action will not affect prairie dog towns or black-footed ferret habit, no mitigation measures will be implemented for the black-footed ferret.

Summary of Project Impacts

All disturbances associated with the construction and operation of the Unit have occurred, and no impacts to the black-footed ferret will result from the long term operation of the Paradox Unit.

BONYTAIL CHUB *(Gila elegans)*

Status, Distribution, and Abundance

Bonytail chub were listed as an endangered species on April 23, 1980. In the upper basin of the Colorado River, critical habitat is designated for the bonytail chub in portions of the Colorado, Green, and Yampa Rivers (Federal Register, 1994b). The bonytail chub is also listed as endangered in Colorado and protected in Utah (USFWS, 1987). The primary causes of decline of this species have been listed as changes in land use patterns, water development, competition from nonnative fishes, and hybridization with other introduced species.

Bonytail chub were historically found to be widespread and abundant in rivers throughout the Colorado River Basin, however, populations have been greatly reduced. This species is now one of the rarest native fish in the basin. A small number of old fish (i.e., ages of 40 years or more) are all that remain living in the wild, and recruitment is thought to be virtually nonexistent. Nowhere has reproductive success been documented. In the lower basin, a small population persists in the Colorado River in Lake Mohave and there are recent records from Lake Havasu. In the upper basin, recent captures have occurred in Dinosaur National Monument on the Yampa River, Desolation and Gray Canyons on the Green River, and Black Rocks and Cataract Canyon on the Colorado River (Federal Register, 1994b).

Bonytail chubs have never been reported occurring in the Dolores River (Valdez et al., 1982) and were not reported during recent surveys of the Dolores River carried out by Bio/West (Valdez et al., 1992). Portions of the Dolores River, especially the section between Bradfield Bridge, 10 miles downstream of McPhee Dam and Paradox Valley, may offer suitable habitat for future bonytail reintroductions (BOR, 1989).

Life Requisites

The bonytail chub is adapted to mainstream rivers, where it has been observed in pools and

eddies. In reservoirs, the fish occupies a variety of habitat types. In Lake Mohave, the bonytail chub has been observed in eddy habitats. Spawning requirements have never been documented in a river, but it is reported that spawning occurs in June and July at water temperatures of about 64 °F. The available data suggest that habitats required for conservation of the bonytail chub include river channels, and flooded, ponded, or inundated riverine habitats that would be suitable for adults and young, especially if competition from nonnative fishes is reduced (Federal Register, 1994bc). Proposed modifications in the operation of McPhee Reservoir to increase flows during the summer and dry years should enhance the aquatic habitat of the bonytail chub and supplement water depletions resulting from the long term operation of the Unit.

Consequences of the Proposed Action

The minor depletions of 516 acre-feet/year resulting from the proposed action would not affect the bonytail chubs or their designated critical habitat. The improved water quality in the Dolores and Colorado Rivers resulting from the proposed action will benefit the bonytail chub and the aquatic resources the species is dependent upon in its environment.

Recommended Mitigation Measures

No mitigation measures for the bonytail chub are recommended; however, improved water quality, which is the primary goal of the long term operation of the Unit, should benefit the species.

Summary of Project Impacts

The long term operation of the Unit would result in minor water depletions. However, these depletions should not affect the bonytail chub and should be offset by improvements in water quality. Proposed modifications in the operation of McPhee Reservoir should supplement water depletions resulting from the long term operation of the Paradox unit.

COLORADO SQUAWFISH *(Ptychocheilus lucius)*

Status, Distribution, and Abundance

The Colorado squawfish was first classified as endangered on March 11, 1967, and was later given full protection under the Endangered Species Act of 1973 following formal listing in January 1974 (Federal Register, 1974). In the upper basin of the Colorado River, critical habitat is designated for the Colorado squawfish in portions of the Colorado, Green, Yampa, White and San Juan Rivers (Federal Register, 1994b). Colorado squawfish are the only federally protected fish species addressed in this assessment which have been historically reported from the Dolores River (Valdez et al., 1992). Colorado squawfish are also designated as endangered by the CDOW and have been granted some form of protected status in all of the remaining Colorado River Basin states

(USFWS, 1987). The cause of the decline of the Colorado squawfish is unknown but is probably related to a combination of factors including direct loss of habitat, changes in flow regime, blockage of migration routes, water temperature changes, and interactions with introduced fish species (USFWS, 1987).

Colorado squawfish were once abundant in the mainstem of the Colorado River and most of its major tributaries in Colorado, Wyoming, Utah, New Mexico, Arizona, Nevada, California, and Mexico. The remaining native populations total fewer than 10,000 adult individuals and are restricted to the upper basin in Colorado, Wyoming, Utah and New Mexico (USFWS, n.d.). The largest populations are found in segments of the Green, Yampa, White, Gunnison, and Colorado Rivers above Lake Powell and there is a small reproducing population in the San Juan River (Federal Register, 1994bc; Maddux et al., 1993). In the lower basin, the last known adult Colorado squawfish was taken by a fisherman in 1975 from the mouth of Havasu Creek. Lower basin recovery efforts in recent years have included the reintroduction of over 300,000 hatchery-reared fish into several locations, including the Salt and Verde Rivers in Arizona (Maddux et al., 1993; USFWS, n.d.).

Colorado squawfish spawning has been documented in canyons in the Yampa and Green Rivers (Tyus, 1991). Reproduction is associated with declining flows in June, July, and August and average water temperatures ranging from 22 to 25 °C (72 to 77 °F). River-mile 130 on the Colorado River, near the Colorado-Utah State line, also has been identified as a spawning site, and radio-tagged adults have moved to a specific 0.1-mile-long section in four different years (Osmundson and Kaeding, 1989; USFWS unpublished data, 1992-1993). In the mainstem Colorado River, spawning occurs at many locations (McAda and Kaeding, 1991). They also suggested that Colorado squawfish spawning in the Colorado River may have been adversely impacted by construction of mainstem dams and a 48-percent reduction in peak discharge. On the San Juan River, a spawning reach has been identified between river-miles 133.4 and 129.8, near the confluence of the Mancos River (Ryden, 1995).

The Service (USFWS, 1994) considers the Dolores River to be Colorado squawfish habitat based on historic records of occurrence in the drainage. Small squawfish have been collected from unidentified locations in the Paradox Valley as late as 1962 (Seethaler, 1978). The Dolores River may have functioned as a spawning tributary for breeding populations inhabiting the upper Colorado River in the vicinity of the confluence of the two rivers (Valdez et al., 1992). No reports or records of occurrence were found that indicate Colorado squawfish occupied or utilized the Dolores River upstream of Paradox Valley.

Colorado squawfish were rarely found and, in some cases, reported to be absent from the lower Dolores River above the Colorado/Utah State line by the 1950's and 1960's, (Valdez et al., 1982). Conditions likely worsened in the mid-1960's as recurrent spills and leeching of uranium mill wastes into the San Miguel River near the town of Uravan decimated much of the aquatic life in the 60-mile reach of the Dolores River from the confluence of the San Miguel River to the confluence with the

Colorado River (Valdez et al., 1992).

No squawfish were found in a 1971 survey of the Dolores River from the town of Dolores to the confluence with the Colorado River (Holden and Stalnaker, 1975). In 1981, similar findings were reported in an extensive fishery and aquatic habitat survey of the river from the Paradox Valley to the Colorado River (Valdez et al., 1982). This led the authors to speculate that the only probable area in the Dolores River that squawfish may periodically exist would be in close proximity to the Colorado River confluence. In subsequent surveys conducted in 1990 and 1991, four Colorado squawfish were captured in the lower 177 miles of the Dolores River from Bradfield Bridge to the confluence with the Colorado River (Valdez et al., 1992). All of these squawfish were collected in 1991 and were captured within 1.25 miles of the confluence with the Colorado River. It is not known whether these fish were temporarily using the Dolores River or were permanent residents; however, their close proximity to the Colorado River may indicate that these fish were only temporary inhabitants.

The apparent decline of the Colorado squawfish in the Dolores River has been tied to a combination of human-induced and naturally occurring conditions. Alteration of the river's historic habitat can largely be traced to flow changes (mainly low summer flows) associated with irrigation diversions, contamination from uranium mills near the towns of Uravan and Slick Rock, and the proliferation of introduced species.

In the late 1800's, a trans-basin diversion dam was constructed on the Dolores River near the town of Dolores by the Montezuma Valley irrigation Company. Before completion of McPhee Dam, most all the flow of the river was diverted for irrigation use during late summer and early fall. The dam diverted nearly all of the river during the summer and fall low-flow period. The USGS gauging station—"Dolores River at Bedrock CO"—recorded zero flow on numerous occasions before completion of McPhee Dam. These low-/no-flow conditions resulted in extremely high concentrations of salt in the Dolores River leaving the Paradox Valley. These conditions resulted in the elimination of most aquatic life in the Dolores River from Paradox Valley to the confluence with the San Miguel (BOR, 1989).

Uranium processing facilities operated during the late 1940's through the 1960's severely impacted water quality in the San Miguel and lower Dolores Rivers and may have contributed to the decline of the Colorado squawfish in the basin (USFWS, 1994). Several toxic spills into the San Miguel River are known to have occurred from the uranium processing plant located at Uravan, Colorado. A second uranium processing facility near Slick Rock, Colorado, was reported to be operational over generally the same time frame (Valdez et al., 1992). The combination of less-than-favorable conditions discussed above concludes that "from the standpoint of preservation of rare and endangered fish species, the Dolores River system appears to have little importance" (Holden and Stalnaker, 1975).

Life Requisites

The Colorado squawfish was once the top native carnivore in the Colorado River system. As an adult, it is a voracious predator capable of attaining weights exceeding 80 pounds and lengths of nearly 6 feet, however, specimens weighing more than 15 pounds have rarely been found since 1970 (USFWS, 1987). Squawfish are well-adapted to the major rivers in the Colorado River Basin where hydraulic regimes can be characterized by variable flows, high silt loads, and periods of high turbulence. Young-of-the-year, juveniles, and sub-adults are most frequently found in shallow backwater areas with silt and sand substrates and little or no current. Older, larger squawfish prefer deeper, moving water but use a wide variety of habitats throughout their life cycle. Migration is an important component in the reproductive cycle of the Colorado squawfish. Mature adults have been known to migrate up to 200 miles upstream or downstream to reach spawning areas on the Colorado, Green, and Yampa Rivers. Tyus (1990) hypothesized that migration cues, such as high spring flows, increasing river temperatures, and chemical inputs from flooded lands and springs may be important to successful reproduction (Federal Register, 1994b). Temperature preferences in nature have not been established, however, evidence from the Lower Colorado River Basin, where water temperatures often exceed 35 °C (95 °F), suggest broad thermal limits for the Colorado squawfish (USFWS, 1987).

After spawning, adult Colorado squawfish utilize a variety of riverine habitats, including eddies, backwaters, shorelines, and other backwater habitats (Tyus, 1990). During the winter, adult Colorado squawfish use backwaters, runs, pools, and eddies, but are most common in shallow, ice-covered shoreline areas (Osmundson and Kaeding, 1989; Wick and Hawkins, 1989). In spring and early summer, adult squawfish use shorelines and lowlands inundated during typical spring flooding. This natural lowland inundation is viewed as important for their general health and reproductive conditioning (Osmundson and Kaeding, 1989; Tyus, 1990). Use of these habitats presumably mitigates some of the effects of winter stress and aids in providing energy reserves required for migration and spawning.

In the Green River Basin, larval Colorado squawfish emerge from spawning substrates and enter the stream drift as young fry. The larval fish are actively or passively transported downstream for about 6 days, traveling an average distance of 100 miles to reach nursery areas in lower gradient reaches. These areas are nutrient-rich habitats that consist of ephemeral along-shore embayments that develop as spring flows decline (Federal Register, 1994b). Young-of-year Colorado squawfish are most often found in backwaters, since backwaters provide nursery and feeding habitat (USFWS, 1987).

Consequences of the Proposed Action

The minor depletions of 516 acre-feet/year resulting from the proposed action would not affect the Colorado squawfish or its designated critical habitat. The improved water quality in the Dolores and Colorado Rivers resulting from the proposed action may beneficially effect designated critical

habitat in the Colorado River and therefore the species.

Recommended Mitigation Measures

No mitigation measures are recommended; however, improved water quality, which is the primary goal of the long term operation of the Unit, should benefit the species.

Summary of Project Impacts

The long term operation of the Unit would result in minor water depletions. However, these depletions should not affect the Colorado squawfish and should be offset by improvements in water quality and the potential modifications in flow releases from McPhee Dam. Proposed changes in the operation of McPhee Reservoir should mitigate the affects of minor water depletions that would result from the long term operation of the Unit. Chronic low flows from McPhee Dam, especially during the summer and other dry periods, would be avoided. If sufficient flows were present, the Dolores River would have suitable habitat for the reintroduction of experimental populations of Colorado squawfish (Valdez et al., 1992).

HUMPBACK CHUB

(Gila cypha)

Status, Distribution, and Abundance

The humpback chub was a member of the original list of endangered species prepared in 1964 and was afforded protection by the Endangered Species Act of 1973 (Federal Register, 1974). In the upper basin, critical habitat is designated for the humpback chub in portions of the Colorado, Green, and Yampa Rivers (Federal Register, 1994b). The humpback chub is also designated as endangered by the State of Colorado and protected by the State of Utah (USFWS, 1987).

A combination of factors has been blamed for the decline of this fish: stream alteration (dams, irrigation, dewatering, and channelization); competition with and predation from introduced fish species; pollution and eutrophication; parasitism; changes in food base; and fishing pressure (USFWS, 1987). In the Yampa River, reduced spring peak flows, availability of shoreline eddy and deep canyon habitats, and competition and predation by nonnative fish were reported as potential limiting factors for humpback chub. The impact of hybridization with other species is currently being evaluated (Federal Register, 1994b).

This Colorado River native was not described as a species until 1946. This has been attributed to the presently restricted distribution in remote, white water canyons. Humpback chub are medium-sized as adults (12-16 inches) and are well-adapted for negotiating turbulent water, having a pronounced dorsal hump, abruptly tapered body, and large deeply forked tail (caudal) fin. The historic distribution of humpback chub included large, white water canyons on the Colorado River system including the mainstem Colorado and four of its tributaries—the Green, Yampa, White, and

Little Colorado Rivers (USFWS, 1987). In the lower basin, the largest remaining population occurs in the Little Colorado and Colorado Rivers in the Grand Canyon. In the upper basin, humpback chub are found in the Black Rocks/Westwater Canyon and Cataract Canyon of the Colorado River, Desolation and Gray Canyons of the Green River, and Yampa and Whirlpool Canyons in Dinosaur National Monument, Green and Yampa Rivers (Federal Register, 1994b). The humpback chub has never been reported to occur in the Dolores River (Holden and Stalnaker, 1975). Humpback chub were not reported during recent surveys carried out in the Dolores River by Bio/West in 1992 (Valdez et al., 1992).

Life Requisites

Humpback chub in reproductive condition are usually captured in May, June, or July, depending on location. Spawning occurs soon after the highest spring flows when water temperatures approach 66 °F. Investigators have implicated flow reductions and low water temperatures in the Grand Canyon as factors curtailing successful spawning of the fish in addition to increasing competition from other species (Federal Register, 1994b)

Existing populations of humpback chub tend to occupy remote, specialized habitats, most often associated with deep, turbulent water over substrates of sand, silt, boulder, and bedrock (UFWS, 1987). Most of the existing information on habitat preferences has been obtained from adult fish in the Little Colorado River, the Grand Canyon, and the Black Rocks of the Colorado River. In these locations, the fish are found associated with boulder-strewn canyons, travertine dams, pools, and eddies. Some habitat-use data also are available from the Yampa River Canyon where the fish occupy similar habitats and also use rocky runs, riffles, rapids, and shoreline eddies. This diversity of habitat use suggests that the adult fish are adapted to a variety of habitats, and studies of tagged fish indicate that they move between habitats, presumably in response to seasonal habitat changes and life history needs (Federal Register, 1994b).

Habitat suitable for humpback chub may exist in the section of the Dolores River between Bradfield Bridge, 10 river-miles downstream of McPhee Dam, to Paradox Valley. However, fish and/or habitat surveys for this section of the Dolores River are incomplete and not well documented. Limited potential existed for the recovery of *Gila sp.* as long as transbasin diversions continued to deplete the Dolores River flow during the irrigation season and poor water quality continued as a limiting factor to native fish populations (Valdez et al., 1982; USBOR, 1989).

Consequences of the Proposed Action

The minor depletions of 516 acre-feet/year resulting from the proposed action would not affect the humpback chub or its designated critical habitat. The improved water quality in the Dolores and Colorado Rivers resulting from the proposed action may beneficially affect designated critical habitat in the Colorado River and therefore the species.

Recommended Mitigation Measures

Mitigation measures that might affect the humpback chub are not recommended; however, improved water quality, which is the primary goal of the long term operation of the Unit, should benefit the species. Poor water quality continues as a limiting factor to native fish populations in the Dolores River (Valdez et al., 1982; BOR, 1989).

Summary of Project Impacts

The long term operation of the Paradox Unit would result in minor water depletions. However, these depletions should not affect the humpback chub and should be offset by improvements in water quality. In addition, proposed changes in the operation of McPhee Reservoir should mitigate the affects of minor water depletions that would result from the long term operation of the Unit. Chronic low flows from McPhee Dam, especially during the summer and other dry periods, would be avoided which would benefit the humpback chub.

MEXICAN SPOTTED OWL (*Strix occidentalis lucida*)

Status, Distribution, and Abundance

The final rule listing the Mexican spotted owl as a threatened species under the authority of the Act was published in the Federal Register on March 16, 1993. The Mexican spotted owl is also listed as threatened in Arizona, Utah, and Colorado. The species is threatened by destruction and modification of habitat caused by even-aged timber harvest methods and wildfires, decreased habitat suitability, and potential increased predation associated with habitat fragmentation (Federal Register, 1994b).

There are three recognized subspecies of spotted owls. The northern spotted owl (*Strix occidentalis caurina*) is found from southwestern British Columbia to just north of San Francisco Bay; the California spotted owl (*Strix occidentalis occidentalis*) is found in the Sierra Nevada Mountains and the costal ranges of California south of San Francisco Bay; and the Mexican spotted owl (*Strix occidentalis lucida*) is found from southern Utah and Colorado through Arizona, New Mexico, and west Texas into the mountains of central Mexico (USFS, nd).

In Colorado, systematic surveys conducted annually since 1989 have confirmed the rarity and limited distribution of *S. o. lucida* in the state. Except for three adult birds in Mesa Verde National Park and nearby Ute Mountain Ute tribal land, all confirmed owl sightings have been in the San Isabel National Forest and nearby BLM lands in the Canon City area (Boyle and Franklin, 1993b). The most recent statewide survey results, for years 1992-1994, yielded documented sightings of 19, 26, and 15 owls, respectively, at 13 survey sites in southwestern Colorado and the southern Front Range (Verner, 1995).

Results of two seasons of surveys conducted in 1992 and 1993 in suitable habitats bordering the Paradox Valley project area included tributaries (side canyons) of the Dolores River immediately upstream and downstream of the Paradox Valley; ridges adjacent to Disappointment Valley; Carpenter Ridge north of the town of Paradox; and side canyons of the San Miguel River near Norwood (Boyle and Franklin 1993a, 1993b). No evidence of Mexican spotted owls, either calls or sightings, was reported at any of the survey sites. Similar results were reported in surveys conducted during 61994 at 27 survey locations in the San Juan National Forest (Olterman, 1995).

The Service has identified 112 proposed critical habitat units totaling 4,770,223 acres in Arizona, Colorado, New Mexico, and Utah. In Colorado, 104,103 acres were identified as potential critical habitat (Federal Register, 1994b). All critical habitat proposed in Colorado is located in Archuleta County and a very small portion of eastern La Plata County. No critical habitat is proposed in Montrose County in which the Unit is located.

Life Requisites

The Mexican spotted owl typically inhabits old growth warm- and cold-temperate forests characterized by steep slopes, canyons, and rocky cliffs (Federal Register, 1993b). Vegetative and structural preferences may vary across its range, but mixed-conifer communities appear to be the most frequently used. Vegetative attributes most commonly associated with preferred nesting and roosting habitat include high canopy closure (60 to 80 percent); a multi-layered canopy with large overstory trees of various species; a high incidence of mature trees with broken tops, large cavities, mistletoe infections, and other evidence of decadence; large snags; and accumulations of fallen trees and other woody debris. These habitat characteristics are best expressed in old growth groves (perhaps 200 years or older) with the absence of active management (Federal Register, 1994ba).

At the northern edge of its range in northeastern Arizona, southwestern Colorado, and Utah, Mexican spotted owls may occur year-round at 4,400 to 6,800 feet within the pinion-juniper zone below higher-elevation mixed conifer forests. These lower zones often include narrow steep-sided canyons exhibiting shaded, cool, and humid conditions that support dense growths of riparian and conifer plant associations favorable to inhabitation (Federal Register, 1993c; Federal Register, 1994ba).

Information on the reproductive cycle of the Mexican spotted owl is limited. Spotted owls breed for the first time at 2 to 3 years of age. Adult spotted owls are solitary from October through January. Beginning sometime in February or March, pairs on a territory begin to roost together and begin calling every night, especially at dusk (USFS, n.d.). Most owls lay their eggs in April with some reports as early as March being reported (Federal Register, 1993c). Clutch size varies from one to three eggs with a brood size of one or two owlets; however, broods of three occur occasionally in southern New Mexico (Federal Register, 1993c). The incubation period is approximately 30 days

with most eggs hatching by the end of May. Fledgling occurs in June with the young becoming fully independent by October. Reproductive success can vary widely from year to year.

Mexican spotted owls feed primarily on mammals; however, birds, reptiles, and insects also comprise their diet. Woodrats (*Neotoma* spp.) are the primary prey, especially in rock canyon areas. Since owls initiate their attack on prey from relatively short distances, a multi-storied forest, with its many potential perches, offers an advantage to the owl. Natural predators of the spotted owl include hawks (e.g., *Accipiter gentilis*, *Buteo* spp.) and great horned owls (*Buteo virginianus*) (Federal Register, 1993c).

The Mexican spotted owl is threatened by (1) habitat loss as a result of logging and fires, (2) increased predation associated with habitat fragmentation, and until recent years, (3) lack of adequate protective regulations. Because the time required for spotted owl habitat to regenerate typically exceeds 100 years, any action that would contribute to the loss of suitable habitat will reduce the likelihood for survival and recovery of the Mexican spotted owl (Federal Register, 1991).

Consequences of the Proposed Action

Implementation of the proposed action will have no effect on the Mexican spotted owl. Recent spotted owl surveys in the general vicinity of the proposed project failed to locate any individuals or nesting pairs. Furthermore, none of the project facilities are located in, or adjacent to, suitable spotted owl nesting or roosting habitat. Furthermore, no critical habitat for the Mexican spotted owl has been designated in the Paradox Valley.

Neither the anticipated improvement in downstream water quality or the small annual depletion to the Dolores River is expected to result in any impacts to the Mexican spotted owl or its designated or potential habitat.

Recommended Mitigation Measures

Since the proposed project would not impact the Mexican spotted owl, no mitigation measures are recommended for this species.

Summary of Project Impacts

There would be no impacts resulting from this project that would affect the Mexican spotted owl.

RAZORBACK SUCKER
(Xyrauchen texanus)

Status, Distribution, and Abundance

The razorback sucker was listed as an endangered species in the Federal Register on October 23, 1991. The razorback is listed as endangered by the State of Colorado, and protected by the State of Utah (USFWS, 1987). In the upper basin of the Colorado River, critical habitat for the razorback sucker is designated for portions of the Green, Yampa, Duchesne, Colorado, White, Gunnison, and San Juan Rivers (Federal Register, 1994b).

The razorback sucker is the only member of its genus and is a member of the sucker family, Catostomidae. Causes for the decline of the razorback sucker have been listed as dams and impoundments; principally land and water use practices, changing flow regimes, and river channel characteristics that eliminate preferred backwater habitats (USFWS, 1987).

The razorback sucker was once abundant throughout 3,500 miles of the Colorado River Basin primarily in the mainstem and major tributaries in Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming; and in the States of Baja California del Norte and Sonora of Mexico. These fish were most abundant downstream of present-day Lake Mead and very abundant around Yuma, Arizona. Razorback suckers historically occurred in most warm water reaches of the Gila River drainage to the New Mexico/Arizona border. Razorback suckers were abundant in the lower Salt River and in lower Tonto Creek and occurred in the Verde River to Perkinsville, Arizona. Upstream distribution in the Salt River may have been limited by extensive canyon habitat.

In the upper basin, razorback suckers historically occurred in the Colorado, Green, and San Juan River Basins. Razorback suckers also were found in the Gunnison River upstream to Delta, Colorado. Historic distribution of razorback suckers in the Green River was from its confluence with the Colorado River upstream to Green River, Wyoming. Razorback suckers were reported common in the lower White River near Ouray, Utah, and occurred in the lower Yampa River but were considered rare upstream to the Little Snake River, Colorado.

Upper basin razorback sucker distribution has been reduced to about 750 miles. The fish persists in the lower Yampa and Green Rivers, mainstream Colorado River, and lower San Juan River, but there is little recruitment in these remnant populations. The largest extant riverine population occurs in the Upper Green River Basin. It consisted of only 1,000 fish in 1989. Recent information suggests that this population may have declined to less than 500 fish. In the absence of conservation measures, it is presumed that all wild populations in the basin will soon be lost as old fish die without sufficient natural recruitment (Federal Register, 1994b).

In the lower basin, several researchers noted the decline of razorback suckers shortly after impoundment of Lake Mead in 1935 (Maddux, 1993). Now, a substantial population exists only in Lake Mohave (an estimated 25,000 individuals). Small numbers of razorback suckers sporadically occur in Lake Mead and the Grand Canyon and below Lake Mohave in the mainstem and associated impoundments and canals. Successful spawning has been documented in Lake Mohave and numerous larvae have been collected. However, juveniles have been extremely rare in collections since the early 1950's (Maddux, 1993). These populations are small and recruitment is virtually nonexistent. The formerly large lower basin populations have been virtually extirpated from other riverine environments (Federal Register, 1994b).

Life Requisites

Razorback suckers have been observed spawning in reservoirs, but no reproductive success has been documented (USFWS, 1987). Habitat use and spawning behavior of adult razorback suckers in riverine habitats have been studied in the Green River Basin and in the upper Colorado River. Fish in the Green River Basin spawn in the spring with rising water levels and increasing temperatures. Razorback suckers move into flooded areas in early spring and begin spawning migrations to specific locations as they become reproductively active, and spawning occurs over rocky runs and gravel bars (Federal Register, 1994b).

In nonreproductive periods, adult razorback suckers occupy a variety of riverine and impounded habitat types including eddies, backwaters, gravel pits, flooded bottom lands, flooded mouths of tributary streams, slow runs, sandy riffles, and others. Summer habitats used include deeper eddies, backwaters, holes, and midchannel sandbars. During winter, adult razorback suckers use main channel habitats similar to those used during other times of the year, including eddies, slow runs, riffles, and slack waters (Federal Register, 1994b).

Habitats used by young razorback suckers have not been fully described because of the low number of young fish present in the basin. However, most studies indicate that the larvae prefer shallow, littoral zones for a few weeks after hatching, then disperse to deeper water areas. Laboratory studies indicated that in a riverine environment, the larvae enter stream drift and are transported downstream (Federal Register, 1994b).

Thirty seven of 52 (71 percent) of the razorback suckers collected in one study were captured in two abandoned gravel pits near Grand Junction, Colorado (USFWS and Reclamation, 1982). The three habitats in which razorback suckers were captured most frequently were gravel pits, backwaters, and runs with the majority being gravel pits and backwater habitats typically with velocities near zero and a silt substrate. The study indicated that adult razorback suckers exhibited a preference for depths of 2.5 to 6.8 feet and flow conditions at or near 0.0 feet per second.

The razorback sucker has displayed a degree of versatility in its ability to survive and spawn in different habitats. However, razorback sucker populations continue to decline and are considered

below the survival level (Federal Register, 1993). Cumulative environmental impacts from interactions with non-native fish, high winter flows, reduced high spring flows, seasonal changes in river temperatures, and lack of inundated shorelines and bottom lands are factors that potentially limit the survival, successful reproduction, and recruitment of this species. Because there has been little or no recruitment of young to the adult population, special consideration is given to habitats required for reproduction and recruitment (Federal Register, 1994b).

Consequences of the Proposed Action

The minor depletions of 516 acre-feet/year resulting from the proposed action would not affect the razorback sucker or its designated critical habitat. The improved water quality in the Colorado River resulting from the proposed action may beneficially affect their designated critical habitat and therefore the species.

Recommended Mitigation Measures

Mitigation measures that might affect the razorback sucker are not recommended; however, improved water quality, which is the primary goal of the long term operation of the Unit, should benefit the species.

Summary of Project Impacts

The long term operation of the Unit would result in minor water depletions. However, these depletions should not affect the razorback sucker and should be offset by improvements in water quality. In addition, proposed changes in the operation of McPhee Reservoir should mitigate the effects of minor water depletions that would result from the long term operation of the Unit. Chronic low flows from McPhee Dam especially during the summer and other dry periods would be avoided which would benefit the razorback sucker.

SOUTHWEST RIVER OTTER *(Lutra canadensis sonora)*

Status, Distribution, and Abundance

The southwest river otter was previously listed by the Service as a category 2 candidate species and listed by the State of Colorado as endangered. Due to recent changes in the classification of category species as documented in this report, the southwest river otter is no longer listed as a candidate species.

River otter were believed to be banished from Colorado earlier in this century. River otter were reintroduced to the Dolores River Basin in 1988 and are currently thriving. River otters thriving in

the Dolores River today were introduced from populations from several states outside the Southwestern United States and it is highly unlikely that any river otters that inhabit the Dolores

River is *Lutra canadensis sonora* (Beck, 1996). The State of Colorado, however, applies the State Endangered status to all populations of otters that have been introduced throughout the state.

Life Requisites

Food habitat studies of river otter in the Dolores River show that crayfish constitute a major portion of their diet. Typically, otter consume the most easily caught prey available which is crayfish in the Dolores River. In winter months, otter prey extensively on channel catfish and carp in the lower Dolores River.

Consequences of the Proposed Action

Improved water quality will result from the long term operation of the Unit. Improved water quality should benefit the populations of fish and crustaceans in the river which are the primary food base for river otters.

Recommended Conservation Measures

Proposed modifications in the operation of McPhee Reservoir should enhance riverflows of the Dolores River and improve the habitat of the river otter.

Summary of Project Impacts

Long term operation of the Unit will result in minor water depletions to the Dolores River. It is highly unlikely that the State endangered southwest river otter inhabits the Dolores River. River otters in the Dolores River are reintroductions from other sections of the United States. However, improvements in water quality and potential increase in waterflows due to modifications in the operation of McPhee Dam will benefit any river otters that presently inhabit the Dolores River.

SOUTHWESTERN WILLOW FLYCATCHER *(Empidonax traillii extimus)*

Formal classification of the southwestern willow flycatcher as a federally-listed endangered species became effective March 29, 1995 (Federal Register, 1995). Prior to issuance of the formal designation, the Service had proposed listing as endangered with critical habitat (Federal Register 1993a); however, at the current time, designation of critical habitat has been deferred pending evaluation of public comments and receipt of additional biological data. None of the land identified as being under consideration for inclusion as critical habitat in the 1993 proposed rule was located

1,448 acre-foot water depletion associated with the Unit's operation. However, further testing since 1989 resulted in alteration of brine removal and disposal methods and; hence, a change in the project as consulted on in 1989. Additionally, the razorback sucker (Xyrauchen texanus) has been federally listed, critical habitat for the endangered fishes has been designated and the amount of water depleted has been reduced. All of these changes necessitated reinitiation of formal section 7 consultation.

PROJECT DESCRIPTION

The Paradox Valley Unit Project is located in T. 47 N., R. 18 W., sections 3, 4, 9, 16, 19, 20, 21, and 30 near Bedrock, Montrose County, Colorado. The facility's purpose is to remove salt laden brine water as part of the Salinity Control Project in the Colorado River Basin. This will be accomplished by intercepting and injecting the brine water into a 16,000 foot deep well which enters porous Mississippian and Precambrian rock formations. Removal of the brine water and water used at the Unit will result in a 516 acre-foot depletion to the Dolores River.

During original construction, 24 brine water collection wells were installed; however, subsequent testing revealed that only 10 wells were needed for adequate brine removal. The 10 wells are located in sections 9 and 16 on the east side of the Dolores River. An additional unconnected well will be kept available for possible future use but the other 13 wells will be or have been plugged or abandoned. In addition to the production wells, 68 groundwater testing wells have been installed to monitor water table levels, determine fresh and brine water interaction, and to determine brine water movement.

The brine from the 10 production wells will be piped to a central surface treatment facility residing on 1.5 acres in section 16. The treatment facility will filter the brine water and pump it into two 25,000 gallon storage tanks. The water will then pass through a second filter and continue through a pipeline to the injection facility located on 6.5 acres in section 30.

The injection facility consists of a building to house controls and injection pumps. A water treatment plant with associated storage tanks and ponds and a Well Annulus Monitoring System are also located on the 6.5 acre site. One of the two 25,000 gallon storage tanks will be used to store the brine water while the other will be a backup and used during maintenance of the other tank. Fresh water from the Dolores River in section 20 is pumped to the operating tank to dilute the brine and control calcium sulfate precipitation. The fresh water also will be filtered through equipment, storage tanks, a flocculation pond, and a backwash pond to provide the facility's service water. The WAMS system consists of a pump and electronic monitoring system that is used to maintain pressure in the injection well.

The 70 percent brine water mixture will be pumped through a 5½-inch diameter injection tube to a perforated liner that extends through the injection zone, which starts at approximately 14,000 feet below the surface. The brine water will migrate through the porous rock

formations which will act as a closed system reservoir preventing escapement of the brine into surface waters.

BASIS FOR BIOLOGICAL OPINION

This biological opinion addresses an average annual depletion of approximately 516 acre-feet from Dolores River in the Upper Colorado River Basin. Water depletions in the Upper Basin have been recognized as a major source of impact to endangered fish species. Continued water withdrawal has restricted the ability of the Colorado River system to produce flow conditions required by various life stages of the fishes.

Critical habitat has been designated for the Colorado squawfish, humpback chub, bonytail, and razorback sucker within the 100-year floodplain in portions of their historic range (59 F.R. 13374). Destruction or adverse modification of critical habitat is defined in 50 CFR 402.02 as a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. In considering the biological basis for designating critical habitat, the Service focused on the primary physical and biological elements that are essential to the conservation of the species without consideration of land or water ownership or management. The Service has identified water, physical habitat, and biological environment as the primary constituent elements. This includes a quantity of water of sufficient quality that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage for each species. Water depletions reduce the ability of the river system to provide the required water quantity and hydrologic regime necessary for recovery of the fishes. The physical habitat includes areas of the Colorado River system that are inhabited or potentially habitable for use in spawning and feeding, as a nursery, or serve as corridors between these areas. In addition, oxbows, backwaters, and other areas in the 100-year floodplain, when inundated, provide access to spawning, nursery, feeding, and rearing habitats.

BIOLOGICAL BACKGROUND

Colorado Squawfish

The Colorado squawfish evolved as the main predator in the Colorado River system. The diet of Colorado squawfish longer than 3 or 4 inches consists almost entirely of other fishes (Vanicek and Kramer 1969). The Colorado squawfish is the largest cyprinid fish (minnow family) native to North America and, during predevelopment times, may have grown as large as 6 feet in length and weighed nearly 100 pounds (Behnke and Benson 1983). These large fish may have been 25-50 years of age.

Based on early fish collection records, archaeological finds, and other observations, the Colorado squawfish was once found throughout warmwater reaches of the entire Colorado River Basin, including reaches of the upper Colorado River and its major tributaries, the Green River and its major tributaries, and the Gila River system in Arizona (Seethaler 1978). Colorado squawfish were apparently never found in colder, headwater areas. Seethaler (1978) indicates that the species was

abundant in suitable habitat throughout the entire Colorado River basin prior to the 1850's. Historically, Colorado squawfish have been collected in the upper Colorado River as far upstream as Parachute Creek, Colorado (Kidd 1977). The Dolores River historically provided habitat for the Colorado squawfish at least up to the Paradox Valley (Seethaler 1978).

A marked decline in Colorado squawfish populations can be closely correlated with the construction of dams and reservoirs between the 1930's and the 1960's, introduction of nonnative fishes, and removal of water from the Colorado River system. Behnke and Benson (1983) summarized the decline of the natural ecosystem. They pointed out that dams, impoundments, and water use practices are probably the major reasons for drastically modified natural river flows and channel characteristics in the Colorado River Basin. Dams on the main stem have essentially segmented the river system, blocking Colorado squawfish spawning migrations and drastically changing river characteristics, especially flows and temperatures. In addition, major changes in species composition have occurred due to the introduction of nonnative fishes, many of which have thrived as a result of changes in the natural riverine system (i.e., flow and temperature regimes). The decline of endemic Colorado River fishes seems to be at least partially related to competition or other behavioral interactions with nonnative species, which have perhaps been exacerbated by alterations in the natural fluvial environment.

The Colorado squawfish currently occupies about 1,030 river miles in the Colorado River system (25 percent of its original range) and is presently found only in the Upper Basin above Glen Canyon Dam. It inhabits about 350 miles of the main stem Green River from its mouth to the mouth of the Yampa River. Its range also extends 160 miles up the Yampa River and 104 miles up the White River, the two major tributaries of the Green River. In the main stem Colorado River, it is currently found from Lake Powell extending about 201 miles upstream to Palisade, Colorado (Tyus et al. 1982), and in the lower 60 miles of the Gunnison River, a tributary to the main stem Colorado River (Burdick pers. comm. 1995). Possibly due to Uranium mill tailing contamination in the last 40 years the Dolores River currently only harbors Colorado squawfish in the lower couple miles above its confluence with the Colorado River (Valdez et al. 1992).

Critical Habitat

Critical habitat has been designated within the 100-year floodplain of the Colorado squawfish's historical range in the following sections of the Upper Basin (59 F.R. 13374).

Colorado, Moffat County. The Yampa River and its 100-year floodplain from the State Highway 394 bridge in T. 6 N., R. 91 W., section 1 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).

Utah, Uintah, Carbon, Grand, Emery, Wayne, and San Juan Counties; and Colorado, Moffat County. The Green River and its 100-year floodplain from the confluence with the Yampa River in T. 7 N.,

R. 103 W., section 28 (6th Principal Meridian) to the confluence with the Colorado River in T. 30 S., R. 19 E., section 7 (Salt Lake Meridian).

Colorado, Rio Blanco County; and Utah, Uintah County. The White River and its 100-year floodplain from Rio Blanco Lake Dam in T. 1 N., R. 96 W., section 6 (6th Principal Meridian) to the confluence with the Green River in T. 9 S., R. 20 E., section 4 (Salt Lake Meridian).

Colorado, Delta and Mesa Counties. The Gunnison River and its 100-year floodplain from the confluence with the Uncompahgre River in T. 15 S., R. 96 W., section 11 (6th Principal Meridian) to the confluence with the Colorado River in T. 1 S., R. 1 W., section 22 (Ute Meridian).

Colorado, Mesa and Garfield Counties; and Utah, Grand, San Juan, Wayne, and Garfield Counties. The Colorado River and its 100-year floodplain from the Colorado River Bridge at exit 90 north off Interstate 70 in T. 6 S., R. 93 W., section 16 (6th Principal Meridian) to North Wash, including the Dirty Devil arm of Lake Powell up to the full pool elevation, in T. 33 S., R. 14 E., section 29 (Salt Lake Meridian).

New Mexico, San Juan County; and Utah, San Juan County. The San Juan River and its 100-year floodplain from the State Route 371 Bridge in T. 29 N., R. 13 W., section 17 (New Mexico Meridian) to Neskahai Canyon in the San Juan arm of Lake Powell in T. 41 S., R. 11 E., section 26 (Salt Lake Meridian) up to the full pool elevation.

Biology

The life-history phases that appear to be most critical for the Colorado squawfish include spawning, egg fertilization, and development of larvae through the first year of life. These phases of Colorado squawfish development are tied closely to specific habitat requirements. Natural spawning of Colorado squawfish is initiated on the descending limb of the annual hydrograph as water temperatures approach 20 °C. Spawning, both in the hatchery and in the field, generally occurs in a 2-month timeframe between July 1 and September 1, although high flow water years may suppress river temperatures and extend spawning in the natural system into September. Conversely, during low flow years when the water warms earlier, spawning may occur in late June.

Temperature also has an effect on egg development and hatching. In the laboratory, egg mortality was 100 percent in a controlled test at 13 °C. At 16 °C to 18 °C, development of the egg is slightly retarded, but hatching success and survival of larvae was higher. At 20 °C to 26 °C, development and survival through the larval stage was up to 59 percent (Hamman 1981). Juvenile temperature preference tests showed that preferred temperatures ranged from 21.9 °C to 27.6 °C. The most preferred temperature for juveniles and adults was estimated to be 24.6 °C. Temperatures near 24 °C are also needed for optimal development and growth of young (Miller et al. 1982).

Only two Colorado squawfish confirmed spawning sites, as defined in the Colorado Squawfish Recovery Plan, have been located in the Basin: river mile 16.5 of the Yampa River and river mile 156.6 of the Green River. These areas have the common characteristics of coarse cobble or boulder substrates forming rapids or riffles associated with deeper pools or eddies. It is believed that a stable, clean substrate is necessary for spawning and incubation. Substrates are swept clean of finer sediments by high flows scouring the bed prior to the spawning period.

O'Brien (1984) studied the hydraulic and sediment transport dynamics of the cobble bar within the Yampa River spawning site and duplicated some of its characteristics in a laboratory flume study. Based on field observations, he reported:

"On the rising limb of the hydrograph, sands are deposited in the cobble interstices. These sands are interchanged between the bed and the suspended zone for discharges less than bankfull. Depending on the supply-capacity relationship, either deposition or scour could be occurring. When the cobbles move, the sand, of course, is washed from the interstices and may be completely removed from around the cobbles. Rearrangement of the cobbles will result in more stability of the armor layer. On the falling limb, the armor layer becomes a trap for sands until finally, the sand reservoir is again filled. Without cobble movement, sand will be scoured only to a depth of one-half to one median cobble diameter below the cobble bed surface."

In the flume experiments, the sand level was observed approximately 0.50 to 1 cobble diameter below the surface of the cobble bed, which compared to field observations of sand depth at approximately 0.50 to 1 median cobble diameter. O'Brien reported a cobble size range of 50-100 mm with a median size of 75 mm at the spawning site. Milhous (1982) proposes discharges of approximately 0.50 of that required to initiate cobble movement will be capable of extracting sands and fines from the cobble substrate. Thus, after the supply of sand diminishes, flows of sufficient magnitude and duration are required to scour the cobble bed in preparation for spawning and incubation.

Although the location of spawning areas in the Colorado River is not well defined, the presence of larvae downstream of the Walker Wildlife Area, in the Loma to Black Rocks reach and near the confluence of the Dolores River, demonstrates that spawning does occur. Osmundson and Kaeding (1989 and 1991) reported that water temperatures in the Colorado River were suitable for spawning in the Grand Junction area. In 1986, a year of high runoff, suitable temperatures for spawning (20 °C) occurred in the first week of August. In 1989, a year of low runoff, the mean temperature reached 20 °C during the last week of June. Miller et al. (1982) and Archer et al. (1986) demonstrated that Colorado squawfish often migrate considerable distances to spawn in the Green and Yampa Rivers, and similar movement has been noted in the main stem Colorado River.

Miller et al. (1982) concluded from collections of larvae and young-of-year below known spawning sites that there is a downstream

drift of larval Colorado squawfish following hatching. Extensive studies in the Yampa and upper Green Rivers have demonstrated downstream distribution of young Colorado squawfish from known spawning areas (Archer et al. 1986; Haynes et al. 1985). Miller et al. (1982) also found that young-of-year Colorado squawfish, from late summer through fall, preferred natural backwater areas of zero velocity and less than 1.5-foot depth over a silt substrate. Juvenile Colorado squawfish habitat preferences are similar to that of young-of-year fish, but they appear to be mobile and more tolerant of lotic conditions away from the sheltered backwater environment.

Information on radio-tagged adult Colorado squawfish during fall suggests that fish seek out deepwater areas in the Colorado River (Miller et al. 1982), as do many other riverine species. River pools, runs, and other deep water areas, especially in upstream reaches, are important winter habitats for Colorado squawfish.

Very little information is available on the influence of turbidity on the endangered Colorado River fishes. It is assumed, however, that turbidity is important, particularly as it affects the interaction between introduced fishes and the endemic Colorado River fishes. Because these endemic fishes have evolved under natural conditions of high turbidity, it is concluded that the retention of these highly turbid conditions is an important factor for these endangered fishes. Reduction of turbidity may enable introduced species to gain a competitive edge which could further contribute to the decline of the endangered Colorado River fishes.

Migration

Radio-telemetry studies show upstream and downstream movement of adult Colorado squawfish in the main stem Colorado River. The most dramatic movement was exhibited by a fish implanted with a radio transmitter at Gypsum Canyon in upper Lake Powell on April 5, 1982. The fish was contacted next in the lower Cataract Canyon area on July 9, 1982. The next contact was made above the Black Rocks area of Ruby Canyon, some 160 miles upstream. The movement was accomplished in 41 days and is believed to be related to spawning. At the end of September 1982, this fish was located in the Colorado River in the vicinity of Clifton, Colorado (river mile 178), nearly 200 river miles from its furthest documented downstream location.

Other radio-tagged fish in the Colorado River have not displayed such dramatic migratory behavior. Radio-telemetry studies conducted by the Colorado River Fishery Project from 1982-1989 (Miller et al. 1982; Archer et al. 1986; Osmundson and Kaeding 1989), which focused on upstream reaches of the Colorado River in and around the Grand Valley, provide the best indication of use of the 15-mile reach above the confluence of the Gunnison River at one time or another during the field season. Movement of these fish during a field season was generally limited to 25-30 miles.

During 1986-1988, the Fishery Project radio telemetered 17 adult Colorado squawfish collected from the 15-mile reach above the Gunnison River in June (Osmundson and Kaeding 1989). The fish exhibited a

diversity of localized movement throughout the Grand Valley but spent a major part of time in the 15-mile reach. Two remained in the reach throughout the estimated spawning period.

Spawning Activity

A suspected prespawning aggregation of adult Colorado squawfish was observed by Fishery Project personnel at river mile 178.3 in the 15-mile reach above the Gunnison River confluence in mid-July 1982. In the first observation, three radio-tagged fish were tracked to one riverine pool area, and nine adults at or near spawning condition were then captured there after limited net sampling efforts. The aggregation occurred a few days after mean daily water temperature had reached 20 °C and during a time when runoff flows were dropping off sharply. A second aggregation was noted at river mile 175.3, 12 days after the initial observation. Drifting trammel nets through an area occupied by two fish equipped with transmitters yielded an additional male Colorado squawfish in spawning condition. During this same time period, an adult female was captured near river mile 175 that weighed nearly 1 pound more than when previously captured a month earlier, suggesting the development of spawning (gravid) condition.

Larval Occurrence

Fishery Project studies included the routine sampling of the larval-fish community both within and downstream of the 15-mile reach. During 5 years of investigation, 70 larval squawfish were collected with fine-mesh hand nets from the two Colorado River reaches in the Grand Valley immediately upstream and downstream of its confluence with the Gunnison River. Although the sampling effort was similar in the two river reaches, 96 percent of the larval captures occurred downstream of the Gunnison River confluence (river miles 162-164). Only two (3 percent) of the larvae were collected from the upstream reach. These observations may indicate that most fish were spawned in the downstream reach or that the larvae were deposited in the upstream reach and drifted downstream to the area where most of the captures were recorded.

Postlarval Young-of-Year Occurrence

No postlarval young-of-year Colorado squawfish greater than 25 mm total length were collected from above the Gunnison River confluence in a total of 57 samples collected in the fall of 1982-1986. However, a total of 62 Colorado squawfish were collected in an 18-mile reach below the confluence of the Gunnison River (54 samples). The 1982-1984 catch rate of young-of-year Colorado squawfish in the 10-mile reach immediately downstream of the confluence of the Gunnison River (river miles 160-170) warranted classification of this reach as a "Young-of-Year Nursery Area" by the Basin Biology Subcommittee (U.S. Fish and Wildlife Service 1984).

Nonspawning Adult Occurrence

Osmundson and Kaeding (1989) reported that adult Colorado squawfish catch rates in the upstream 15-mile reach were twice as high as those in the adjacent downstream river reach. During 1986-1989 adults were most

abundant in a 1.3-mile segment (river miles 174.4-175.7) of the 15-mile reach during high water, particularly in two gravel-pit ponds that were accessible during high flows. These fish may have moved into these ponds to feed and rest, or they may have been attracted to the warm, productive environments that the ponds provided (pond temperatures were as much as 10.5 °C warmer than the adjacent river). Some of the squawfish captured from one pond were well tuberculated by June 3, when nearby river temperatures were only 10 °C-13 °C (Kaeding, pers. comm.). It has been hypothesized by some investigators that thermal energy units above those provided in the mainstream are important to gonadal maturation. If this is true, then access to these sheltered off-channel pools may be very important to successful spawning in the upper reaches of the Colorado River. Historically, bottomlands that routinely flooded during the spring runoff period would have provided these warm productive habitats; in recent years, flooded gravel pits may have provided the only comparable habitat.

Razorback Sucker

The razorback sucker, an endemic species unique to the Colorado River Basin, was historically abundant and widely distributed within warmwater reaches throughout the Colorado River Basin. Historically, razorback suckers were found in the main stem Colorado River and major tributaries in Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming, and in Mexico (Ellis 1914; Minckley 1983). Bestgen (1990) reported that this species was once so numerous that it was commonly used as food by early settlers and, further, that commercially marketable quantities were caught in Arizona as recently as 1949. In the Upper Basin, razorback suckers were reported in the Green River to be very abundant near Green River, Utah, in the late 1800's (Jordan 1891). An account in Osmundson and Kaeding (1989) reported that residents living along the Colorado River near Clifton, Colorado, observed several thousand razorback suckers during spring runoff in the 1930's and early 1940's. In the San Juan River drainage, Platania and Young (1989) relayed historical accounts of razorback suckers ascending the Animas River to Durango, Colorado, around the turn of the century.

A marked decline in populations of razorback suckers can be attributed to construction of dams and reservoirs, introduction of nonnative fishes, and removal of large quantities of water from the Colorado River system. Dams on the main stem Colorado River and its major tributaries have segmented the river system and drastically altered flows, temperatures, and channel geomorphology. Major changes in species composition have occurred due to the introduction of numerous nonnative fishes, many of which have thrived due to man-induced changes to the natural riverine system.

The current distribution and abundance of the razorback sucker have been significantly reduced throughout the Colorado River system (McAda 1987; McAda and Wydoski 1980; Holden and Stalnaker 1975; Minckley 1983; Marsh and Minckley 1989; Tyus 1987). The only substantial population of razorback suckers remaining, made up entirely of old adults (McCarthy and Minckley 1987), is found in Lake Mohave; however, they do not appear to be successfully recruiting. While limited numbers of razorback

suckers persist in other locations in the Lower Colorado River, they are considered rare or incidental and may be continuing to decline.

In the Upper Basin, above Glen Canyon Dam, razorback suckers are found in limited numbers in both lentic and lotic environments. The largest population of razorback suckers in the Upper Basin is found in the upper Green River and lower Yampa River (Tyus 1987). Lanigan and Tyus (1989) estimated that from 758 to 1,138 razorback suckers inhabit the upper Green River. In the Colorado River, most razorback suckers occur in the Grand Valley area near Grand Junction, Colorado; however, they are increasingly rare. Osmundson and Kaeding (1991) report that the number of razorback sucker captures in the Grand Junction area has declined dramatically since 1974.

Razorback suckers are in imminent danger of extirpation in the wild. The specific causes of this species' continued decline are largely unknown at this time. As Bestgen (1990) pointed out:

"Reasons for decline of most native fishes in the Colorado River Basin have been attributed to habitat loss due to construction of mainstream dams and subsequent interruption or alteration of natural flow and physio-chemical regimes, inundation of river reaches by reservoirs, channelization, water quality degradation, introduction of nonnative fish species and resulting competitive interactions or predation, and other man-induced disturbances (Miller 1961, Joseph et al. 1977, Behnke and Benson 1983, Carlson and Muth 1989, Tyus and Karp 1989). These factors are almost certainly not mutually exclusive, therefore it is often difficult to determine exact cause and effect relationships."

The virtual absence of any recruitment suggests a combination of biological, physical, and/or chemical factors that may be affecting the survival and recruitment of early life stages of razorback suckers. Within the Upper Basin, recovery efforts endorsed by the Recovery Implementation Program include the capture and removal of razorback suckers from all known locations for genetic analyses and development of discrete brood stocks if necessary. These measures have been undertaken to develop refugia populations of the razorback sucker from the same genetic parentage as their wild counterparts such that, if these fish are genetically unique by subbasin or individual population, then separate stocks will be available for future augmentation. Such augmentation may be a necessary step to prevent the extinction of razorback suckers in the Upper Basin.

Critical Habitat

Critical habitat has been designated within the 100-year floodplain of the razorback sucker's historical range in the following sections of the Upper Basin (59 F.R. 13374).

Colorado, Moffat County. The Yampa River and its 100-year floodplain from the mouth of Cross Mountain Canyon in T. 6 N., R. 98 W., section 23 (6th Principal Meridian) to the confluence

with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).

Utah, Uintah County; and Colorado, Moffat County. The Green River and its 100-year floodplain from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to Sand Wash in T. 11 S., R. 13 E., section 20 (6th Principal Meridian).

Utah, Uintah, Carbon, Grand, Emery, Wayne, and San Juan Counties. The Green River and its 100-year floodplain from Sand Wash at river mile 96 at T. 11 S., R. 13 E., section 20 (6th Principal Meridian) to the confluence with the Colorado River in T. 30 S., R. 19 E., section 7 (6th Principal Meridian).

Utah, Uintah County. The White River and its 100-year floodplain from the boundary of the Uintah and Ouray Indian Reservation at river mile 18 in T. 9 S., R. 22 E., section 21 (Salt Lake Meridian) to the confluence with the Green River in T. 9 S., R. 20 E., section 4 (Salt Lake Meridian).

Utah, Uintah County. The Duchesne River and its 100-year floodplain from river mile 2.5 in T. 4 S., R. 3 E., section 30 (Salt Lake Meridian) to the confluence with the Green River in T. 5 S., R. 3 E., section 5 (Uintah Meridian).

Colorado, Delta and Mesa Counties. The Gunnison River and its 100-year floodplain from the confluence with the Uncompahgre River in T. 15 S., R. 96 W., section 11 (6th Principal Meridian) to Redlands Diversion Dam in T. 1 S., R. 1 W., section 27 (Ute Meridian).

Colorado, Mesa and Garfield Counties. The Colorado River and its 100-year floodplain from Colorado River Bridge at exit 90 north off Interstate 70 in T. 6 S., R. 93 W., section 16 (6th Principal Meridian) to Westwater Canyon in T. 20 S., R. 25 E., section 12 (Salt Lake Meridian) including the Gunnison River and its 100-year floodplain from the Redlands Diversion Dam in T. 1 S., R. 1 W., section 27 (Ute Meridian) to the confluence with the Colorado River in T. 1 S., R. 1 W., section 22 (Ute Meridian).

Utah, Grand, San Juan, Wayne, and Garfield Counties. The Colorado River and its 100-year floodplain from Westwater Canyon in T. 20 S., R. 25 E., section 12 (Salt Lake Meridian) to full pool elevation, upstream of North Wash, and including the Dirty Devil arm of Lake Powell in T. 33 S., R. 14 E., section 29 (Salt Lake Meridian).

New Mexico, San Juan County; and Utah, San Juan County. The San Juan River and its 100-year floodplain from the Hogback Diversion in T. 29 N., R. 16 W., section 9 (New Mexico Meridian) to the full pool elevation at the mouth of Neskahai Canyon on the San Juan arm of Lake Powell in T. 41 S., R. 11 E., section 26 (Salt Lake Meridian).

Biology

Specific information on biological and physical habitat requirements of the razorback sucker is very limited. Until very recently, fisheries research investigations throughout the Upper Basin have focused on the three listed Colorado River fishes, and data collected on the razorback sucker was largely coincident to those studies. Localized extirpation of razorback suckers from some localities, coupled with the species' continued decline in numbers and distribution, has prompted some research; however, details of its life history requirements, particularly in riverine environments, are still not fully understood.

In general, a natural hydrograph with a large spring peak, a gradually descending limb into early summer, and low stable flows through summer, fall, and winter are thought to create the best habitat conditions for endangered fishes while maintaining the integrity of the channel geomorphology. Prior to construction of large main stem dams and the suppression of spring peak flows, low velocity, off-channel habitats (seasonally flooded bottomlands and shorelines) were commonly available throughout the Upper Basin (Tyus and Karp 1989; Osmundson and Kaeding 1991). The absence of these seasonally flooded riverine habitats is believed to be a limiting factor in the successful recruitment of razorback suckers in their native environment (Tyus and Karp 1989; Osmundson and Kaeding 1991). Tyus (1987) and McAda and Wydoski (1980) reported springtime aggregations of razorback suckers in off-channel impoundments and tributaries; such aggregations are believed to be associated with reproductive activities. Tyus and Karp (1990) and Osmundson and Kaeding (1991) reported off-channel habitats to be much warmer than the main stem river and that razorback suckers presumably moved to these areas for feeding, resting, sexual maturation, spawning, and other activities associated with their reproductive cycle. While razorback suckers have never been directly observed spawning in turbid riverine environments within the Upper Basin, captures of ripe specimens, both males and females, have been recorded (Valdez et al. 1982; McAda and Wydoski 1980; Tyus 1987; Osmundson and Kaeding 1989; Tyus and Karp 1989; Tyus and Karp 1990; Osmundson and Kaeding 1991; Platania 1990) in the Yampa, Green, Colorado, and San Juan Rivers. Sexually mature razorback suckers are generally collected on the ascending limb of the hydrograph from mid-April through June and are associated with coarse gravel substrates (depending on the specific location).

Outside of the spawning season, adult razorback suckers occupy a variety of shoreline and main channel habitats including low runs, shallow to deep pools, backwaters, eddies, and other relatively slow velocity areas associated with sand substrates (Tyus 1987; Tyus and Karp 1989; Osmundson and Kaeding 1989; Valdez and Masslich 1989; Osmundson and Kaeding 1991; Tyus and Karp 1990).

Habitat requirements of young and juvenile razorback suckers in the wild are largely unknown, particularly in native riverine environments. Life stages, other than adults, have not been collected anywhere in the Upper Basin in recent times. The last confirmed documentation of razorback sucker juvenile in the Upper Basin was a capture in the Colorado River near Moab, Utah (Taba et al. 1965).

The current range of the razorback sucker in the Colorado River extends upstream to Rifle, Colorado. Most razorback suckers captured in the Grand Valley area have been located in flooded gravel-pit ponds adjacent to the river. However, Osmundson and Kaeding (1989) documented razorback sucker movement in various river habitats in the Grand Valley area. Additional surveys since 1988 have documented razorback suckers in riverside ponds as far upstream as river mile 235 near Rifle, Colorado (Burdick 1992).

Humpback Chub

Humpback chub generally do not make migrational movements in the upper Colorado River and tend to reside throughout the year within a limited reach of river. Humpback chub are found inhabiting narrow, deep canyon areas and are relatively restricted in distribution. They seldom leave their canyon habitat (U.S. Fish and Wildlife Service 1982). While humpback chub are regularly found dispersed in the Green and Yampa Rivers, the only major populations of humpback chub known to exist in the Upper Basin are located in Black Rocks and Westwater Canyons on the Colorado River.

Critical Habitat

Critical habitat has been designated within the humpback chub's historical range in the following sections of the Upper Basin (59 F.R. 13374).

Colorado, Moffat County. The Yampa River from the boundary of Dinosaur National Monument in T. 6 N., R. 99 W., section 27 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).

Utah, Uintah County; and Colorado, Moffat County. The Green River from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to the southern boundary of Dinosaur National Monument in T. 6 N., R. 24 E., section 30 (Salt Lake Meridian).

Utah, Uintah and Grand Counties. The Green River (Desolation and Gray Canyons) from Sumner's Amphitheater in T. 12 S., R. 18 E., section 5 (Salt Lake Meridian) to Swasey's Rapid in T. 20 S., R. 16 E., section 3 (Salt Lake Meridian).

Utah, Grand County; and Colorado, Mesa County. The Colorado River from Black Rocks in T. 10 S., R. 104 W., section 25 (6th Principal Meridian) to Fish Ford in T. 21 S., R. 24 E., section 35 (Salt Lake Meridian).

Utah, Garfield and San Juan Counties. The Colorado River from Brown Betty Rapid in T. 30 S., R. 18 E., section 34 (Salt Lake Meridian) to Imperial Canyon in T. 31 S., R. 17 E., section 28 (Salt Lake Meridian).

Bonytail

Little is known about the biological requirements of the bonytail, as the species has drastically declined in numbers in the Upper Basin shortly after 1960. Until recently, the Service considered the species extirpated from the Upper Basin; however, a recently collected specimen which exhibits many bonytail characteristics could indicate a small, extant population (Kaeding et al. 1986). It is thought that, should this species persist in the Colorado River, the preferred habitat would be in the larger river reaches.

Critical Habitat

Critical habitat has been designated within the bonytail's historical range in the following sections of the Upper Basin (59 F.R. 13374).

Colorado, Moffat County. The Yampa River from the boundary of Dinosaur National Monument in T. 6 N., R. 99 W., section 27 (6th Principal Meridian) to the confluence with the Green River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian).

Utah, Uintah County; and Colorado, Moffat County. The Green River from the confluence with the Yampa River in T. 7 N., R. 103 W., section 28 (6th Principal Meridian) to the boundary of Dinosaur National Monument in T. 6 N., R. 24 E., section 30 (Salt Lake Meridian).

Utah, Uintah and Grand Counties. The Green River (Desolation and Gray Canyons) from Sumner's Amphitheater (river mile 85) in T. 12 ., R. 18 E., section 5 (Salt Lake Meridian) to Swasey's Rapid (river mile 12) in T. 20 S., R. 16 E., section 3 (Salt Lake Meridian).

Utah, Grand County; and Colorado, Mesa County. The Colorado River from Black Rocks in T. 10 S., R. 104 W., section 25 (6th Principal Meridian) to Fish Ford in T. 21 S., R. 24 E., section 35 (Salt Lake Meridian).

Utah, Garfield and San Juan Counties. The Colorado River from Brown Betty Rapid in T. 30 S., R. 18 E., section 34 (Salt Lake Meridian) to Imperial Canyon in T. 31 S., R. 17 E., section 28 (Salt Lake Meridian).

ENVIRONMENTAL BASELINE

The environmental baseline includes the past and present impacts of all Federal, State, and private actions and other human activities in the action area; the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal section 7

consultation; and the impact of State or private actions contemporaneous with the consultation process.

In formulating this opinion, the Service considered adverse and beneficial effects likely to result from cumulative effects of future State and private activities that are reasonably certain to occur within the Project area, along with the direct and indirect effects of the Project and impacts from actions that are part of the environmental baseline (50 CFR 402.02 and 402.14 (g) (3)).

The physical and biological features that were the basis for designating the critical habitat for the endangered fishes are water, physical habitat, and biological environment. These primary constituent elements were determined necessary for survival and recovery of the endangered fishes in the Upper Colorado River Basin. The primary constituent element water is described as a quantity of sufficient quality and with a hydrologic regime that is required for each life stage. Physical habitat includes areas of the river that are inhabited or potentially habitable by endangered fishes for use in spawning, nursery, feeding, and rearing or corridors between these areas. Biological environment includes food supply, predation, and competition.

Water Quantity

The environmental baseline for water quantity includes all historical depletions in the Upper Basin, depletions resulting from projects which have previously undergone section 7 consultation, and depletions resulting from projects contemporaneous with this consultation.

Water Quality

Some of the contaminants of concern within waters of the Upper Basin include heavy metals, selenium, salts, PAHs, and pesticides. Selenium is of particular concern because of its documented effects on fish (and wildlife) reproduction. Many chemical, physical, and biological factors affect the toxicity of environmental contaminants to biological organisms. Chemical and physical factors include contaminant type, chemical species or form, pH, water temperature, dissolved oxygen, hardness, salinity, and multiple-chemical exposure (antagonism and synergism). Duration of exposure, quantity of contaminant, and exposure pathways from the environment to the organism also affect toxicity. Some trace elements are beneficial to organisms at low concentrations but may be toxic at higher concentrations. Biological and physiological factors affecting toxicity include species, age, sex, and health of the organism.

Selenium concentrations can be elevated in areas where irrigation occurs on soils which are derived from or which overlie Upper Cretaceous marine sediments. Percolation of irrigation water through these soils and sediments leaches selenium into receiving waters. Other sources of selenium include powerplant fly ash and oil refineries. Water depletions, by reducing dilution effects, have increased the concentrations of selenium and other contaminants. In 1995, Colorado's Water Quality Control Commission reduced the chronic selenium standard

from 17 µg/L to 5 µg/L. The Service recommended the level be lowered to 2 µg/L.

Physical Habitat

Water depletions, by affecting the quantity and timing of flows, have reduced the ability of the river to create and maintain habitats and have reduced the frequency and duration of availability of certain habitats.

Habitat Formation

The formation of a variety of channel habitats, including gravel/cobble bars and substrates used by Colorado squawfish for spawning, is essential to ensure the availability of the range of habitats required by all endangered fish life stages to fulfill daily requirements (foraging, resting, spawning, avoiding predation, etc.) under various flow conditions. The number and distribution of these channel habitats can be described as channel habitat complexity, diversity, or heterogeneity. Osmundson and Kaeding (1991) found that adult Colorado squawfish in the Grand Valley prefer river segments with a complex morphometry over those that are simple.

Some important habitats, such as inundated floodplain depressions used by razorback suckers for spawning, are located outside the channel. Floodplain depressions are principally derived from abandoned main channels, side-channels, backwaters, and meander cutoffs.

The creation of complex channel habitat and the formation and eventual abandonment of channel features from which floodplain depressions are formed occur primarily during spring runoff when flows are of sufficient size and duration to cause major changes in channel morphology through significant erosion and deposition of bed and bank materials. The reduction in the magnitude, duration, and frequency of high spring flows has slowed the rate at which channel morphology changes. Consequently, the creation of complex channel habitat and floodplain depressions has slowed. The placement of riprap and other bank stabilization measures and the construction of dikes and levees impede changes in channel morphology and contribute to the slowed creation of complex channel habitat. In addition, the construction of dikes and levees reduces existing channel habitat complexity by causing channelization of the river. Dikes and levees also isolate existing floodplain depressions from the channel during high flows. The slowed creation of complex channel habitats and new floodplain depressions, the reduction of existing channel habitat complexity, and the isolation of existing floodplain depressions have acted to reduce the quantity and quality of important habitat for endangered fishes.

Habitat Maintenance

Backwaters, used by various life stages of endangered fish, are damaged by the deposition of fine sediments which reduces their depth and consequently their duration and frequency of inundation. Gravel and cobble substrates, used by squawfish for spawning, are damaged by the infiltration of fine sediments. The establishment of vegetation on

backwater sediments and on bars further reduces the value of these habitats for endangered fishes. Furthermore, higher flows are required to flush sediments from vegetated backwaters than from unvegetated ones. Osmundson and Kaeding (1991) reported observations that, on the 15-mile reach during the drought years of 1988 to 1990, backwaters were filling in with silt and spring flows were not sufficient to flush out the fine sediment. Also, they reported that tamarisk colonized sand and cobble bars. The lower frequency of high water years, therefore, decreases the frequency at which silt and sand is flushed from backwaters, fine sediments are flushed from gravel/cobble substrates, and vegetation is scoured from backwaters and bars. As a result, the frequency at which these habitats are suitable for use by endangered fishes has decreased.

Seasonal Habitat Availability

Summer (August-October): Osmundson et al. (1995) reported that, in the 15-mile reach, availability of habitats did not differ significantly between periods of moderate flows and low flows. Though absolute area of habitat decreases with declining flows, relative area or percent composition of habitat types changes little. However, squawfish habitat use patterns did change. The fish used a greater variety of habitats during moderate flows than during low flows. During moderate flows, the fish used primarily backwaters, eddies, and pools. During low flows, the fish used slow and fast runs almost exclusively. The change in habitat use without a corresponding change in relative habitat availability indicates that other factors also influence habitat selection. These factors could include changes in quality of physical habitat features such as diversity, depth, dissolved oxygen, etc., or changes in biotic interactions. Osmundson et al. (1995) interpreted the squawfish behavioral changes as reflective of suboptimal conditions; the behavioral changes demonstrate the ability of the species to modify their habitat use patterns to temporarily cope with adverse conditions and do not demonstrate habitat preferences under optimum conditions.

Winter (November-March): Osmundson et al. (1995) reported that, in the 15-mile reach, flows during the winter are usually moderate because no water is diverted for irrigation and because additional water is released through upstream dams to increase reservoir storage capacity in anticipation of spring runoff. The relative availability of slow runs and riffles during the winter was very similar to their availability during summer. As in the summer, backwaters, eddies, and pools were the preferred types of habitat in the winter. However, whereas eddies were most preferred in summer, pools were most preferred in winter. Adult squawfish used fewer habitat types overall during winter than during summer. Although fast runs and riffles were used during the summer, they were not used during the winter. The colder water temperatures in winter which cause lower metabolic rates may account for the avoidance of high velocity sites. Absolute area of pools increases as flows decrease and slow runs lose velocity. Because Osmundson et al. (1995) did not sample low flows in the winter, they could not determine if pools would still be preferred in the winter at lower flows.

Spring (April-July): Osmundson and Kaeding (1989) reported that squawfish use of low velocity habitats such as backwaters and flooded gravel pits is greatest during the spring runoff. It is believed that

squawfish use these habitats during the runoff to escape the high velocity, low temperature flows of the main channel. Because backwaters, flooded gravel pits, and other low velocity habitats are considerably warmer than the main channel during the runoff, these habitats allow squawfish to extend their growing season substantially. The earlier warming of these habitats also may be important in enabling squawfish to reach spawning condition by the time flow and temperature in the main channel are optimum for spawning. Osmundson et al. (1995) reported that, in the 15-mile reach, the numbers of backwaters and flooded gravel pits increases with increasing spring flows. (Although the number of backwaters eventually decreases as increasing flows convert backwaters to sidechannels, the number of other low velocity habitats likely increases as increasing flows inundate additional bottomlands.) The decrease in the magnitude, duration, and frequency of high spring flows, then, decreases the quantity and the duration and frequency of availability of important low velocity, higher temperature habitat in the spring. This could be affecting squawfish growth and spawning success.

Also, the quantity and frequency of availability of inundated floodplain depressions used by razorback suckers for spawning is dependent on the magnitude and frequency of spring flows necessary to inundate these areas. The decrease in the magnitude and frequency of spring flows necessary to inundate floodplain depressions is believed to be largely responsible for poor razorback sucker spawning success.

Biological Environment

Food supply, predation, and competition are important elements of the biological environment. Food supply is a function of nutrient supply and productivity, which could be limited by the presence of contaminants. The modification of flow regimes, water temperatures, sediment levels, and other habitat conditions caused by water depletions has contributed to the establishment of nonnative fishes. Predation and competition from nonnative fishes have been clearly implicated in the population reductions or elimination of native fishes in the Colorado River Basin (Dill 1944, Osmundson and Kaeding 1989, Behnke 1980, Joseph et al. 1977, Lanigan and Berry 1979, Minckley and Deacon 1968, Meffe 1985, Propst and Bestgen 1991, Rinne 1991, and others). Data collected by Osmundson and Kaeding (1991) indicated that during low water years nonnative minnows capable of preying on or competing with larval endangered fishes greatly increased in numbers.

Nonnative fishes compete with native fishes in several ways. The capacity of a particular area to support aquatic life is limited by physical habitat conditions. Increasing the number of species in an area usually results in a smaller population of most species. The size of each species population is controlled by the ability of each life stage to compete for space and food resources and to avoid predation. Some nonnative fishes' life stages appear to have a greater ability to compete for space and food and to avoid predation in the existing altered habitat than do some native fishes' life stages.

Nonnative fishes are often stocked in and enter rivers from off-channel impoundments. The periodic introduction of these nonnative fishes into

a river allows them to bypass limitations to reproduction, growth, or survival that they might encounter in the river. Consequently, populations of nonnative fishes in the river are enhanced. Endangered and other native species in the river experience greater competition and predation as a result.

EFFECTS OF THE ACTION

Water Quantity

The Project would cause an average annual new depletion of 516 acre-feet.

Water Quality

The Project's depletion would cause a proportionate decrease in dilution which in turn would cause a proportionate increase in heavy metal, selenium, salts, PAHs, pesticides, and other contaminant concentrations in the Colorado River. An increase in contaminant concentrations in the river would likely result in an increase in the bioaccumulation of these contaminants in the food chain which could adversely affect the endangered fishes, particularly the predatory Colorado squawfish. Selenium is of particular concern due to its effects on fish reproduction and its tendency to concentrate in low velocity areas that are important habitats for Colorado squawfish and razorback suckers.

Physical Habitat

High spring flows are very important for creating and maintaining complex channel geomorphology and suitable spawning substrates, creating and providing access to off-channel habitats, and possibly stimulating Colorado squawfish spawning migrations. Adequate summer and winter flows are important for providing a sufficient quantity of preferred habitats for a duration and at a frequency necessary to support all life stages of viable populations of all endangered fishes. To the extent that the Project will reduce flows, the ability of the river to provide these functions will be reduced.

Biological Environment

The modification of flow regimes, water temperatures, sediment levels, and other habitat conditions caused by water depletions has contributed to the establishment of nonnative fishes. To the extent that it would reduce flows and contribute to further habitat alteration, the Project would contribute to an increase in nonnative fish populations. Endangered fishes would experience increased competition and predation as a result.

Summary

The Service has concluded that the depletion of water caused by the Paradox Valley Unit will impact the primary constituent elements necessary for the survival and recovery of endangered fishes in the Upper Basin. Without actions taken to offset impacts, further flow reductions are likely to jeopardize the continued existence of the

endangered fishes and adversely modify or destroy their critical habitat. The Dolores River currently contributes flows that benefit the endangered fishes in the Colorado River and water quality has returned to levels suitable for the possibility of endangered fishes reintroduction (Valdez et al. 1992).

REASONABLE AND PRUDENT ALTERNATIVE

Regulations (50 CFR 402.02) implementing section 7 of the Act define reasonable and prudent alternatives as alternative actions, identified during formal consultation, that: (1) can be implemented in a manner consistent with the intended purpose of the action; (2) can be implemented consistent with the scope of the action agency's legal authority and jurisdiction; (3) are economically and technologically feasible; and (4) that the Service believes would avoid the likelihood of jeopardizing the continued existence of listed species or would avoid the destruction or adverse modification of critical habitat.

Background

On January 21-22, 1988, the Secretary of the Interior; the Governors of Wyoming, Colorado, and Utah; and the Administrator of the Western Area Power Administration were cosigners of a Cooperative Agreement to implement the "Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin" (U.S. Fish and Wildlife Service 1987). An objective of the Recovery Program was to recover the listed species while providing for new water development in the Upper Basin.

In order to further define and clarify processes outlined in sections 4.1.5, 4.1.6, and 5.3.4 of the Recovery Program, a Section 7 Agreement and a Recovery Implementation Program Recovery Action Plan was developed (U.S. Fish and Wildlife Service 1993). The Agreement establishes a framework for conducting all future section 7 consultations on depletion impacts related to new projects and all impacts associated with historic projects in the Upper Basin. Procedures outlined in the Agreement will be used to determine if sufficient progress is being accomplished in the recovery of the endangered fishes to enable the Recovery Program to serve as a reasonable and prudent alternative to avoid jeopardy. The Plan was finalized on October 15, 1993, and has been reviewed and updated annually.

In accordance with the Agreement, the Service assesses the impacts of projects that require section 7 consultation and determine if progress toward recovery has been sufficient for the Recovery Program to serve as a reasonable and prudent alternative. If sufficient progress is being achieved, biological opinions are written to identify activities and accomplishments of the Recovery Program that support it as a reasonable and prudent alternative. If sufficient progress in the recovery of the endangered fishes has not been achieved by the Recovery Program, actions from the Plan are identified which must be completed to avoid jeopardy to the endangered fishes. For historic projects, these actions serve as the reasonable and prudent alternative as long as they are completed according to the schedule identified in the Plan. For new projects,

these actions serve as the reasonable and prudent alternative so long as they are completed before the impact of the project occurs.

In determining if sufficient progress has been achieved, the Service considers: (a) actions which result in a measurable population response, a measurable improvement in habitat for the fishes, legal protection of flows needed for recovery, or a reduction in the threat of immediate extinction; (b) status of fish populations; (c) adequacy of flows; and (d) magnitude of the project impact. In addition, the Service considers support activities (funding, research, information and education, etc.) of the Recovery Program if they help achieve a measurable population response, a measurable improvement in habitat for the fishes, legal protection of flows needed for recovery, or a reduction in the threat of immediate extinction. The Service evaluates progress separately for the Colorado River and Green River subbasins; however, it gives due consideration to progress throughout the Upper Basin in evaluating progress toward recovery.

In its April 5, 1996, annual review of sufficient progress, the Service concluded that the Recovery Program has made sufficient progress to enable it to serve as the reasonable and prudent alternative for projects with an average annual depletion of less than 1,500 acre-feet. This was a reduction from the 3,000 acre-feet threshold that was set for 1995. The Service identified five actions which must be completed before the threshold will be raised back to 3,000 acre-feet:

1. Finalization and implementation of the nonnative fish stocking procedures.
2. Granting of a decree by the water court that allows for release of water from Steamboat Lake for instream flow purposes and finalization of a contract to provide up to 3,000 acre-feet of water from Steamboat Lake for the endangered fishes.
3. Completion of a short-term agreement to supply and deliver up to 21,650 acre-feet of water from Ruedi Reservoir for enhancing instream flows in the 15-mile reach.
4. Approval of an FY 1997 work plan to implement high priority nonnative fish control projects in Colorado and Utah.
5. Develop and agree to the scope and objectives of a strategy for addressing recovery of the endangered fishes in the 15-mile reach of the Colorado River, including a process and schedule for completing the strategy in a timely manner.

The following excerpts summarize portions of the Recovery Program that address depletion impacts, section 7 consultation, and project proponent responsibilities:

"All future section 7 consultations completed after approval and implementation of this program (establishment of the Implementation Committee, provision of congressional funding, and initiation of

the elements) will result in a one-time contribution to be paid to the Service by water project proponents in the amount of \$10.00 per acre-foot based on the average annual depletion of the project This figure will be adjusted annually for inflation [the current figure is \$13.41 per acre-foot] Concurrently with the completion of the Federal action which initiated the consultation, e.g., . . . issuance of a 404 permit, 10 percent of the total contribution will be provided. The balance . . . will be . . . due at the time the construction commences"

It is important to note that these provisions of the Recovery Program were based on appropriate legal protection of the instream flow needs of the endangered Colorado River fishes. The Recovery Program further states:

" . . . it is necessary to protect and manage sufficient habitat to support self-sustaining populations of these species. One way to accomplish this is to provide long term protection of the habitat by acquiring or appropriating water rights to ensure instream flows Since this program sets in place a mechanism and a commitment to assure that the instream flows are protected under State law, the Service will consider these elements under section 7 consultation as offsetting project depletion impacts."

Thus, the Service has determined that depletion impacts, which the Service has consistently maintained are likely to jeopardize the listed fishes, can be offset by (a) the water project proponent's one-time contribution to the Recovery Program in the amount of \$13.41 per acre-foot of the project's average annual depletion, (b) appropriate legal protection of instream flows pursuant to State law, and (c) accomplishment of activities necessary to recover the endangered fishes as specified under the Plan. The Service believes it is essential that protection of instream flows proceed expeditiously, before significant additional water depletions occur.

The Service has determined that, because the project's average annual new depletion of 516 acre-feet is below the current sufficient progress threshold of 1,500 acre-feet, the Recovery Program can serve as the reasonable and prudent alternative to avoid jeopardy to the Colorado squawfish, razorback sucker, humpback chub, and bonytail and can serve as the reasonable and prudent alternative to avoid destruction or adverse modification of critical habitat caused by the project's depletion.

Additionally, the Paradox Valley Unit is a Bureau of Reclamation project and the Bureau has agreed to contribute \$1.5 million annually to the Recovery Program. Because of this ongoing contribution and the commitment by the Bureau to operate Upper Colorado River Basin projects under its control to provide instream flows for the endangered fishes as

identified in the Recovery Program, no contribution for existing or future Bureau projects will be collected as part of the section 7 consultation process. As a result, no contribution is necessary for the 516 acre-foot depletion resulting from the operation of the Paradox Valley Unit.

INCIDENTAL TAKE

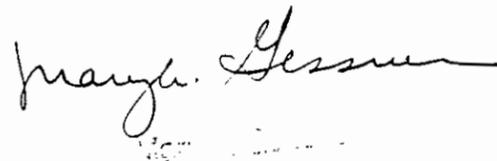
Section 9 of the Endangered Species Act, as amended, prohibits any taking (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct) of listed species without a special exemption. Under the terms of section 7(b)(4) and section 7(0)(2), taking that is incidental to and not intended as part of the agency action is not considered taking within the bounds of the Endangered Species Act, provided that such taking is in compliance with the incidental take statement.

The Service does not anticipate that the proposed action will result in any incidental take of the endangered fishes.

CONCLUSION

This concludes the Service's biological opinion on the impacts of the proposed project. This opinion was based upon the information described herein. If new information becomes available, if a new species becomes listed, if incidental take occurs, if the total average annual amount of water depleted by this project changes, or if any other project element changes which alters the operation of the project from that which is described in your correspondence and which may affect any endangered or threatened species in a manner or to an extent not considered in this biological opinion (see 50 CFR 402.16), formal section 7 consultation should be reinitiated.

Thank you for your cooperation in the formulation of this biological opinion and your interest in conserving endangered species.


Mary Gessner

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PARADOX VALLEY UNIT

FINAL ENVIRONMENTAL ASSESSMENT

**Responses to Comments on the
1996 Draft Supplemental Definite Plan Report
and Environmental Assessment**

Appendix D

APPENDIX D
Comment Letters and Responses

Introduction

In October 1996, the Paradox Valley Unit Draft Supplemental Definite Plan Report and Environmental Statement were distributed to the public. An announcement of its availability was sent to the media and copies were available for review at Reclamation's Durango Office and local libraries. The report accompanied by a letter inviting comment was also mailed to parties who had expressed interest.

The following letters were received at Reclamation's Durango Office commenting on the draft report. Each letter is followed by a response to issues raised therein.



United States Department of the Interior

BUREAU OF RECLAMATION

Upper Colorado Region
Western Colorado Area Office

OCT 23 1996

Northern Division
2764 Compass Drive
PO Box 60340
Grand Junction CO 81506-8785

Southern Division
835 E 2nd Avenue
PO Box 640
Durango CO 81302-0640

WCS-CSeale
ENV-6.00

Dear Interested Party:

The Bureau of Reclamation invites you to comment on the enclosed Draft Supplemental Definite Plan Report¹ (DPR) and Environmental Assessment (EA) for the Paradox Valley Unit, Colorado. The report describes the disposal of natural brine inflow by deep well injection, an environmentally preferred solution supported by the Environmental Protection Agency. The Paradox Valley deep-well injection facility is located approximately 1.2 miles south of Bedrock, Colorado.

Disposal of brine by an evaporation pond method was the plan of project development in 1979. Information gained later in project planning revealed that an alternative plan of injecting brine into deep wells described in the original DPR might result in less impact to the environment. Subsequent testing has proved that this method of brine disposal to be the preferred alternative.

The EA evaluates the effects of operating the injection facility to reduce salt-loading in the Dolores River by intercepting and disposing of naturally occurring brine groundwater entering the river in the unit area.

As the Dolores River crosses Paradox Valley, it picks up approximately 200,000 tons of salt that it contributes annually to the Colorado River. The deep injection well and associated brine well field facilities have the capability to reduce this salt contribution to the Dolores River by 50-70 percent.

You may send your written comments on the Supplemental DPR and EA to the Bureau of Reclamation, Attention: Clarice Seale, PO Box 640, Durango, Colorado 81302-0640, or Fax (970) 385-6539. The deadline for comments is November 12, 1996. Copies of the original DPR and EA are available upon request.

Sincerely,

ACTING FOR Patrick J. Schumacher
Southern Division Manager

Enclosure

¹ A Definite Plan Report is a Bureau of Reclamation document prepared by the planning division to summarize the purpose, design and operation of a proposed project.

Grand Junction, Colorado
November 26 , 1996

Bureau of Reclamation Attention: Clarice Seale
P. O. Box 640
Durango, CO 81302-0640

Re: Comments, Paradox Valley Unit Draft Supplemental Definitive
Plan Report and Environmental Assessment.

Figure 3, Page 20 of the Environmental Assessment shows, and on page 20 it is stated that "clearly, fluid pressure changes are being manifested at depths shallower than originally proposed." The text on page 20 goes on to say "Based upon the observation of injection sequences six and seven, Reclamation considers it unlikely that fluid pressure changes would extend above the -3 km depth observed to date..." Figure 3 shows injection sequences labeled 11 through 17. Are "six" and "seven" included in "11 through 17"? I heartily agree that continuous monitoring and accurate determination of earthquake focal depths is necessary. I think it may be likely that the fractures (faults?) will continue to propagate upward.

How confident is BOR that the problem of anhydrite deposition in the Leadville will be solved by the 70/30 ratio of brine to fresh water? Is this ratio derived from actual tests or is it interpolated from the USGS test results at 80/20 ratio of brine to fresh water which showed little reduction in anhydrite precipitation, and the results at 35/65 ratio of brine to fresh water, which showed suppressed anhydrite precipitation. (Geochemical effects of deep-well injection of the Paradox Valley brine into Paleozoic carbonate rocks, Colorado, U. S. A., R. J. Rosenbauer, J. I. Bischoff and Y. K. Kharaka, *Applied Geochemistry*, Vol 7, pp 273-292, 1992). Has additional testing been done on Leadville rocks using 70% brine and 30% fresh water?

The Paradox Valley unit is essentially a "point source" of a large volume of salt, and efforts to eliminate or reduce the salt input to the Dolores river should continue. I think it would be well to do an assessment of the probability of success at this time for the Proposed Action - Continue Operation of Test Injection Well versus the probability of success for the Radium Evaporation Pond Alternative. My background is in oil and uranium exploration; in those businesses more projects fail than are successful, because subsurface geology is fraught with surprises and sometimes disappointments. I hope the Proposed Action works, but policy makers in government, and the general public should be made aware that sometimes a change of course may be needed, and that the Radium Evaporation Pond Alternative may have to be followed.

Very truly yours,

Loyd A. Carlson
Loyd A. Carlson, Geologist
1155 Grand Avenue
Grand Junction, CO 81501

Phone 970-243-7257

7-1596B (9-89)
Bureau of Reclamation

EIVV

United States Department of the Interior

BUREAU OF RECLAMATION

Upper Colorado Region
Western Colorado Area Office



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NOV 20 1996

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Durango CO 81302-0640

WCS-SPowers
ENV-6.00

Mr. Loyd Carlson
1155 Grand Avenue
Grand Junction CO 81501

Subject: Draft Supplement to Definite Plan Report and Environmental Assessment, Paradox Valley Salinity Control Unit, Colorado River Basin Salinity Control Project, Colorado

Dear Mr. Carlson:

As discussed with Stan Powers of my staff, enclosed is additional information concerning the Paradox Unit injection well. If you have any questions or need additional information, please contact Stan at (970) 385-6555.

Sincerely,

ACTING FOR Pat Schumacher
Southern Division Manager

Enclosure

SPowers:bjw:11/20/96:1water/powers/carlette.wpd

F

S



*engineering
construction
management*

FINAL REPORT

**DRILLING AND TESTING
PHASE**

INJECTION TEST WELL NO. 1

**COLORADO RIVER BASIN SALINITY CONTROL PROJECT
PARADOX VALLEY UNIT, COLORADO**

**FENIX & SCISSON, INC.
TULSA, OKLAHOMA**

**BUREAU OF RECLAMATION
CONTRACT NO. 6-CC-40-03250**

FINAL COMPLETION REPORT

KEDA JOB NO. 10-1189
FEBRUARY, 1989

PREPARED BY
KEN E. DAVIS ASSOCIATES
HOUSTON, TEXAS

KEN E. DAVIS
ASSOCIATES



Clarence L. Harr
Consulting Petroleum Geologist

BUREAU OF RECLAMATION
INJECTION TEST WELL NO. 1
SW SE Sec. 30, T. 47 N., R. 18 W.
Paradox Valley
Montrose County, Colorado

ELEVATION: K.B. 5028 Ft. G.L. 4996 Ft.

TOTAL DEPTH: 16,000 Ft. PRECAMBRIAN

LOG TOPS

FORMATION	DRILLED			TRUE		
	DEPTH	THICKNESS	DATUM	DEPTH	THICKNESS	DATUM
TRIASSIC						
Chinle	Surf.	391	+4996	Surf.	390	+4996
Moenkopi	391	749	+4637	390	750	+4638
PERMIAN						
Cutler	1140	7190	+3888	1140	7173	+3888
PENNSYLVANIAN						
U. Honaker Trail	8330	3710	-3302	8313	3693	-3285
LaSal	12040	76	-7012	12006	76	-6978
L. Honaker Trail	12116	268	-7088	12082	268	-7054
Paradox	12384	261	-7356	12350	260	-7322
Hatch	12645	230	-7627	12610	229	-7582
Ismay	12875	265	-7847	12839	265	-7811
1st Main Salt	13140	219	-8112	13104	218	-8076
2nd Main Salt	13535	69	-8507	13497	69	-8469
Base Salt	13604		-8576	13566		-8538
Lower Paradox	13604	127	-8576	13566	127	-8538



Clarence L. Harr
Consulting Petroleum Geologist

FINAL GEOLOGICAL WELL REPORT

Report Section V

BUREAU OF RECLAMATION
INJECTION TEST WELL NO. 1
PARADOX VALLEY
30 - 47N - 18W
MONTROSE COUNTY, COLORADO

Paradox Valley Unit
Salt Brine Injection Project
Bedrock, Colorado

BUREAU OF RECLAMATION
Contract 4-CA-40-01660
Project 10-760

CLARENCE L. HARR
Consulting Petroleum Geologist



United States Department of the Interior

BUREAU OF RECLAMATION

Upper Colorado Region
Western Colorado Area Office

MAY 10 1997

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Southern Division
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WCS-RPasquale
ENV-6.00

Mr. Loyd A. Carlson, Geologist
1155 Grand Avenue
Grand Junction CO 81501

Subject: Our Response to Your Letter of November 26, 1996, Commenting on the Draft Supplemental Definite Plan Report and Environmental Assessment, Paradox Valley Unit, CRSP, Colorado

Dear Mr. Carlson:

Please accept my apology for being so long in responding to your letter.

In the first paragraph of your letter you note the confusion caused by a typographical error. The injection sequences are one through seven. The mention of sequences 11 through 17 is an error. We agree with your assessment of the value of continuous monitoring. The Environmental Protection Agency has concurred and language to that effect is included in the long-term operations permit.

To address your concern that the fractures will continue to propagate upwards, we offer the following:

Given a finite pressure increase at the bottom of the well, the fluid pressure increase at some distance from the bottom of the well must be less than that pressure increase and the farther a given point is from the well perforations the smaller the pressure perturbation will be. In other words, Delta Pressure is a strong function of distance. Further, as fluid is forced upwards it is doing work against gravitational body forces, this accounts for the preferential movement of fluid pressure changes laterally. I would argue there will be a fairly definite upper limit (vertically) to fluid pressure changes. Based upon the results of the first seven injection sequences we hypothesize that limit (assuming the injection pressures used in the future are equal to or less than those used previously) will likely be consistent with those shown in the DPR. One of the goals of further earthquake monitoring is to evaluate the validity of this assumption. This is why we try to have near real-time locations of the earthquakes.

To address your concern as to whether or not the problem of anhydrite deposition in the Leadville (Formation) will be solved by the brine to a freshwater ratio, we offer the following:

Based on the tests conducted by the U.S. Geological Survey and consultation with others experienced in this field, Reclamation has determined that the risk associated with the injection of a 70% brine solution is acceptable. However, we are currently conducting on site pilot test to determine the feasibility of using membrane nanofiltration technology to remove sulfate from the brine to allow injection without dilution.

Should you have any other questions or want further information, please contact either Stan Powers or me at the letterhead address or by telephone at (970)385-6500.

Sincerely,

A handwritten signature in black ink, appearing to read 'R. Pasquale', with a large, stylized initial 'R'.

Ralph W. Pasquale, Chief
Land, Recreation, and Environmental Resources Group
Southern Division

22 November 1996

2611 N. College Drive
Durango, CO 81301

Ms. Cookie Seale
Durango Projects Office,
Bureau of Reclamation
P.O. Box 640
835 E. Second Avenue
Durango, CO 31301

Dear Ms. Seale,

I write this letter to comment on the Colorado River Basin Salinity Control Project, Paradox Valley Unit Draft Supplemental Definite Plan Report and Environmental Assessment released October 1996. Please enter it into the public record.

From all appearances, the Paradox Valley Project (PVU) shows indications of being a well-designed and essential component of Colorado River Basin desalinization and water quality control efforts. I, nonetheless, found one aspect of the financial analysis to be somewhat troubling.

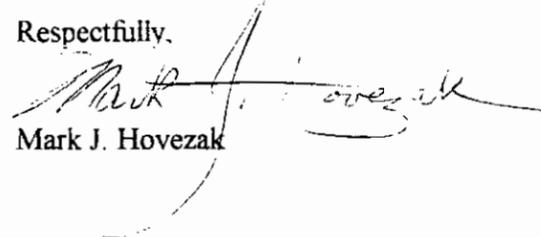
Both the PVU and Animas La-Plata Project (ALP) salinity value per ton have been indexed to 1993 dollars using the consumer price index. The reported indexed annual value to society per ton of salt removed by the PVU is \$334 and is based on direct benefits only (page IV-11). The economic loss to society per ton of salt, projected to be introduced into the Colorado River Basin by ALP, is reported as \$50 (page 30, ALP Economic and Financial Analyses Update, USDI, BOR, June 1995). Several outcomes appear to be possible due to this apparent discrepancy:

- (1) the PVU benefits, estimated at \$42,752,000 per year for removal of 128,000 tons of salt, are grossly inflated;
- (2) the annual estimated \$7,901,000 cost of ALP salinity, at \$50 per ton is underestimated by the huge amount of \$284 per ton.
- (3) The PVU salinity reduction benefits are overestimated **and** the ALP salinity costs underestimated.

For these reasons several questions linger, not so much about the appropriateness of PVU, but about the use of numbers associated with reporting on the PVU as part of the public record. Is the project as sound on economic grounds as reported? If so, why are per unit salinity values so different between ALP and PVU? Since salinity production costs and salinity reduction benefits are essentially equivalent, and are calculated the same basin-wide using the same index, shouldn't the amounts be the same for each ton of salt regardless of whether the source is ALP runoff or PVU brine wells? If 'outcome 1' (above) is true, does BOR interest in the promotion of the environmentally and economically unsound ALP influence and confound the accurate reporting of economic facts on other projects? If 'outcome 2' (above) is true, are the facts reported accurately

in ALP documents? If 'outcome 3' (above) is true, are any facts related to salinity accurate?
What are the facts in regard to this issue?

Respectfully,

A handwritten signature in cursive script, appearing to read "Mark J. Hovezak". The signature is written in black ink and is positioned above the printed name.

Mark J. Hovezak

United States Department of the Interior

BUREAU OF RECLAMATION

Upper Colorado Region
Western Colorado Area Office



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2764 Compass Drive
PO Box 60340
Grand Junction CO 81506-8785

Southern Division
835 E 2nd Avenue
PO Box 640
Durango CO 81302-0640

WCS-KBeck
TRA-0.00

DEC 20 1996

Mr. Mark J. Hovezak
2611 North College Drive
Durango CO 81301

Dear Mr. Hovezak:

Thank you for your letter of November 22, 1996. The question you raised on the discrepancy between the two reports is well taken. The wording needs to be changed to clarify the discussion on the salinity control program's annual costs and benefits.

The annual benefits of salinity control are projected at approximately \$340 for each ton of salt removed from the Colorado River system. The \$340 is an estimate of the foregone downstream water user damage that would have occurred from the effects of high salt concentrations on agricultural conveyance facilities, crops and household water pipes and appliances (i.e., hot water heaters, water softeners, dishwashers, clothes washers, swamp coolers, etc.). The annual cost to construct facilities to reduce salt loading from the river, is approximately \$50 per ton of salt removed. These two values (salinity costs and benefits) can be compared to the adage "pay me now or pay me later" when promoting proper automobile maintenance. In this instance, the construction of facilities to remove salinity (performing the timely and proper maintenance) will yield a net annual saving of approximately \$290 per ton of salt removed ($\$340 - \$50 = \$290$). Conversely, if the salt was not removed from the river, we could anticipate approximately \$340 in related damage for each ton of salt carried downriver during the year (resulting from a lack of proper and timely maintenance).

As the upper basin states develop their water supplies in accordance with the Colorado River Basin Compact, salinity concentrations will increase in the Colorado River. The Colorado River Basin Salinity Control Program has been enacted, in part, to ameliorate the negative aspects of this planned development.

With regard to your question about why the salinity impact of the project's depletion is not included in the economic evaluation, it is a complicated state's rights issue. Without a question, Colorado's unused allocation of water from the Colorado River Compact is creating

numerous economic benefits downstream and that developing this water would eliminate these benefits. Among many other possible benefits, these flows dilute saline sources in the lower Basin, produce power at several downstream dams, and the water is used by millions of California residents. However, the Basin States assert the right to develop their compact allocations and that any interim benefits caused by the lack of development of their allocation are only temporary. Therefore, the loss of these "temporary" benefits caused from a state's allocation flowing downriver are not included in the impacts or cost analysis. As you correctly identified, the impact of salt loading does not fall into this category and is included in the cost analysis.

If you have any questions or need further assistance, please call me at (970) 385-6558.

Sincerely,

Ken Beck
Project Team Leader
Southern Division

KBeck:bjw:12/20/96:1water/beck/havezak.wpd

Ms. Cookie Seale
Durango Projects Office
Bureau of Reclamation
P.O. Box 640
Durango, CO 81301

RE: Comments on the Paradox Valley Unit Environmental Assessment

Nov. 25, 1996

Dear Ms. Seale:

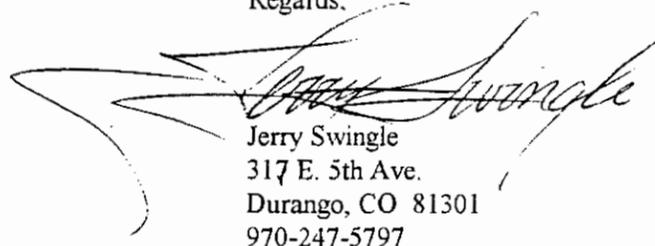
There are major discrepancies in how the Bureau of Reclamation treats downstream salinity costs in the Colorado River Basin depending on what project the Bureau is trying to justify. When the Bureau is analyzing a salinity control project, downstream salinity costs (and therefore benefits from salt removal) are quite high. When the Bureau is analyzing a water project which increases salinity, downstream salinity costs mysteriously drop.

In the Paradox Valley Unit Environmental Assessment, where the Bureau is justifying the construction of salinity control features, downstream salinity costs are quite high, \$334 per ton of salt in 1993 dollars. (Paradox Valley Unit Environmental Assessment, Oct. 1996, p. IV-11.) If one were to use the \$334 per ton figure in the Animas-La Plata Project's Economic Analysis, the benefit/cost ratio would drop from 0.36:1.00 to 0.25:1.00. Instead, since the Bureau is trying to justify the Animas-La Plata Project, which adds salinity to the Colorado River, the downstream costs of salinity suddenly drop to \$50 per ton in 1993 dollars. (Animas-La Plata Project, Economic and Financial Analyses Update, June 1995, p. 30.) The Bureau states, "The \$50 unit cost was generally accepted by the peer reviewers as also being representative of the loss of economic value to downstream users."

In addition, in its Animas-La Plata Project analysis, the Bureau incorporates only the cost of salinity caused by the concentrating effects of water consumption. The cost of the actual increase in salt loading by the project is neglected. Yet, in its benefit-cost analysis of the Dolores Project, the Bureau incorporates the costs of salt loading, because salinity control features are part of the project, and neglects the concentrating effects of water consumption. (Dolores Project, Final Supplement to Definite Plan Report, Dec. 1988, p. 66.)

When is the Bureau going to give us a consistent analysis of downstream salinity costs and benefits created by its actions and stop manipulating numbers and method of analysis to justify its projects? Please include a copy of these comments in your Animas-La Plata Project file. Thank you.

Regards,



Jerry Swingle
317 E. 5th Ave.
Durango, CO 81301
970-247-5797

cc. Richard Sanderson - U.S. Environmental Protection Agency
Katie McGinty - Council on Environmental Quality



United States Department of the Interior

BUREAU OF RECLAMATION

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PO Box 640
Durango CO 81302-0640

WCS-KBeck
TRA-0.00

Mr. Jerry Swingle
317 E. 5th Ave.
Durango CO 81301

Dear Mr. Swingle:

Thank you for your letter of November 22, 1996. The question you raised on the discrepancy between the two reports is well taken. The wording needs to be changed to clarify the discussion on the salinity control program's annual costs and benefits.

The annual benefits of salinity control are projected at approximately \$340 for each ton of salt removed from the Colorado River system. The \$340 is an estimate of the foregone downstream water user damage that would have occurred from the effects of high salt concentrations on agricultural conveyance facilities, crops and household water pipes and appliances (i.e., hot water heaters, water softeners, dishwashers, clothes washers, swamp coolers, etc.). The annual cost to construct facilities to reduce salt loading from the river is approximately \$50 per ton of salt removed. These two values (salinity costs and benefits) can be compared to the adage "pay me now or pay me later" when promoting proper automobile maintenance. In this instance, the construction of facilities to remove salinity (performing the timely and proper maintenance) will yield a net annual saving of approximately \$290 per ton of salt removed ($\$340 - \$50 = \$290$). Conversely, if the salt was not removed from the river, we could anticipate approximately \$340 in related damage for each ton of salt carried downriver during the year (resulting from a lack of proper and timely maintenance).

As the upper basin states develop their water supplies in accordance with the Colorado River Basin Compact, salinity concentrations will increase in the Colorado River. The Colorado River Basin Salinity Control Program has been enacted, in part, to ameliorate the negative aspects of this planned development.

If you have any questions or need further assistance, please call me at (970) 385-6558.

Sincerely,

Ken Beck
Project Team Leader
Southern Division

200 000

GLEN A. MILLER
2264 Willow Wood Road
Grand Junction, CO 81503
Home 970-245-4347 - Work 970-243-1642

~~November 12, 1996~~

Bureau of Reclamation
Attn: Clarice Seale
P.O. Box 640
Durango, CO 81302-0640

RE: Paradox Unit EA
October, 1996

Gentlemen:

Thank you for the opportunity to comment on the Paradox EA. However, I respectfully must point out that the copy in the Mesa County Library was not made available to the public until November 5, 1996 -- ONE WEEK is not adequate public time for review. My comments below are not comprehensive, but they point out several obvious unsupported conclusionary statements and shortfalls in the EA.

1. P. II-2, Par. 3: The injection zone is described as Mississippian to Cambrian Age. Prior data on the bore hole indicates that Pre-Cambrian crystalline bedrock is also open to the well bore. Is this now part of the injection zone?

2. P. II-2, Par. 4-5: The descriptions of and conclusions about the injection zone capacity and overlying barrier are somewhat misleading. There are no adequate data to support the claim that long-term injection can occur without undesirable results. The supposed adequate salt barrier has already been breached by injected brine. This appears to be a violation of injection regulations.

The injection zone is not a "Black Hole," as it appears to have been assumed, but its "take" is dependent upon, (1) compression of native fluids that presently fill all available pore space, (2) deformation of the rock fabric, and (3) increased discharge of fluids from the injection zone. Apparently, little or nothing is known by the EA preparers of any of these conditions. All three factors are greatly complicated by the several faults (Fig. II-3) in the vicinity.

3. The data on hypocenters of earthquakes shown on Fig. II-3 and Figs. 2-5 indicate that a large part of the "hydrofracturing" (one form of rock deformation noted above) is taking place progressively upward from the injection zone, probably along faults that are pre-existing zones of weakness.

The hypocenters, which reflect "...where the fluid is flowing in the subsurface..." (P. 17), appear to have migrated vertically upward to about 4,000 feet above the top of the injection zone. This is about 3,600-3,700 feet above the top of the salt barrier. Again, this appears to not be in compliance with injection regulations. The upward migration rate appears to be volume controlled, and computes at about 50 feet of upward migration per acre-foot injected, or about 70 feet per day at planned rates. Under constant injection at this rate, brine could appear at the surface in less than six months.

If/when this occurs, the project will be shut down and we taxpayers will lose the entire investment. The conclusion on P. 23 (Par. 3) that "Reclamation considers it unlikely fluid pressure changes would extend above the (-) 3 Km depth..." is unsupported by data, flies in face of evidence and geohydrologic principles, and cannot be used to justify continuing this project on the same path.

4. The assumption that diluting the brine with river water will solve the "Scale Formation" problem is fraught with uncertainty. Addressing this problem thusly is reminiscent of a pre-drilling USBR report on the project, which declared the injected brines and receiving zone brines to be "compatible!" The precipitation of calcium sulfate could be the ultimate limiting factor in the project, because the potential exists to precipitate several 100 tons per year in the injection zone.

5. Monitoring of critical hydrologic parameters is woefully lacking. Thus, there is no way to learn about cause-effect, and no "early-warning" system to provide an alert to undesirable effects.

A. Deep monitoring wells are needed, especially near the injection well ("nested" piezometers in several zones), to track the upward migration of fluids. The above-noted computed migration rates could be somewhat attenuated as more permeable near-surface zones are invaded.

B. The boundary faults near the injection well are in hydraulic connection with the river alluvium. Shallow alluvial monitoring wells are needed to determine if brine is entering the alluvium from the sub-surface.

Bureau of Reclamation
November 12, 1996

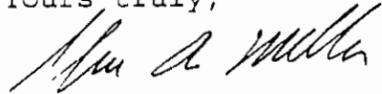
Page 3

C. The lateral extent of pressure rise could be expected to be manifest as very small but detectable land-surface deformation. A levelling net and/or tilt-meter system within the injection well fault block and onto the adjacent blocks should detect such deformation. Such deformation can also be measured in deep monitoring wells.

In summary, the project should not continue to inject brine without a scientific assessment of the entire system, and without adequate monitoring. In many respects, the original surface evaporation concept looks more and more desirable as an alternative.

Thank you.

Yours truly,



Glen A. Miller

GAM/an

cc: Mr. Steve Miller, CWCB
Ms. Ruth Hutchins



United States Department of the Interior

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MAY 16 1997

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WCS-RPasquale
ENV-6.00

Mr. Glen A. Miller
2264 Willow Wood Road
Grand Junction CO 81503

Subject: Our Response to Your Letter of November 12, 1996, Commenting on the Draft
Supplemental Definite Plan Report and Environmental Assessment, Paradox Valley
Unit, CRBSCP, Colorado

Dear Mr. Miller:

Please accept my apology for being so long in responding to your letter.

The following addresses your comments in the order given in your letter.

(1) As part of the well completion process, a portion of the injection well at depths within the Precambrian was perforated and could be expected to transmit injectate away from the well. The volume of fluid was expected to be low, however, based on the physical properties of the rocks in that interval.

(2) It is not clear at this point how extensive the transmission of injectate above the salt layer has been. At least one source of confusion lies with the over simplified geological interpretation that was presented in the early evaluations at this site. (As with most other projects, as time has passed and additional data has been gathered a more complete and complex picture of the process has emerged.) The zone paralleling the Paradox Valley appears to be offset by a number of normal (down to the east, northeast) faults that trend parallel to the strike of the valley. The well is within this zone. The shallowest hypocenters are to the northwest of the well where the Leadville limestone is expected to be the shallowest. Further, the earthquake hypocenters are inferred to define a zone of elevated pore pressures that, combined with the existing state of stress at that point, lead to brittle failure. The actual location of the injectate is most likely much closer to the well than the furthest earthquake hypocenters. The injectate is believed to be displacing existing pore fluid ahead of the "brine front." This mechanism will be many orders of magnitude more important in "take" than will fluid compression.

Given the number of faults inferred from the seismic reflection data and the earthquake data it is highly likely that at least some injectate has been pushed above the salt "barrier." This assertion could have been strongly defended if no seismic data, no earthquake data, and nothing but the pictorial representation of the geometry were available. That at least some brine will find a pathway upwards at least a short distance along preexisting fractures seems a certainty. (This is true of every injection well that has ever operated or been proposed.) The important question is, will there be a significant amount of injectate traveling upwards? At this time it appears there probably has been minimal upward migration. This contention is based on several observations:

(A) The shallowest hypocenters occurred fairly early in injection sequence six; during the following sequence (the most prolonged), no further shallowing of hypocenters was observed.

(B) To the west where the shallowest hypocenters were located, the Leadville Formation is much shallower than the depth inferred at the well.

(C) Observations from injection over the past several months have shown no shallow events to the west. Almost all events observed recently have been to the east and relatively deep (~5.4km). Again, if the interpretation of parallel normal faults is correct, the Leadville would be deeper in this area.

(D) As discussed above, there will be a "spatial lag" between the earthquake hypocenters and the injectate. The hypocenters are inferred to outline an outer boundary for the position of the injectate.

(3) As discussed above, recent observations (which have occurred over a period exceeding six months) have yielded a suggestion of deeper injectate transfer to the east, not continuing shallowing to the west. Simple physical calculations suggest the magnitude of upward migration of injectate must be limited. Given a finite bottom hole pressure, upward migration will be severely limited by gravity and frictional losses along the narrow fluid transfer paths. This is one of the key reasons for continued earthquake monitoring as a requirement of the permit for this site. The earthquake monitoring program will help us to continue to define the upper limits of fluid migration.

(4) This comment is a statement and no response is appropriate.

(5) A specific statement is made in this question that the boundary faults near the well are in hydraulic connection with the river system. If this is the case, the members of D8330 are unaware of any data that confirms or denies this statement. We would be very interested in any data that could prove this connection.

General comment addressing your concern that there has not been adequate hydraulic modeling of the Unit: Envirocorp used a model based on limited data to evaluate the injection reservoir and predict the injection pressures and life of the well. Testing of this well has provided additional data necessary to conduct a sophisticated modeling effort. Modeling will be conducted as the need is further defined and funding allows.

Should you have any other questions or want further information, please contact either Stan Powers or me at the letterhead address or by telephone at (970) 385-6500. If you wish to discuss the geological aspects in depth, you may contact Mr. Jon Ake at (303) 236-4195 extension 276.

Sincerely,

A handwritten signature in black ink, appearing to read 'R. Pasquale', with a large, stylized initial 'R'.

Ralph W. Pasquale, Chief
Land, Recreation, and Environmental Resources Group
Southern Division

STATE OF COLORADO
Roy Romer, Governor
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WILDLIFE
AN EQUAL OPPORTUNITY EMPLOYER

John W. Mumma, Director
6060 Broadway
Denver, Colorado 80216
Telephone: (303) 297-1192

2300 South Townsend
Montrose, CO 81401
November 8, 1996

Bureau of Reclamation
Southern Division
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Durango, CO 81302-0640

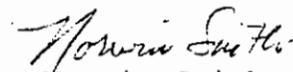
Attention: Clarice Seale:

The Division of Wildlife has reviewed the October 1996 Draft Supplemental Definite Plan Report (DPR) and Environmental Assessment (EA) for the Paradox Valley Unit Salinity Control Project. The CDOW has found the documents to be complete and accurate regarding the items related to Wildlife, Fish and Wetland/Riparian Habitats.

The Division concurs with the analysis and environmental assessment. All of the biological impacts associated with the proposed deep well injection project have been identified and the proposed conservation measures are acceptable to the Colorado Division of Wildlife.

Thank you for giving us the opportunity to comment on this Draft Report.

Sincerely,


Norwin Smith
Wildlife Manager

cc: B. Clark
M. McLain



United States Department of the Interior

FISH AND WILDLIFE SERVICE

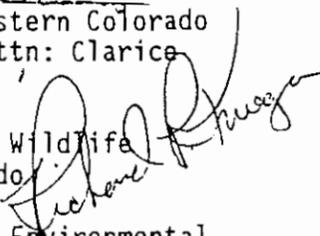
Ecological Services
Western Colorado Office
764 Horizon Drive, South Annex A
Grand Junction, Colorado 81506-3946

IN REPLY REFER TO:

ES/CO:BR
65412-GJ

November 12, 1996

To: Southern Division Manager, Bureau of Reclamation, Western Colorado Area Office, Southern Division, Durango, Colorado (Attn: Clarice Seale)

From: Acting Assistant Colorado Field Supervisor, Fish and Wildlife Service, Ecological Services, Grand Junction, Colorado 

Subject: Comments on Draft Supplemental Definite Plan Report, Environmental Assessment, and Biological Assessment for the Colorado River Basin Salinity Control Project's Paradox Valley Unit, October 1996

The Fish and Wildlife Service has reviewed the subject documents with accompanying cover letter dated October 23, 1996. The Paradox Valley Unit is intended to collect underground flows of salt rich brine water before the brine enters the Dolores River at Paradox Valley. The brine will be deposited in porous geologic formations several thousand feet down using injection wells. The Service realizes the need for reduction of Colorado River salt content to benefit Lower Colorado River Basin water users and possibly fish and wildlife. The Service allowed phases of the brine removal facility to be built in the 1970's and 1980's because of this realization. Consequently, the Service believes that continuing operation of the brine removal facility, as described in the preferred alternative, is acceptable with existing mitigation measures and future reasonable and prudent alternatives that will avoid jeopardy to endangered species.

The Service previously formally consulted on the Paradox Valley Unit Project in 1977 and 1989. During the 1989 consultation, the Service concurred with "no effect" determinations for the black-footed ferret (*Mustela nigripes*), bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), and *Echinocereus triglochidiatus* var. *inermis* (Spineless hedgehog cactus) due to lack of direct affects on habitat, absence of the species during surveys, and mitigation measures incorporated into planning documents. The Service did not concur with "no effect" determinations for water depletion impacts to the Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), or the bonytail (*Gila elegans*) and thus wrote a biological opinion.

Changes in the project and delays in testing the injection wells resulted in delays in finalizing operation plans. During that time period additional species that could be impacted by the project were federally listed and critical habitat was designated for the endangered fishes. Consequently,

further consultation was recommended by the Service during a 1994 inquiry by the Bureau of Reclamation. Subsequently, the Bureau requested species lists and prepared the current biological assessment.

The current biological assessment does not discuss impacts on the spineless hedgehog cactus since it has been delisted. However, the biological assessment discusses impacts on the other species in the 1989 assessment as well as the Mexican spotted owl (*Strix occidentalis lucida*), southwestern willow flycatcher (*Empidonax traillii extimus*), razorback sucker (*Xyrauchen texanus*), and the endangered fishes critical habitat.

The Service concurs with your "no effect" determinations in the biological assessment for the peregrine falcon, bald eagle, black-footed ferret, Mexican spotted owl, and southwestern willow flycatcher. The Service concurs because important habitat and prey availability of the above species does not appear to be directly impacted by the facility or by the amount of water depleted by operations.

The Service, once again, does not concur with your "no effect" determinations for the endangered fishes or their critical habitat. The Bureau used as rationale for their "no effect" determinations that they contribute money and participate in the Recovery Program for the Endangered Fishes in the Upper Colorado River Basin (Recovery Program), that the 516 acre-foot water depletion is a minor depletion and the program has achieved sufficient progress to offset minor depletions, and that reoperation and releases out of McPhee Reservoir would offset those depletions. The Bureau also concluded that removal of the salt would improve water quality and create a beneficial affect to the endangered fishes and their critical habitat.

Even though 516 acre-feet is considered a "minor" depletion under the Recovery Program and the Bureau participates in the Recovery Program, that does not mean that there is "no effect" to the endangered fishes or their critical habitat. Mitigation cannot be used to avoid a "may affect" determination unless that mitigation results in impacts that are beneficial, discountable, or insignificant. The Service has a policy that any water depletion should warrant a "may affect" determination for the endangered fishes and their critical habitat and does not believe that formal consultation can be avoided in this case. The Bureau also has a policy that their water depletions result in a "may affect" determination for the endangered fishes and their critical habitat (Steve McCall, BOR, pers. comm., 1996).

Though the Service believes that salt removal could be beneficial to the Colorado squawfish and the other endangered fishes, the beneficial affect is somewhat in question. In the biological assessment the Bureau referenced Seethaler (1978) who reported small squawfish being caught in the Dolores River as far up as Paradox Valley as late as 1962. The Bureau also referenced Valdez et al. (1992) in the biological assessment whom reported that salt levels become diluted once the San Miguel River enters the Dolores River. Valdez et al. (1992) also mention in their report that the Dolores River appears suitable for Colorado squawfish reintroduction and; therefore, they do not believe that the salt levels are a limiting factor. As the Bureau points

out in the biological assessment, it is suspected that reduction of squawfish range in the Dolores River may be due to other factors such as past Uranium mining operations. Hence, the Colorado squawfish and the other endangered fishes may not be impacted by the salt loading. To say that removal of the salt will be a benefit to the endangered fishes beyond historical conditions will be difficult to conclude due to various anthropogenic effects in the last century.

The Bureau is correct that because of their participation in the Recovery Program the Service does not apply the water depletion fee to the Bureau for "minor" depletions. However, neither the section 7 agreement nor the release of water make the depletion a "no effect" impact in the Service's (or Bureau's) opinion. The salt reduction could be beneficial, but that does not override the necessity for formal consultation due to the water depletion impacts. The Service believes that a "may affect" determination is warranted and recommends that the Bureau request, via memorandum, initiation of formal consultation.

Literature Cited

- Seethaler, K.H. 1978. Life history and ecology of Colorado squawfish (*Ptychocheilus lucius*) in the upper Colorado River Basin. M.S. thesis. Utah State University, Logan, Utah.
- Valdez, R.A., W.J. Masslich, and A. Wasowicz. 1992. Dolores River Native fish habitat suitability study (UDWR Contract No. 90-2559), Report No. TR-272-02. BIO/WEST Inc., Logan, Utah. 111pp. + appendix.

cc: BR, Grand Junction (Attn: Steve McCall)
CDOW, Durango (Attn: Mike Japhet)
FWS/ES, Golden
FWS/ES, SLC (Attn: Reed Harris)



United States Department of the Interior

BUREAU OF RECLAMATION

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DEC 17 1996

WCS-RPasquale
ENV-7.00

MEMORANDUM

To: Acting Assistant Colorado Field Supervisor, Fish and Wildlife Service,
Ecological Services, 764 Horizon Drive, South Annex A, Grand Junction CO

From: Patrick J. Schumacher
Southern Division Manager *Patrick J. Schumacher*

Subject: Re-Initiation of Section 7 Consultation - Paradox Valley Unit Salinity Control Project,
Colorado

In accordance with your memorandum of November 12, 1996, we hereby request re-initiation of Section 7 Consultation on the Paradox Valley Unit Salinity Control Project. This is to be based on the October 1996 Draft Supplemental Definite Plan Report and Environmental Assessment (DPR/EA) which also includes our revised Biological Assessment. We have received comments on the draft and are incorporating them. None of the comments received affect the Biological Assessment.

The draft DPR/EA reflects the program change from the original DPR brine evaporation pond to deep well injection for brine disposal and the proposed change in status of the project from "experimental" to long-term operations. A draft EA on deep well injection, the Environmental Protection Agency's preferred method, was circulated for comment in 1986 and deep well injection has been undergoing testing since 1991. This draft DPR/EA reflects the comments received on the 1986 draft EA as well as the program results to date. The chronology of previous coordination between Reclamation and the Service is also presented in the draft. Re-consultation is necessary because the Service does not concur with the Reclamation determination of no-effect for endangered fishes or their critical habitat. The conclusions of re-consultation are required before the draft can be finalized.

Ralph Pasquale of my staff spoke with Terry Ireland and was assured that such consultation could be expedited.

Your cooperation in this matter will be greatly appreciated.

RPasquale:dmr:12/13/96:[lregrp-pasquale-pdx.fws]

HUTCHINS

1574 L Road
Fruita, Colorado 81521
(970) 858-7363
November 29, 1996

Bureau of Reclamation
Attn.: Clarice Seale
P.O. Box 640
Durango, CO 81302-0640

Re: Colorado River Basin Salinity Control Project, Paradox Valley Unit
Draft Supplemental Definite Plan Report and Environmental Assessment
October 1996

Dear Clarice Seale:

Please thank your office for extending the comment period from November 12 to November 29, 1996. The extension is greatly appreciated.

And thank you for allowing the public an opportunity to comment on the "Colorado River Basin Salinity Control Project's Paradox Valley Unit Draft Supplemental Definite Plan Report and Environmental Assessment, October 1996."

Comments on the "Draft Supplement Definite Plan Report" are as follows:

page II-2, paragraph 3

"...The remaining 1,789 feet of the bore is the injection zone, with Mississippian-age Leadville limestone serving as the primary injection formation and lower Devonian- and Cambrian-age formations serving as secondary injection zones."

The original injection area stated on the well permit was limited from the top of the Leadville Limestone to the top of the Precambrian Granite. Was the well permit modified in 1990 to include the upper portions of the Precambrian Granite and Cambrian Granite at approximately 16,000 feet below ground level? And why was the modification needed to extend the injection area? I would like to include the following reference clipped from the Williams Brothers Engineering Company's report: "Feasibility Study, Deep-Well Injection of Brine, Paradox Valley Unit, April 13, 1981." This study was prepared for the U.S. Department of the Interior, Water and Power Resources Service, Denver, Colorado.

page 13-2, paragraph 4

"Many residents of Colorado are aware that the Rocky Mountain Arsenal Disposal Well in Denver was implicated in the recorded increase of earth tremors in the Denver area in 1962-1965. The implication may be valid; however, it should be noted that this unusual well was drilled into non-porous, non-sedimentary Precambrian rocks. Disposal of the waste liquid into the fractures of the non-porous rock was attempted. Disposal wells typically are completed in porous,

If the construction of the Paradox Unit is considered completed, how is the money for this experimentation and potential development of a new technique going to be financed?

Will a supplement to the Draft Supplemental Definite Plan Report be required?

Was Paradox Valley Brine (PVB) initially injected into the well prior to the fresh water buffer injection? Did the precipitation of the initial PVB injection cause problems?

Has an acidification procedure been used during this two-year testing period? If so, when and why was it needed?

Why is this procedure omitted in a description of this report?

page IV-1, paragraph 1, last sentence

"... Testing of the well is complete, with the results indicating that this method of brine disposal is physically and economically feasible."

Does the Salinity Control Forum accept this statement: "that testing of the well is complete"? This report stated a new concept for sulphate removal will be attempted.

Is testing deep-well injection as a viable way to remove salt still in a testing mode? Is more time needed before acceptance by the Forum?

Is the Forum satisfied that all is well when a new method for removing sulfates is underway?

Will the states agree to start the repayment contracts?

If repayment is initiated and is to go for 50 to 100 years, can repayment stop if the project proves to be unworthy and not viable?

page IV-2, paragraph 2

"Water levels are checked in the wells during project operations and the data are used to determine what effect pumping the brine production wells has on the water table, and how the fresh water and brine interact, and how the brine moves within the aquifer."

Would have all pumped brine from the 10 wells being used actually reached the Dolores River?

Has salt reduction to the Dolores River actually happened during the injection testing?

Is it possible to measure a reduction in the river?

Why is the information or an explanation not included in this report?

page IV-4, paragraph 1

"... These 350-horsepower, alternating current..."

page IV-10, paragraph 1

...“The life of the Unit would be dependent upon the injection well reservoir capacity, which is unknown. When the present injection reservoir is filled, pumping pressures and related costs would increase.”

How does this statement match with that on page IV-5, paragraph 2?

And how much attention did the BOR and EPA pay to the “U.S. Department of the Interior Geologic Survey: Evaluation of Hydrogeologic Aspects of Proposed Salinity Control Program in Paradox Valley, Colorado” by L.F. Konikow and M.S. Bedinger, Open-File Report 78-27, Denver, Colorado, 1978? An excerpt follows from page 20, paragraph 3:

“Another option for handling the brine within Paradox Valley involves subsurface disposal through deep-well injection. An examination of the stratigraphic section for the area does not indicate a high probability of encountering a suitable reservoir rock that could sustain a long-term injection of a significant percentage of the discharge from the brine well field. A significant expenditure would be required simply to evaluate and test the physical feasibility of this option. If it were physically feasible, its implementation would then require high initial design and construction costs, and possibly also high annual maintenance and operating costs. If high-pressure injection is required, consideration must also be given to possible geologic hazards, such as induced earthquake activity or upward migration of the injection brine along existing faults, fractures, or abandoned deep wells.”

page V-3, paragraph 1

“The second injection well would be drilled at the site of an abandoned oil well, causing the same environmental effect as was caused by drilling the first well. The injection well would be drilled to Mississippian-Age Leadville Limestone as the primary injection zone and would be similar to the first well in construction.”

Williams Brothers Engineering Company report: “Feasibility Study Deep-Well Injection of Brine, Paradox Valley Unit” dated April 13, 1981, on page 1-1, Section 1: “Executive Summary—Conclusions” advised just that for the initial test well—using an abandoned oil well.

Why did not the BOR follow this suggestion in 1986 when drilling started? Is the current well a non-performing wildcat well which should be abandoned? A “dry hole” so to speak?

The price for drilling two wells as outlined on page V-3, Table V-1, is interesting.

The BOR has reported to Congress over the years that the Paradox Unit is anticipated to cost \$94.4 million. Proposal of a second well added to the first is estimated at \$94,757,016.00. Did the figure of \$94.4 million presented to Congress anticipate drilling of another well in addition to the test well?

Why did the BOR not follow the original recommendation of Williams Brothers and use the old oil well?

I would suggest that the BOR go to Congress for additional funding for the needed new developments, that the Salinity Control Forum not accept the project as construction completed, and that testing under the proposed O&M program (not construction), not be acceptable. The project is not a tried and true project. The process has been trial and error.

Thank you for this comment period. My current indisposition has not allowed me to use my typing service. I will fax this to you today, November 29, 1996, and hopefully have this typed for your permanent records.

Sincerely,

Ruth P. Hutchins

Ruth P. Hutchins



United States Department of the Interior

BUREAU OF RECLAMATION

Upper Colorado Region
Western Colorado Area Office

MAY 28 1997

Northern Division
2764 Compass Drive
PO Box 60340
Grand Junction CO 81506-8785

Southern Division
835 E 2nd Avenue
PO Box 640
Durango CO 81302-0640

WCS-CSeale
ENV-6.00

Ruth Hutchins' Family
1574 L Road
Fruita CO 81521

Subject: Comments from Ruth Hutchins, Paradox Valley Unit Draft Supplemental Definite Plan Report and Environmental Assessment, Paradox Valley Unit, Colorado River Basin Salinity Control Project, Colorado

Dear Family Members:

The Bureau of Reclamation received a letter from Ruth Hutchins, now deceased, commenting on topics of interest to her in the above draft report issued last fall. To our regret, a response to her comprehensive questions did not reach her before her death. The following information is provided as a matter of interest to family and friends.

Depth Intervals for Injection and Rationale of Perforations

Several sections of the 1981 Williams Brothers Feasibility Study are cited and a question regarding observed and future upward migration of injectate is posed. Several of the statements taken from the Williams Brothers report are incorrect. That report has a number of inaccuracies and errors.

All of the formations drilled below the Leadville limestone contained natural fractures and some formations showed a limited degree of primary porosity. The injection liner was perforated through these formations to take advantage of any porosity, either primary or secondary, which may be available in the injection well.

Very little fluid (as manifested by pressure changes large enough to lead to micro earthquakes) appears to be injected into the Precambrian interval. The overwhelming majority of fluid appears to be entering the Leadville intervals.

Upper Limit to Fluid Migration

Given a finite pressure increase at the bottom of the well, the fluid pressure increase at some

distance from the bottom of the well must be less than that pressure increase; and the greater distance a given point is from the well perforations, the smaller the pressure perturbation will be. In other words, Delta Pressure is a strong function of distance. Further, as fluid is forced upwards it is doing work against gravitational body forces, this accounts for the preferential movement of fluid pressure changes laterally. We believe there will be a fairly definite upper limit (vertically) to fluid pressure changes. Based upon the results of the first seven injection sequences, we hypothesize that limit (assuming the injection pressures used in the future are equal to or less than those used previously) will likely be consistent with those shown in the Definite Plan Report for the Paradox Valley Unit. One of the goals of continued earthquake monitoring is to evaluate the validity of this assumption. This is why we try to have near real-time locations of the earthquakes.

Whether Anhydrite deposition in the Leadville (Formation) will be solved by the brine to a freshwater ratio

Based on tests conducted by the U.S. Geological Survey and consultation with others experienced in this field, Reclamation has determined that the risk associated with the injection of a 70% brine solution is acceptable. However, we are currently conducting an onsite pilot test to determine the feasibility of using membrane nanofiltration technology to remove sulfate from the brine to allow injection without dilution.

Earthquakes of Magnitude Zero

It is possible to have earthquakes of magnitude zero (or even negative magnitudes). This is a function of attempting to make our magnitude scale (which is based upon signal duration) consistent with the popular "Richter Magnitude Scale." This measure of earthquake "size" was developed several decades ago in California using a certain standardized instrument. The scale was defined such that a magnitude three earthquake at a distance of 100 km would have a zero displacement on the standard instrument. That standard reference instrument was a very insensitive instrument by today's standards. As a result, when we look at very small earthquakes (often referred to as micro earthquakes) that are not felt using newer instruments, the computed magnitudes can be less than zero.

We hope this answers Ms. Hutchins' questions. If further information is desired, please contact either Stan Powers or Ralph Pasquale at the letterhead address or by telephone at (970) 385-6500.

Sincerely,



FOR
Ralph Pasquale, Chief
Land, Recreation & Environmental
Resources Group
Southern Division

in Colorado. The Colorado Division of Wildlife currently identifies the southwestern willow flycatcher as having an undetermined status.

The southwestern willow flycatcher is one of five currently recognized subspecies of willow flycatchers in North America. All are neotropical migrants, wintering in Mexico, Central America, and perhaps northern South America (Tibbitts et al., 1994). The southwestern willow flycatcher's historic and current breeding range includes southern California, southern Nevada, southern Utah, Arizona, New Mexico, and western Texas. Southwestern Colorado (and the southern portions of Utah and Nevada) are believed to be the northernmost extent of its breeding range, although nesting records for southwestern Colorado are lacking (Federal Register, 1995a; Tibbitts et al., 1994). Where nesting activity has been documented, the southwestern willow flycatcher arrives at its breeding habitats as early as mid- to late-May and may remain until mid-August depending on altitude, latitude, and re-nesting (Tibbitts et al., 1994).

The Bureau of Land Management (BLM) conducted surveys for nesting willow flycatchers along the Dolores River both upstream and downstream of the Paradox Valley during spring 1994 (Ferguson, 1995). No birds were found along surveyed reaches located close to project facilities, although a number of suitable habitat sites were identified and mapped. A possible unconfirmed sighting, at the mouth of La Sal Creek upstream of project facilities, was reported earlier in the 1994 season, but was not revisited during the spring 1994 BLM survey effort.

Investigations by the National Biological Service during the spring 1994 breeding period along the Animas, La Plata, and Mancos Rivers did not reveal the presence of southwestern willow flycatchers on the Mancos River (Sedwick, 1994). Willow flycatchers were detected at five sites all on the La Plata River. Survey results concluded that all individuals observed were migrants and nonterritorial except at one site where a breeding male was determined to be territorial, but no evidence of breeding was found. The investigator concluded, as a result of this survey, that very few willow flycatchers occur in southwestern Colorado on either of the drainages surveyed, either in migration or during the breeding season, and that limited breeding may occur, and is suspected, but could not be documented (Sedwick, 1994).

These surveys—both of which were conducted along degraded river segments on the fringe of the subspecies' purported historic range—tend to suggest that utilization of similar marginal habitat in the vicinity of the project would be unlikely. Furthermore, given the uncertain northern limit of the breeding range and the general absence of confirmed breeding records and observed territorial behaviors in southwestern Colorado, it is likely that willow flycatchers observed in the Paradox Valley area are migrant northern subspecies (*E.t. adastus*, *E.t. traillii*, *E.t. campestris*) or hybrids in route to or from more northerly breeding areas rather than the less common southwestern subspecies.

Life Requisites

The southwestern willow flycatcher is most frequently associated with riparian habitats along rivers, streams, or other wetlands, where dense growths of willows, seepwillow, arrowweed, buttonbush, or other native shrubs and medium-sized trees dominate—often with a scattered overstory of larger, mature cottonwoods (Federal Register, 1995a; Tibbitts et al., 1994). Although preferring these structurally diverse native associations, the southwest willow flycatcher is also known to utilize thickets dominated by tamarisk and Russian olive. (Tibbitts et al., 1994).

Nest sites are well concealed in thickets of trees and shrubs approximately 4-7 m (13-23 ft) in height, with dense foliage from approximately 0-4 m (13 ft) above ground and a high percentage of canopy cover. The diversity of plant species immediately surrounding the nest site can range from low to high and may be either even- or uneven-aged, but is usually dense and structurally homogeneous (Federal Register, 1995a).

The southwestern willow flycatcher virtually always nests near surface water or saturated soil (Federal Register, 1995a). Typically, wet conditions (surface water or saturated soil) are adjacent to or underlie nest sites; however, a range of mesic conditions appears to be suitable for *E.f. extimus* nesting. Nest sites may be adjacent to active stream channels or may be located at abandoned channels or oxbows where riparian vegetation exists but little or no surface water is present. Some nest sites may have surface water early in the nesting season but dry significantly by mid-summer (late-June to early-July) (Tibbitts et al., 1994).

Available information indicates that patches of suitable vegetation as small as 1.23 acres can support one or two nesting pairs (Federal Register, 1995a); however, patches composed of very narrow riparian zones, with large distances between patches and individual plants typically are not selected (Tibbitts et al., 1994).

Stream gradient may also be an important determinant in the suitability of habitat. To date, no nest sites have been located along steep-gradient streams characterized by almost continuous riffles, rapids, falls, or other cataracts. This may be because higher-gradient streams tend to form narrower riparian corridors or are confined within narrow, scoured canyons (Tibbitts et al., 1994).

Threats to the subspecies include brood parasitism by the brown-headed cowbird, replacement of native riparian vegetation by exotic tamarisk, livestock browsing and trampling, pesticide contamination, predation, and probable loss of winter habitat due to tropical deforestation (Federal Register, 1995a; Sedgwick, 1994; Tibbitts et al., 1994).

The control of livestock and exotic vegetation in the riparian zone would be an important conservation measure for any willow flycatchers that might potentially inhabit the Paradox Valley. Proposed modifications in the operation of McPhee Reservoir which could enhance riparian zones along the Dolores River may also benefit the species.

Consequences of the Proposed Action

Potential southwestern willow flycatcher habitat is present along the west bank of the Dolores River and along West Paradox Creek near its confluence with the river. Several acres of predominately tamarisk in fairly large patches is present along the river and its confluence with West Paradox Creek. This riparian zone is supported by the meandering and overflows of West Paradox Creek and good quality groundwater from West Paradox Valley. Pumping from the well field on the east side of the river would not impact this vegetation. All of the project's major facilities and structures are located on the east side of the river on previously disturbed upland sites—situated either well above or well away from the river floodplain. Implementation of the proposed action will not affect the southwestern willow flycatcher.

Recommended Conservation Measures

No conservation measures are recommended for the willow flycatcher as a result of this project.

Summary of Project Impacts

Minor water depletions of the Dolores River will occur. Proposed modifications in the operation of McPhee Reservoir should benefit potential riparian zones habitats of the southwestern willow flycatcher. Improved water quality resulting from the project should increase aquatic invertebrate populations and provide a better food base for potential willow flycatcher populations that may inhabit the area.

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PARADOX VALLEY UNIT

BIOLOGICAL OPINION

Appendix C



United States Department of the Interior

REC'D BOR WCAO-SD
OFFICIAL FILE COPY

JAN 21 '97

FISH AND WILDLIFE SERVICE
Mountain-Prairie Region

IN REPLY REFER TO:

MAILING ADDRESS:	STREET LOCATION:
ES/GJ-6-CO-97-F-001 Post Office Box 25486	134 Union Blvd.
CO/KS/NE/UT	Lakewood, Colorado 80228-1
Denver Federal Center	
Denver, Colorado 80225-0486	

Memorandum

To: Southern Division Manager, Bureau of Reclamation, ~~Western~~
Colorado Area Office, Southern Division, Durango, Colorado

From: Regional Director, Region 6
Fish and Wildlife Service
Denver, Colorado

Subject: Final Biological Opinion for Paradox Valley Unit Salinity
Control Project

In accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), and the Interagency Cooperation Regulations (50 CFR 402), this transmits the Fish and Wildlife Service's final biological opinion for impacts to federally listed endangered species for the Paradox Valley Unit Salinity Control Project.

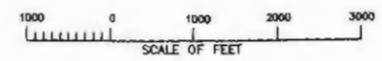
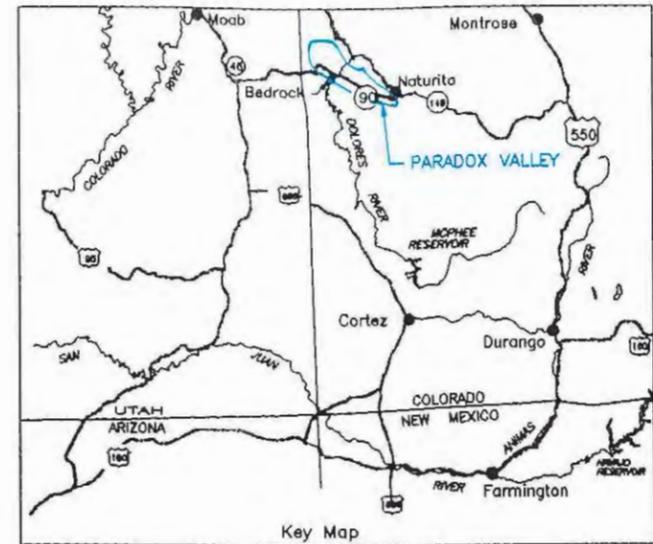
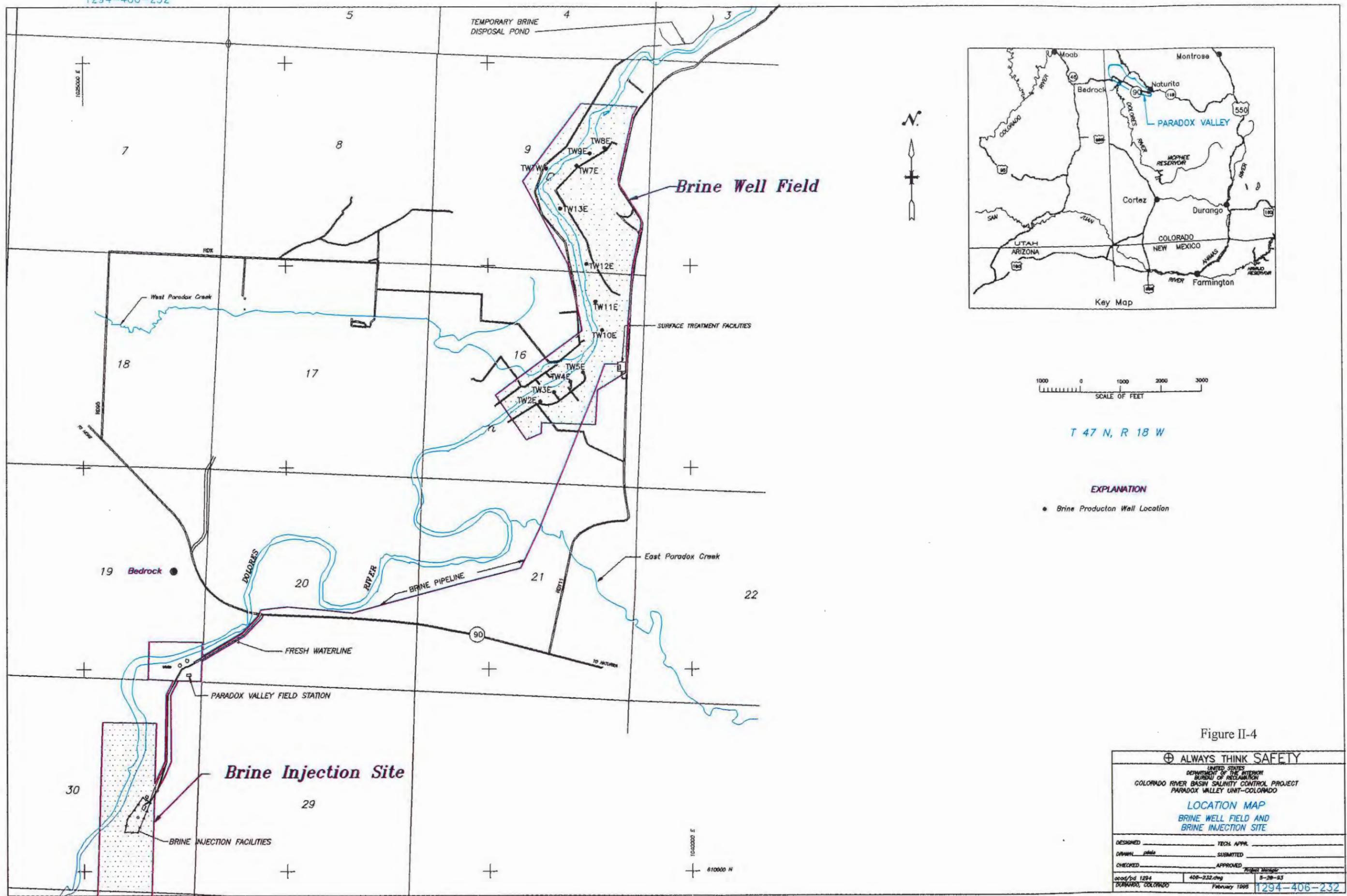
Reference is made to your December 17, 1996, correspondence requesting initiation of formal consultation for the subject project. The Service concurs that the annual depletion of water from the Colorado River Basin "may affect" the endangered Colorado squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), bonytail (Gila elegans), and razorback sucker (Xyrauchen texanus) and "may affect" their critical habitat.

BIOLOGICAL OPINION

Based upon the best scientific and commercial information that is currently available, it is the Service's biological opinion that the proposed project, as described below, is likely to jeopardize the continued existence of the Colorado squawfish, humpback chub, bonytail, and razorback sucker and result in the destruction or adverse modification of their critical habitat. The Service has developed reasonable and prudent alternatives to avoid the likelihood of jeopardy to the endangered fishes and to avoid destruction or adverse modification of their critical habitat.

CONSULTATION HISTORY

The Bureau of Reclamation has intermittently constructed and tested a brine removal facility in the Paradox Valley since 1979. The Service informally consulted on the project in 1977 with the knowledge that testing of the facility was necessary. The Service then formally consulted on the project in 1989 (ES/GJ-6-CO-89-F-09) due to impacts to the Colorado squawfish, bonytail, and humpback chub from a proposed



T 47 N, R 18 W

EXPLANATION

- Brine Production Well Location

Figure II-4

⊕ ALWAYS THINK SAFETY UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION COLORADO RIVER BASIN SALINITY CONTROL PROJECT PARADOX VALLEY UNIT-COLORADO LOCATION MAP BRINE WELL FIELD AND BRINE INJECTION SITE			
DESIGNED _____	TECH. APPR. _____		
DRAWN <i>plm</i>	SUBMITTED _____		
CHECKED _____	APPROVED _____		
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DURANGO, COLORADO	February 1993		

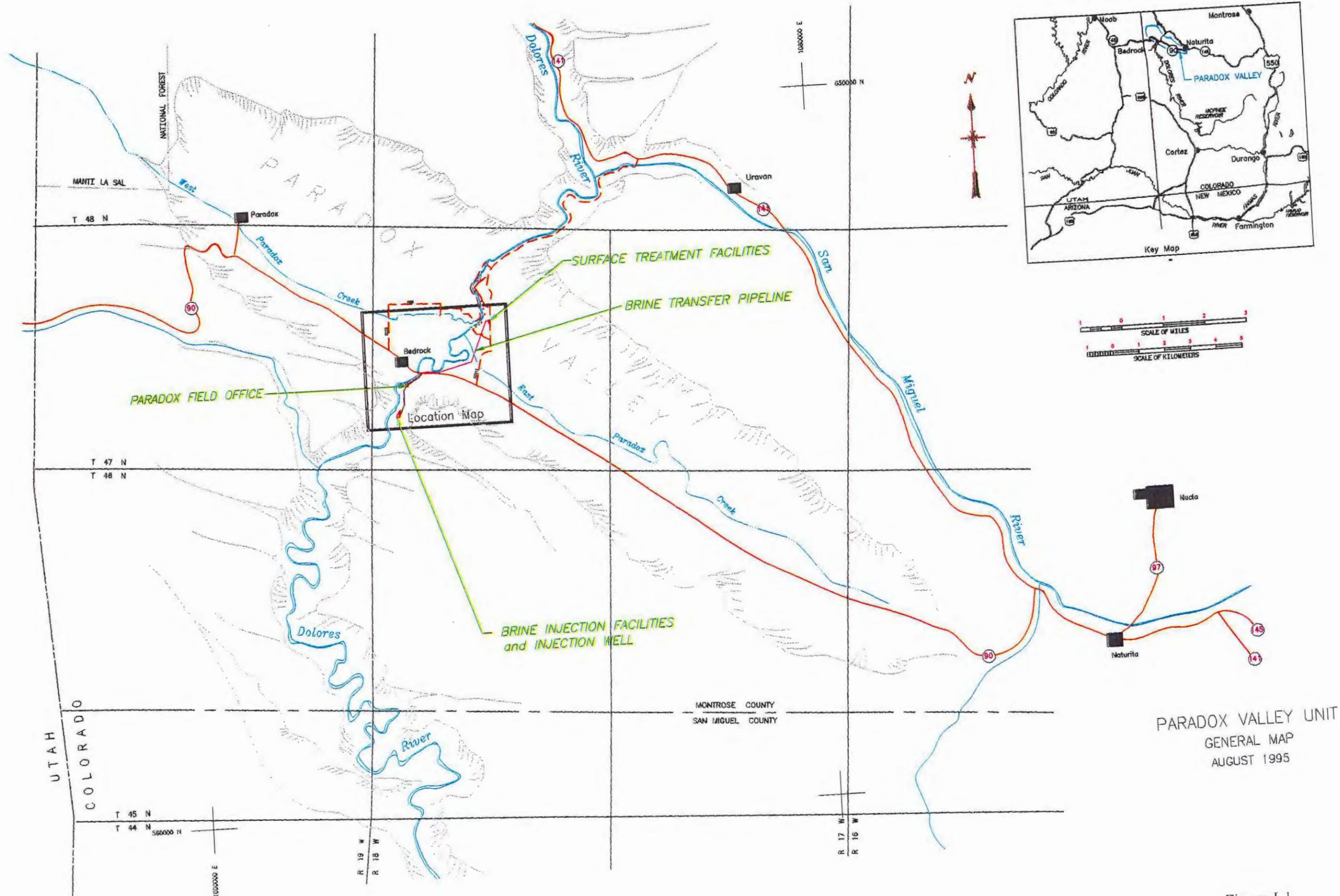


Figure I-1

